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LEADERSHIP IN SCIENCE: A HISTORIOMETRIC STUDY OF LEADER SUCCESS IN FIELDS REQUIRING CREATIVITY

A DISSERTATION APPROVED FOR THE DEPARTMENT OF PSYCHOLOGY

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Abstract

In recent years there has been a marked increase in the study of the influence of leadership on creativity, and the effects of this relationship on organizational performance. While a number of explanations have been broached with regard to the positive effects of leadership on creativity, many of these studies propose different, and often contradictory, methods for leaders to achieve these positive effects on creativity within their organizations and work groups. Additionally, little work has been done examining the effects of leadership on highly creative people in fields requiring creativity. The purpose of this study is to examine existing theories regarding the leadership of creative people in the context of a highly creative population that uses creativity as a fundamental marker of performance: eminent scientists. Ninety-three excerpts from the biographies of scientists were content coded for leader behaviors and performance criteria. The results of this analysis indicate that a model based on strategic planning and project championing may serve as the best explanation of the positive effects of leadership on creativity in a highly creative population.

Introduction

> *Teller approached Oppenheimer for help. Relating the essence of his conversation with Bradbury, he suggested that the former laboratory director use his prestige and influence on his successor. "This has been your laboratory, and its future depends on you," he told Oppenheimer. "I will stay if you tell me that you will use your influence to help me accomplish either of my goals – that is, will you help enlist support for work toward a hydrogen bomb or further development of the atom bomb?" Teller bristled with anger as he recalled Oppenheimer's terse reply: "I neither can nor will do so." – Blumberg*

Creativity, the generation of new and innovative ideas, and the translation of these ideas into action (Mumford & Gustafson, 1988), has long been recognized as one of the most fundamentally important ways to identify successful products at the highest levels of science, art, and marketing (Mumford, Scott, Gaddis, & Strange, 2002). Those individuals recognized as having the greatest impact on their field and the world at large are also often recognized as being the most creative in their field (Mumford et al., 2002). While the importance of creativity has long been recognized in these areas, the recognition of creativity as important to industry is more recent (Drazin, Glynn, & Kazanjian, 1999). Creativity is now recognized as a key goal in many organizations and a critical determinant of organizational performance (Arad, Hanson, & Schneider, 1997). This recent shift, recognizing the importance of creativity in organizations, has led to an increase in the number of scholars studying both the factors that shape creativity, as well as the effects of creativity on fields and organizations (Mumford et al., 2002). While a number of studies have been conducted in recent years examining creative people, and the factors that make them creative, one area that has been largely neglected is the study of leadership with respect to creativity (Jung, 2001).

Traditionally creativity and creative products have been viewed as the outcome of a lone effort, often thought of as an exceptional effort on the part of the individual and usually conducted in isolation (Jung, 2001). If we approach leadership from this traditional view of creative production, we would likely determine that leadership intervention would only serve to hinder creativity. We would expect creative individuals to be highly professional, expert in their field, and autonomous, factors that may obviate the need for leadership (Kerr & Jermier, 1978). However existing work on the effects of leadership on creativity have served to refute these assumptions. A consistent pattern of findings has emerged in which effective leadership is generally found to greatly enhance creativity and creative output (Andrews, 1967; Cummings & Oldham, 1997; Pelz, 1963; Tierney, Farmer, & Graen, 1999). This pattern of findings and increased discussion in the extant literature with regard to the links between leadership and creativity have led to a substantial increase in the number of studies examining leadership and creativity, with many of these studies explaining the effects of leadership on creativity as stemming from unique factors such as motivation and climate (e.g., Baer, Oldham, & Cummings, 2003; Hunter, Bedell-Avers, Mumford, 2007; Tierney & Farmer, 2002).

Although there has been an increase in studies of leadership and creativity in recent years, the samples used have generally been focused on creativity within industry environments and people exhibiting creativity in tasks or jobs that may not fundamentally require creativity. Little work has been done up to this point examining the effects of leadership on creative efforts conducted by those that rely on creative output as a fundamental aspect of their work; scientists, artists, and marketing people for example. Additionally there is a large body of evidence indicating that highly creative people are relatively unique and operate in fundamentally different ways than the average person when engaging in a creative task (MacKinnon, 1970). These highly creative people have largely been left out of the existing studies of leadership and creativity, leading to studies focused more on the average person and their expression of creativity. So what happens when leadership influence is applied to highly creative people, what occurs when a highly creative person is the leader in question, and what is the relationship between leadership and creativity for individuals whose entire field is structured around creative output? These are the questions we sought to address in this study, by examining the predictive value of existing models of leading creative people in a sample of highly creative individuals, eminent scientists.

Creativity and Creative Fields

Organizations, until recent years, have generally had a bias against creativity and innovation, viewing creativity as costly and disruptive to normal operations (Mumford, et al., 2002). While creativity is indeed disruptive in certain types of work, many organizations are now recognizing the importance of creativity to long-term organizational performance and stability (Tushman & O'Reilly, 1997). Many organizations now conduct regular training sessions to attempt to improve the creativity of employees and attempt to identify creative individuals as a part of hiring procedures (Gryskiewicz, 2000). This focus on the importance of creativity to organizations has largely been supported by research showing the effects of creativity on organizational performance. For example, a study conducted by Cohen and Levinthal (1990) showed that organizations with internal research and development staff were better able to exploit new technologies, resulting in increased organizational performance. Studies by Nystrom (1990) and Tushman and Anderson (1986) indicate that organizations with highly creative individuals that are able to innovate and institute technological change are more likely to grow over time. These findings and the general recognition of the importance of creativity by organizations has led to a rapid shift in organizations to put creative talent at a premium and to focus on the development of creative potential (Gryskiewicz, 2000). This focus on creativity has occurred across essentially every type of industry and every professional field (Dess & Pickens, 2000).

Along with an increase in the perceived value of creativity to organizations, there has also been an increase in the study of creativity within academia, with a focus on understanding the factors that make an individual creative. We have seen creativity studied in a number of ways, with studies focusing on climate (Amabile & Gryskiewicz, 1989), strategy (Parnell, Lester, & Menefee, 2000), group interactions (Mumford, Feldman, Hein, & Nago, 2001), structure (Damanpour, 1998), and individual differences (Runco & Sakamoto, 1999). While creativity has certainly been studied broadly, as with industry there has been limited regard for the context that creativity is taking place within. The majority of studies of creativity have not distinguished between activities or fields where creativity is fundamental to success (e.g., science, art, marketing) and fields where it may have added value in some situations but is not essential (e.g., computer science, the military, management) (Mumford et al., 2002).

These studies often attempt to generalize findings from non-creative fields to all other fields, a practice that may not be appropriate given the potentially unique attributes of creative fields with regard to professional norms and standards meant to encourage creative output. Studies examining the fields where creativity is fundamental are needed to ensure that findings based on creativity exhibited in other fields generalize, and if not to point out where differences occur.

The Importance of Leading Creative People

Beyond potential issues with the generalizability of results from non-creative to creative fields, the traditional creativity study presents another problem: a general lack of focus on links between leadership and creativity (Jung, 2001). Leadership has long been viewed as a potential obstacle to creativity, serving to limit the autonomy of creative individuals (Mumford et al., 2002). However, a number of studies have served to refute this view and indicate that leadership is often beneficial to creativity, and may be critical to creative performance in many cases. In a study of 300 scientists working in 20 National Institutes of Health laboratories, Pelz (1963) measured potential, productivity, and article impact along with organizational factors thought to be related to creativity. The intensity of interaction with group leaders was found to be positively related to creativity, while poor supervision and role modeling resulted in very low levels of performance.

Similarly, in a study of 191 research and development employees working in the field of chemical development and production, Tierney, Farmer, and Graen (1999) assessed leader behaviors via leader-member exchange. Creativity, inventions, intrinsic motivation, and use of appropriate problem-solving strategies were all highly correlated with effective leader-member exchange relationships. Along similar lines, Cummings and Oldham (1997) and Oldham and Cummings (1996) assessed creativity in 171 manufacturing workers via patent disclosures, records of suggestions to change company policies, and supervisor ratings of creativity. Management support of new ideas was positively related to creativity, especially for individuals with a general disposition to engage in creative activity.

This pattern of findings suggests that leadership is related to creativity and innovation, in at least some professional environments, and that the type of leadership engaged in has differential effects on creativity. While it appears clear that leadership is related to creativity, how might leadership of creative efforts differ from traditional leadership activities? A number of recent studies have attempted to address this issue, developing models to explain successful leadership of creative efforts. While these models are quite different in some fundamental ways, there do appear to be some common elements that make leading creative people unique as compared to other types of leadership.

First, the type of work where creativity is critical is different than the work commonly engaged in by most people. Creative efforts are generally complex, novel, and ill-defined tasks where solutions must be novel and useful (Ward, Smith, & Finke, 1999). In many fields problems fitting these criteria may be rare, while in other fields such as science, art, and marketing these may be the most common types of problems (Mumford et al., 2002). When addressing these types of problems, problems calling for creative solutions, leaders may not be able to use pre-defined organizational structures when engaging with others, but must instead provide structure and direction for others based on situational demands (Mumford et al., 2002).

Leading creative people and creative efforts may also differ from traditional leadership in the way that leaders engage in influence processes (Mumford, Peterson, & Robledo, in press). Highly creative people have been identified as being highly autonomous, professional, motivated, and critical as compared to the average person (Feist, 1999; Hennessey & Amabile, 2010; Mumford & Gustafson, 1988). Thus we would expect that leaders of creative people may not be able to rely on traditional influence techniques such as authority, conformity, and organizational commitment. Additionally, creative people, due to the types of tasks they typically engage in, have high levels of risk in their work, with many creative efforts leading to failure. Based on the individual-level differences between creative people and the average person, as well as the high level of risk they engage in with their work, we would expect that leaders will need to use unique influence processes to direct the work of creative people.

Finally, leaders of creative people have to address a unique problem stemming from the relationship between creativity and normal organizational functioning. As mentioned, creative efforts are generally high risk. They are also often very costly and may disrupt normal organizational processes. While organizations see value in innovating, they must also maintain normal levels of production during creative efforts. This creates a conflict between an organizations desire to innovate and the inherent risks of innovating to the organization, a conflict that leaders of creative people need to manage in an effort to promote creativity as well as to shield creative people from the conflict, a conflict which may disrupt their ability to be creative (Mumford et al., 2002).

Models to Explain the Effects of Leadership on Creativity

Although there do appear to be some common issues in leading creative people, recent studies on leadership and creativity have produced a number of different models that serve to explain the link between leadership and creative performance. There appear to be six primary models of leadership and creative in the extant literature; models of climate, control, motivation, interactions, teams, and systems exchange relationships. While these models share some similarities, they generally take very different approaches to explaining why leadership may be critical to creative performance, and the way leadership is discussed is not consistent across these models (Engwall, Kling, & Werr, 2005). Indeed, reviews of these models indicate that they provide very different suggestions regarding how creative people should be led (Buijis, 2007). Given these inconsistencies it may be important to examine the predictive value of these different models in a single study, in an effort to determine which models best explain the relationship between leadership and creative performance. Before discussing the method used in this study to compare these models, we will first discuss what makes each model unique and potentially viable as a way of explaining the relationship between leadership and creativity.

Control

The first of the creative leadership models included in this study focuses on leadership via control processes. This model calls for organizations and leaders to facilitate creativity and innovation by creating an environment promoting innovation (Perez-Freijie & Enkel, 2007). The goal is to create an environment that allows a leader and organization to control when and in what context creativity occurs, with the goal of maximizing the benefits of innovation for the organization while minimizing some of the disadvantages we have discussed, such as disruption of normal production. The focus of this model is on eliminating barriers to creativity and promoting factors that may increase creative performance via organizational control mechanisms such as company policies (Thamhain, 2003). Effective leaders of creative people, according to this model, will use influence processes that allow them to direct and structure the work of those engaging in creative endeavors.

The leader-specific factors that may drive innovation according to this model are level of supervision, structuring activities, mission definition, and intellectual stimulation (Mumford et al., 2002). In multiple studies the level of direct supervision a leader engages in has been identified as an inhibitor of creative performance, with very close direct supervision leading to lower levels of creative performance (Barnowe, 1975; Cardinal, 2001, Pelz & Andrews, 1976). Leaders, rather than closely supervising all activities, should instead engage in loose supervision, checking only critical milestones and allowing creative people to work fairly autonomously. With regard to providing a structure in which creativity can occur, it appears that two general types of structuring activities are important for leaders of creative efforts: structuring around expertise and structuring around authority (Damanpour, 1991). According to the Control model, leaders should structure work around the expertise of creative people, with a focus on their specialties, differentiating between functions in groups, professional standards, and technical knowledge of the subject, and it does appear that work divided based on expertise improves creative performance (Damanpour, 1991). It also appears that creative performance is improved when communication can occur in a more open and dynamic way, based not around organizational hierarchy, but instead around meeting the needs of those working on creative projects (Damanpour, 1991). Leaders of creative people should then attempt to establish a flat communication structure within their work groups and organization to promote creativity.

An additional method for leaders to control the direction of creative effort is through the definition of a clear and specific mission or goal (Mouly & Sankaran, 1999). Mission definition allows leaders to control creative activities in two ways: by providing an overall goal for a work group or organization and by providing individual level goals (Amabile, Hadley, & Kramer, 2002). It appears that providing a set of overarching goals, specifically goals with a direct focus on the work being done from a technical standpoint, allows leaders to structure project work in a way that is motivating for creative people (Hounshell, 1992). Finally, leaders may improve creative performance by structuring work around intellectually stimulating creative people (Shin & Zhou, 2003). Ensuring that individuals involved in creative work are intellectually engaged appears to be critical to innovation (Jung, 2001; Mouly & Sankaran, 1999). It appears that leaders who encourage intellectual stimulation via exchange relationships and via direction giving activities are most effective in encouraging innovation (Shipper & Davy, 2002). Intellectual stimulation with regard to exchange relationships commonly takes the form of encouraging followers to share information, engaging in prolonged discussion of creative ideas, and encouraging group members to create new solutions out of disagreements (Maier & Hoffman, 1965). Direction giving may take the form of directly requesting creative solutions, defining the problem being faced, and pointing out anomalous information (Mumford & Gustafson, 2007). This pattern of findings leads to our first hypothesis:

> Hypothesis 1: The Control model of leadership and creativity will predict performance for the leaders of creative endeavors.

Climate

The work centering on organizational climate is one of the better established models with regard to leadership and creativity. A general pattern of findings has appeared indicating that climate, made up of people's perceptions of organizational interactions, has a strong influence on creativity and innovation (Hunter, Bedell, & Mumford, 2005). For example, in a study of new product development in multiple divisions of a manufacturing company, Nystrom (1990) found that differences in climate predicted the level of innovation in each division. Leadership based around climate encourages leaders to foster a climate conducive to creativity, with a focus on those dimensions of climate found to have the greatest impact on creativity (Luria, 2008).

While there are some questions with regard to the methods leaders should use to change or establish a climate appropriate to creativity (Jacobsen & House, 2001) there does appear to be a set of climate factors that consistently play an important role in creative performance (Hunter, Bedell, & Mumford, 2005; Hunter, Bedell-Avers, & Mumford, 2007; James, James, & Ashe, 1990; Isaksen, 2007). These climate factors include perceptions of positive peer groups, positive supervisory relationships, availability of resources, challenge, mission clarity, conflict, autonomy, positive interpersonal exchange, intellectual stimulation, top management support, rewards, flexibility, risk taking, product emphasis, participation, organization, and ideation time. An effective leader within the Climate model will focus their efforts on establishing a climate conducive to creativity based on these factors. Based on the generally consistent effects of climate on creativity and innovation, we would expect:

Hypothesis 2: The Climate model of leadership and creativity will predict performance for the leaders of creative endeavors.

Motivation

Similar to the work on climate, the literature on motivation and its effect on leadership and creativity is well established and has produced a fairly consistent set of results indicating the behaviors a leader should engage in to motivate creative people (Mumford et al., 2002). Motivation, both intrinsic and extrinsic, appears to be necessary for individuals to succeed in a creative endeavor (Baer, Oldham, & Cummings, 2003). This makes logical sense when considering the difficulty of most creative projects and the amount of cognitive resources that must be devoted to being creative (Mumford et al., 2002). While motivation is necessary for creativity, this motivation must be properly expressed and encouraged, an activity which may be central to leader effectiveness in leading creative people.

There do appear to be a number of actions a leader can take and elements of a creative project a leader must attend to in order to properly manage the motivation of creative people (Jaussi, Randel, & Dionne, 2007). First, it appears to be critical that leaders allow individuals to self-select to creative projects (Mumford & Hunter, 2005). Rather than dictating which projects and individual will work on, intrinsic motivation and creative performance appear to be increased by allowing individuals to select the projects they will focus on. Providing concrete rewards, and providing clear objectives that must be met to receive these rewards, appears to increase extrinsic motivation and creativity (Eisenberger & Cameron, 1996). Providing an appropriate level of work complexity appears to be critical to motivation and creativity (Baer, Oldham, & Cummings, 2003). Creative efforts are fundamentally complex, and keeping the level of complexity manageable while also intellectually engaging for the creative people involved appears to increase intrinsic motivation to engage in creative activity on a project. The level of self-efficacy of creative people appears to influence motivation and creative performance, with those individuals exhibiting higher levels of self-efficacy evidencing higher levels of creativity (Tierney & Farmer, 2002). Providing a mission and encouraging identity investment in the mission appears to increase the motivation of creative people leading to higher levels of performance (Jaussi, Randel, & Dionne, 2007). Finally, allowing a high level of professional network activity appears to motivate creative people (Mumford & Hunter, 2005). Leaders that allow communication among professionals in an organization, and even with those outside of the organization, seem to increase intrinsic motivation and engagement with creative projects. Based on this pattern of findings with regard to motivation, leadership, and creativity, we expect that:

> Hypothesis 3: The Motivation model of leadership and creativity will predict performance for the leaders of creative endeavors.

Interactions

The next model, which we will refer to as the Interactions model, focuses on relationships between leaders and their relationships with members of their work group.

The work on this model primarily comes from the LMX literature (e.g., Tierney, Farmer, & Graen, 1999), with these exchange relationships determining the degree to which work groups can produce creative products. A general pattern of evidence in favor of this model has been found, with positive interactions between leaders and members of their work groups leading to higher levels of creativity and innovation in organizations (Amabile, 1988; Basu & Green, 1997; Graen & Scandura, 1987). Based on these finding there appears to be a key set of interactions a leader can engage in that will promote creativity.

First, it appears that encouraging risk-taking is central to improving creative performance, with leader support of risky creative endeavors leading to more creative products (Mumford et al., 2002). This is not unlimited support of risk, but rather support of risk-taking in the context of work appropriate outcomes. Next, providing operational autonomy also appears to be critical to creative performance (Basu & Green, 1997). This mirrors similar results regarding supervision, where the high levels of control seem to discourage creative performance while providing creative people with the opportunity to engage in the work in a manner they see as appropriate is highly motivating. Promoting non-routine activities, where individuals may engage a problem or task in a non-standard way, is related to creative performance (Graen & Scandura, 1987). By promoting non-routine activities leaders encourage creative people to engage problems in ways that may result in unique solutions. Eliminating work-constraints and providing resources both appear to be important to creative performance, allowing creative people to engage fully with a creative task without concern for outside factors that could affect their work but are not directly related to the problem at hand (Mumford et al., 2002). Along similar lines, acting as an advocate for team members increases creative performance, with the leader acting as a buffer between creative people and other individuals in the organization that may have influence on a creative project (Mumford et al., 2002). Recognizing those that successfully innovate or generate a creative solution to a problem seems to increase the motivation of creative people, leading to higher levels of performance (Basu & Green, 1997). Finally, if a leader provides challenging and relevant tasks to team members they are likely to see increased levels of creativity (Mumford et al., 2002). This pattern of research findings suggests that interactions between the leader and work group members are important, and thus:

Hypothesis 4: The Interactions model of leadership and creativity will predict performance for the leaders of creative endeavors.

Teams

The next model that may explain the relationship between leadership and creative performance is a model of leader influence on team structure and team processes. This is model is largely based on much more recent work and thus has a smaller evidence base. Still, there do appear to be some compelling findings with regard to team processes and leader influence in terms of creative performance. The available evidence indicates that leaders can improve creativity in their teams through three primary activities: promoting team processes, encouraging shared mental models, and selection of team members (Taggar, 2002; Pearce & Ensley, 2004; Keller, 2001). Leaders that engage in each of these processes do seem to increase the overall creative performance of teams working on projects requiring creativity (Carmeli & Spreitzer, 2009).

Of these activities, promotion of team processes is potentially the most complicated activity for leaders to engage in successfully given the number of team processes that may influence creativity. Promoting team citizenship, engaging in performance management, effective communication, involving others in decision making, providing feedback, reactions to conflict, avoiding conflict, encouraging diverse experience, and information exchange all seem to play significant roles in leadership's effect on creativity through team processes (Keller, 1989; Taggar, 2002; Thamhain, 2003). By engaging in and promoting these team processes, leaders are able to create a team environment conducive to creative performance at the team level. These teams generally evidence higher levels of cohesion, cooperation, and trust, team level constructs that seem to benefit creativity (Mumford, Feldman, Hein, & Nago, 2001). Beyond encouraging these team processes, leaders can also enhance creative performance of teams by ensuring that teams are operating with a shared mental model (Pearce & Ensley, 2004). Teams with shared mental models do appear to have higher levels of creative performance, likely due to the role these shared mental models may have in reducing the complexity of collaborating on already complex problems requiring creative solutions (Dunham & Freeman, 2000; Frankwick, Walker, & Ward, 1994). Finally, a leader's selection of team members with skills relevant to the problem, high levels of creativity, and the ability to work well together seems to enhance creative performance of teams (Keller, 2001). Based on these conclusions regarding the importance of leader influence on teams and creativity we expect that:

Hypothesis 5: The Teams model of leadership and creativity will predict performance for the leaders of creative endeavors.

Systems Exchange

The final model included in this study is also the most recently developed; a model of leadership's influence on creativity via systems exchange. Systems exchange refers to the ways a leader is able to engage with organizational structures in ways that may benefit their work group (Mumford, Bedell-Avers, & Hunter, 2008). By engaging with these organizational systems, leaders are able to provide organizational resources, top management support, structure, and strategies for task completion to their teams. Systems exchange seems to influence creativity through two leadership activities: championing and strategic planning. Championing refers to the process of individuals emerging to actively and enthusiastically promote innovations through crucial organizational stages (Howell & Boies, 2004). Strategic planning here refers both to the process of planning activities for task completion as well as maintaining knowledge of existing strategies bearing on creative endeavors (Mumford, Bedell-Avers, & Hunter, 2008).

The role of a leader as a project champion appears to be critical to the successful completion of creative projects and innovation, with these champions enabling work groups to overcome organizational pressures and potentially take advantage of these pressures (Markham & Aiman-Smith, 2001). Leaders acting as a champion for a project demonstrate commitment to the project, promote the project within the organization, and are willing to risk repercussions for project failure (Maidique, 1980). Of the activities a leader as champion can engage in to promote creativity, the two most important appear to be acquiring knowledge of organizational norms and selling the benefits of the project to others in an organization (Howell & Boies, 2004). By acquiring knowledge of organizational norms a leader may gain a better understanding of where they should champion a project for maximum effect and to may be able to better structure creative projects to fit within organizational norms and standards, increasing the likelihood that these projects will gain organizational support and resources. (Howell & Boies, 2004). Similarly, selling the benefits of a creative endeavor to those within an organization will increase the likelihood of gaining resources and organizational support, both critical to successfully completing creative projects (Howell & Boies, 2004).

Engaging in strategic planning seems to be critical to a leader's ability to successfully lead creative people in a number of ways. Advanced strategic planning allows leaders to identify important long-term goals and themes both within an organization and within the larger field. These leaders can then structure creative efforts based on these themes in order to position the project as falling within long-term goals more likely to garner attention and support (Mumford et al., 2002). Additionally consideration of down-stream issues through strategic planning ensures that leaders and their teams are able to react quickly to new information, a critical team capability when working on complex, ill-defined problems like those found in many creative endeavors (Mumford, Bedell-Avers, & Hunter, 2008). The two most important strategic planning activities a leader can engage in with regard to encouraging creativity seem to be identifying organizational strategies and initiating organizational learning (Senge, 1990). Identifying organizational strategies allows leaders to structure and support creative projects that enhance the organization's long-term strategies and goals (Cohen & Levinthal, 1990). These projects are then more likely to be seen as critical by the organization, allowing the leader to gain organizational support for the project. Similarly, engaging in organizational learning allows the leader and team to identify goals critical to the organization and structures within the organization that can be used in support of creative efforts (Hirschorn, 2001). This pattern of findings indicates that:

> Hypothesis 6: The Systems Exchange model of leadership and creativity will predict performance for the leaders of creative endeavors.

Eminent scientists

While we have identified a number of models that may explain the apparent relationship between leadership and creativity, it is important to once again note some concerns with these studies. The vast majority of these studies were conducted in samples consisting of people engaged in creative activities in fields which may not fundamentally require creativity. Additionally, these samples were generally made up of individuals exhibiting low or average creativity, as these are often the samples researchers have had access to. Highly creative people are relatively rare, and thus are a difficult population to access in these studies of creativity and leadership. While there are valid reasons for conducting studies on these samples, particularly with regard to examining how leadership can influence creativity in the average person or average employee, the purpose of this study is to examine the influence of leadership on creativity in a highly creative population, and a population that views creativity as fundamental to success in their field. One population which meets each of these criteria is the eminent, or highly successful, scientist. Science is one field that has been identified since the beginning of creativity research as an area where creativity and creative production is fundamental to success (Pelz & Andrews, 1976). Indeed, many of the professional norms and standards within scientific fields appear to be structured around encouraging creativity and innovation (Zuckerman, 1977). Thus it would appear that scientists comprise an population where their work is largely driven by creativity. Additionally, given the importance placed on creativity in science, it is relatively easy to identify highly creative individuals, as those individuals with the greatest success in scientific fields are also often regarded as the most creative (Mumford, Peterson, & Robledo, in press). Therefore it would appear that scientists at the very highest levels of success in their fields comprise a population that both views creativity as fundamental to their work and provides an easily identifiable group of highly creative individuals (Zuckerman, 1977).

Method

Historiometric Case-Study Method

To test the effectiveness of these leadership models in predicting the success of scientist leaders a historiometric case analysis approach was applied. Historiometric studies allow human behavior to be examined through the quantitative analysis of historical records, usually historical records of notable individuals (Simonton, 1990).

The historiometric case-study method has been especially useful in the study of outstanding leadership, due to the access to behavioral data regarding high level leaders. These high-level leaders are generally a very difficult population to access, and the historiometric method allows us to gather data which may be nearly impossible to acquire via any other method (Simonton, 1999). This method is also valued due to the access to behaviors in a real-world context, a context important to the study of scientific leadership given the limitations we have discussed of previous studies in this area (O’Connor, Mumford, Clifton, Gessner, & Connelly, 1995; Simonton, 1990). As we are interested in studying a population, eminent scientists, which may exhibit unique behaviors and operate in unique contexts, the ability to gather data from these scientists’ actually experiences is especially valuable. Additionally, the historiometric method allows us to gather a large quantity of data covering a broad range of topics within a single sample. Given the number of leadership variables from different theoretical areas being examined this is a particularly useful advantage of this method for this study. The issue of the quantity of data needed also motivated our decision to focus on biographies as the sources of historical data in this case, rather than using primary sources (e.g., interviews, personal memoirs or journals). Identification of the wide range of leadership related data needed for this study could be particularly difficult given the potential biases in first-person primary sources and the general brevity of these sources as compared to academic biographies.

Moreover, the historiometric method allows us to examine leadership and follower constructs that may be difficult to identify or explain by examining the presence of these constructs via behaviors. Identifying and studying these constructs as they are expressed via behavior in a given context is critical when the context may determine which leadership processes will occur (Antonakis, Avolio, & Sivasubramaniam, 2003; Simonton, 2003). Finally, the historiometric method allows us to gather data on eminent scientific leaders, a difficult or impossible task using most other common leadership research methods (Simonton, 1999). Not only can we gather data on this difficult to access population but we can examine multiple instances of leadership within each leader across multiple situations (Simonton, 1980). With regard to studying models for explaining the success of leaders of scientific efforts, this was an important advantage of the historiometric method as it allowed us to select leaders for the study who were known to be highly successful, and to select highly successful scientist leaders across multiple scientific areas.

Sample

The sample used to examine the leadership models and their influence on leader performance consisted of excerpts from 93 scholarly biographies of eminent scientists. Procedures recommended by Simonton (1999) for the study of eminent individuals were applied when selecting scientists and biographies for the study. The scientists were identified and biographies were chosen by two psychologists with experience conducting historiometric studies of leaders. These selections were based on a number of criteria. The first step in identifying scientists for study was to compile a database of scientists with scholarly biographies available for study. Initially a broad internet search was conducted to identify eminent scientists across multiple fields. After compiling this initial list we then eliminated scientists from the study if they were not active on or after 1920, in an effort to focus on those scientists doing their work primarily over the last century. An initial check of leadership activity was then done on those scientists remaining using short biographies. Any scientists not engaging in at least one leadership position were dropped from the study. A search was then conducted using the WorldCAT library database to identify available biographies of those scientists identified for study. Scientists with no scholarly biographies available were then dropped from the sample.

Within the biographies identified all biographies written primarily for juvenile audiences, biographies published prior to 1950, and autobiographies or biographies written by immediate family were filtered out. Biographies written prior to 1950 were not included due to a shift that occurred in academic biographies around World War II. Prior to World War II many academic biographies were strongly positively biased toward the subject, while those after World War II generally evidence much higher levels of objectivity. Similarly, autobiographies and biographies written by immediate family were not included due to potential bias issues. Finally, scholarly reviews were examined for the remaining biographies for each scientist, and a biography was selected for each scientist based on these reviews, with a focus on selecting biographies with a high level of detail, documentation, and limited author bias. This resulted in our final pool of 93 biographies of eminent scientists. The final list of scientists and biographies can be found in Figure 1.

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After selecting these biographies, the biographies were reviewed for leadership events. These events were identified by two psychologists as any event in which the scientist of interest was described as leading or directing another individual, group, or organization. Interrater agreement was 0.78 for the selection of these leadership events. These events were compiled from each biography along with any immediate or long-term outcomes described in the biography. The events were between a paragraph in length, at the shortest, to 10 pages in length at the longest, with an average page length of around four pages. The total length of the excerpts given to coders averaged around 35 pages per biography.

Leadership Scales

The scales used to content code leadership constructs from each theoretical area were adapted from rating scales previously used in biographical historiometric research (Eubanks et al., 2010; Mumford et al., 2005; Schwartz, 1994), and are made up of 1 to 5 benchmark rating scales with 1 representing the absence of the construct or a very low level of behavior by the leader, and 5 representing a high level of behavior indicating the leadership construct's presence. Benchmarks were developed based on a review of the literature from each of the theoretical areas being studied. Each area was reviewed for those leadership constructs evidencing the strongest relationship to creative performance. After identifying these key leadership constructs, behavioral markers were developed. The behavioral markers give examples of behaviors tied to each construct which can be used to code an individual leader's actions as described by a third party (the biographer). The first step in writing each marker was to identify definitions of the construct in question from the relevant extant literature. This definition of each construct was included with the behavioral markers to assist coders in understanding the underlying leadership construct. Next, based on this definition, three example behaviors conducted by a leader were written to reflect the expression of the construct of interest. These markers were reviewed by a subject matter expert familiar with the relevant leadership literature. A group of three judges, made up of psychologists familiar with the leadership literature, were asked to rate the biographical excerpts on the presence of behaviors in each event that might indicate each leadership construct. An example of these scales can be found in Figure 2. A list of the constructs included in the ratings for each leadership model can be found in Figure 3.

-------------------------------INSERT FIGURE 2 ABOUT HERE ----------------------------

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To ensure these judges rating the excerpts had adequate knowledge of the relevant constructs and experience with the measure, these judges participated in a 40 hour training program conducted over the course of one month. Each rater was a doctoral student in industrial and organizational psychology with knowledge of the leadership literature and historiometric research methods. This rater training consisted of three primary phases. First, each rater was given a packet of readings summarizing the leadership constructs they would be rating. Meetings were then conducted to clarify any confusion with regard to these constructs. Following these meetings raters received a packet of five biography excerpts not included in the final set used in the study. Raters were instructed to use to practice applying the leadership scale and to familiarize themselves with the types of events they would be coding, the style of the biographies, and the types of behaviors that could appear in the biographies. The raters were also asked to provide feedback on an ambiguous scales or markers. The final phase of training consisted of a set of meetings which allowed the raters to discuss and compare their ratings and to identify any inconsistencies in ratings across raters.

After participating in this training the raters evidenced an adequate level of interrater agreement. A .79 average reliability coefficient was obtained across the leadership ratings scales based on Shrout and Fleiss's (1979) method of assessing interrater agreement. Beyond providing evidence on the reliability of the leadership ratings, initial evidence with regard to the validity of these ratings was also found. As we would expect, the ratings of constructs within each theoretical area evidenced strong positive correlations. For example, within the ratings for Climate constructs, strong positive correlations were found between positive interpersonal exchange and supervisor relations ($r = .58$, $p < .01$), top management support and resources ($r = .51$, $p < .01$), and intellectual stimulation and challenge ($r = .44$, $p < .01$). Among Interaction constructs some examples of strong positive correlations found include eliminating work constraints and providing resources ($r = .45$, $p < .01$), recognition for innovation and promotion of non-routine activity ($r = .27$, $p < .05$), and providing operational autonomy and encouraging risk taking ($r = .32$, $p < .05$). The general pattern of correlations seems to support the validity of the leadership ratings.

Performance and Control Scales

In an effort to identify how the different leadership theories and the constructs underlying each were related to leadership performance, a set of scales was developed based on the scales used to content code the leadership constructs. Performance constructs were identified based on a review of performance constructs used in previous studies of the leadership theories included in this study, with a focus on constructs providing evidence for creative performance. After identifying the performance constructs, markers were developed to assist in content coding. Again, these markers were written by identifying definitions from the literature for each performance construct, constructing three examples of how each construct might appear within a scholarly biography, and conducting a review of these performance constructs with subject matter experts in the leadership area. The scoring system here was also based on previous coding scales used in historiometric studies (Eubanks et al., 2010; Mumford et al., 2005; Schwartz, 1994) and consisted of a 1 to 5 benchmark scale with 1 representing low levels of a performance variable and 5 representing high levels of a performance variable. Three trained raters were asked to use these scales to rate the performance constructs within each biography excerpt. A list of the constructs included in the ratings for performance can be found in Figure 4.

------------------------------INSERT FIGURE 4 ABOUT HERE -------------------------------

In addition to developing performance scales, scales were developed covering a number of potential control variables thought to be related to leadership and creative performance. These controls were identified based on those controls identified in the literature related to each area of leadership theory included in the present study. The same procedure was followed with these controls as with the leadership scale and performance scale. Markers were again written by identifying definitions from the literature for each performance construct, writing examples of behaviors that would evidence the construct, and conducting a review of these controls with subject matter experts in the leadership area. Again, the scoring system here was based on previous coding scales used in historiometric studies (Eubanks et al., 2010; Mumford et al., 2005; Schwartz, 1994) and consisted of a 1 to 5 benchmark scale with 1 representing low levels of a control variable and 5 representing high levels of a control variable. The three trained raters asked to rate performance were also asked to use these scales to rate the controls within each biography excerpt.

The three judges using the performance and control scales also participated in a rater training program to ensure they had adequate experience with the measures. These raters were trained for 40 hours on the scales over the course of one month. Again, all raters were doctoral students in industrial and organizational psychology familiar with the leadership literature and historiometric methodology. This training consisted of the same three phases used to train raters on the leadership scales. Raters were given a packet of readings that included background on the constructs they would be rating. The raters then met to discuss their understanding of the performance and control variables. Judges were then given a set of five practice excerpts drawn from the biographies but not included in the actual study. In the final phase of training the judges met to discuss and compare their ratings of the performance and control constructs.

Beyond the control scales developed for the raters, additional controls were identified which did not require ratings given the nature of the controls. For example, h-index, and index of the productivity of scientists based on an existing formula, was gathered for each scientist from a publicly available database. Other controls collected through database searches or from the identification of the biographical excerpts include variables such as primary field of work, number of awards, number of citations, length of excerpt, and year of publication for the biographies. Data on these controls that could be objectively identified was gathered by two psychologists familiar with the literature through searches of publicly available records on each scientist. A list of the controls can be found in Figure 5.

------------------------------INSERT FIGURE 5 ABOUT HERE -------------------------------

Once again, after participating in training the judges reached an adequate level of interrater agreement. A .77 average reliability coefficient was found across the rating scales for performance, a .81 average reliability coefficient was found across the ratings scales for the controls, and a .96 average reliability coefficient was found for the additional controls not subject to ratings. Examination of the correlations between performance constructs and control constructs seems to provide evidence in favor of the construct validity of these scales. For example, with respect to performance constructs, strong positive correlations were found between public policy influence and field influence ($r = .67$, $p < .01$), number of creative products and technical influence ($r = .42$, $p < .01$), and number of major awards and h-index ($r = .37$, $p < .05$). With respect to the controls, some examples of the strong correlations found include author opinion and documentation ($r = -.48$, $p < .01$), project support and organization size ($r = .55$, $p < .01$), and number of external commitments and time spent in the lab ($r = .31$, $p < .05$). This pattern of findings seems to provide positive evidence of construct validity in addition to demonstrating that the ratings having adequate reliability.

Analyses

For our first set of analyses it was determined that there was a high likelihood that given the number of performance variables drawn from different areas of the leadership literature, and the similarity of some of these variables, it was likely that performance might be explained based on more general performance factors underlying the performance variables identified. An exploratory factor analysis was conducted using the SPSS 20 softwar package, using a promax rotation given the potential for strong correlations among the factors (Stevens, 2002). The eigenvalue was used in determining the number of factors (Kaiser, 1960).

Our next set of analyses consisted of correlating ratings on the theoretical models with one another as well as with the performance factors to allow us to identify the relationships between the different leadership constructs and performance based on the hypothesized relationships. Additionally, the control variables were correlated with each factor to determine which controls would be retained for further analyses and intercorrelations were examined among control variables. After completing this analysis, a set of hierarchical regressions were conducted to examine the relationships between the different constructs in the leadership models based on the hypothesized relationships with performance. This allows us to draw inferences both about the hypothesized relationships between the leadership models and to identify which models are most closely related to the performance factor of interest as compared to the other leadership models. In these analyses, a blocking procedure was used in which those controls significantly correlated with each factor were entered as the first block and the predictors were entered second.

Results

Factor Analysis

A five-factor structure was identified from the exploratory factor analysis, with the solution accounting for 74% of the variance. Based on the consideration of the characteristics of items under each factor, the five factors were named technical influence, professional influence, team leadership, team performance, and theoretical influence. The factor loadings for each factor with descriptive labels can be found in Table 1. Factor loadings greater than 0.40 were used to identify each criterion for inclusion in a factor. The technical influence factor included three performance constructs: *dyadic influence, field influence, and technical influence*. Professional influence included three constructs as well: *organizational influence, public policy* *influence, and h-index*. Team leadership included two constructs: *group influence and number of creative products produced*. Team performance also consisted of two constructs: *number of major awards and number of groups and organizations led*. Finally, the theoretical influence factor only included a single construct: *theoretical influence*.

------------------------------INSERT TABLE 1 ABOUT HERE --------------------------------

Correlational Analyses

The correlations among the aggregate leadership construct ratings are shown in Table 2. The ratings showed the expected strong positive intercorrelations among the leadership ratings. The overall pattern of relationships within the correlations may provide some evidence for the construct validity (Messick, 1989) of the ratings. For example, the motivation constructs displayed the expected pattern of being most strongly related with climate (r = .72) and leadership control (r = .73). Similarly the expected pattern of strong positive relationships was found between the team constructs and climate (r = .66) and leadership control (r = 69). In addition to these intercorrelations, we examined the correlations between these leadership ratings and scores on the performance scales. As expected, the leadership models generally produced positive correlations with the performance factors. Especially strong relationships were found between systems exchange and professional influence (r = .33), systems exchange and team performance (r = .26), and interactions and team leadership (r = .26). Intercorrelations between controls are presented in Table 3. The controls generally evidenced the expected pattern of correlations. For example, the controls for lab work and field work were strongly negatively correlated (*r* = -.83) while lab work and time in lab were positively correlated (*r* = .25).

----------------------------INSERT TABLE 2 ABOUT HERE -----------------------------

----------------------------INSERT TABLE 3 ABOUT HERE -----------------------------

Hierarchical Regression Analyses

The results of regressing the performance factors on the leadership ratings are presented in Table 4. In the case of Technical Influence factor, the ratings produced a multiple R^2 of .35 ($p \leq .05$) and an R^2 change of .44 ($p \leq .05$) indicating that the overall ratings for the leadership constructs were effective predictors of Technical Influence. In this regression analysis only Systems Exchange ($\beta = .28$, $p \leq .05$) produced a sizeable and significant regression weight among the leadership ratings. The ratings for Control produced a sizeable but non-significant beta weight ($\beta = .25$, $p = .057$). The control variables significantly correlated with Technical Influence had no significant effects on the regression. This set of results seems to indicate that of the leadership models included in this study, Systems Exchange provides the adequate prediction of level of Technical Influence for high level scientists, and Control seems to add value to this prediction. With regard to the specific components of Systems Exchange and Control predicting Technical Influence, positive perceptions of creativity ($\beta = .33$, $p \leq .01$) and directing others ($\beta = .39$, $p \leq .01$) produced sizeable and significant regressions weights, indicating the importance of the leader's opinion of creativity and direct influence on actions taken by others are both important to their creative performance, especially with regard to technical innovations.

----------------------------INSERT TABLE 4 ABOUT HERE -----------------------------

For the Professional Influence factor, the leadership ratings produced a multiple R^2 of .45 ($p \leq .05$) and an R^2 change of .39 ($p \leq .05$) indicating that the overall ratings for the leadership constructs were effective predictors of Professional Influence. In this regression only Systems Exchange ($\beta = .27$, $p \leq .05$) produced a sizeable and significant regression weight among the leadership ratings. The control variables significantly correlated with Professional Influence had no significant effects on the regression. Again, this set of results seems to indicate that of the leadership models included in this study Systems Exchange provides adequate prediction of level of Professional Influence for high level scientists. In terms of the specific components of Systems Exchange predicting Professional Influence, level of project risk ($\beta = -.21$, $p \leq .05$) and structuring work around organizational needs ($\beta = .35$, $p \leq .01$) produced sizeable and significant regressions weights. This seems to indicate the importance of the leader's ability to control the amount of risk involved in a given project and ability to focus projects around organizational needs or requests are both important to a scientific leader's creative performance in terms of professional influence.

Regressing the Team Leadership factor on the leadership ratings produced a non-significant multiple R^2 of .04 ($p > .05$) and an R^2 change of .13 ($p > .05$) indicating that the overall ratings for the leadership constructs did not predict leader performance in terms of Team Leadership. The control variables significantly correlated with Team Leadership had no significant effects on the regression. This set of results indicates that the leadership models included in this study do not provide adequate prediction of the Team Leadership factor, pointing to the potential need for further development of leadership theory with regard to explaining the processes leading to group influence by the leader and creative output in terms of product development.

A multiple R^2 of .11 ($p \leq .05$) and an R^2 change of .35 ($p \leq .05$) were produced by regressing the Team Performance factor on the leadership ratings, providing evidence that the overall ratings for the leadership constructs were effective predictors of Team Performance. Once again, only Systems Exchange ($\beta = .33, p \leq .05$) produced a sizeable and significant regression weight among the leadership ratings. The control variables significantly correlated with Team Performance had no significant effects on the regression. This set of results seems to indicate that Systems Exchange provides adequate prediction of level of Team Performance for high level scientists, and is the only one of the leadership theories included which does so. Of the specific constructs falling within Systems Exchange, the leader's ability to account for project costs ($\beta = .29, p \leq .01$) produced sizeable and significant regression weight. Additionally, while non-significant, relatively sizeable regression weights were produced by the leader's network of connections to others ($\beta = .20, p \leq .10$) and the ability of the leader to encourage and manage competition among followers ($\beta = .20, p \leq .10$). This pattern of findings indicates the importance of the leader's ability to control and manage costs, the leader's skill at maintaining a network of connections with other professionals in their field, and the ability of the leader to manage the level of competition engaged in by their followers for Team Performance.

Regressing the Theoretical Influence factor on the leadership ratings produced a significant multiple R^2 of .12 ($p \leq .05$), however this result seems to be due to the influence of the control variables significantly correlated with Theoretical Influence, specifically the degree to which the leader engaged in lab-based work ($\beta = .31, p \leq .05$). Of the leader ratings, none approached significance, and all regression weights were relatively small, with the largest being Climate ($\beta = .16, p = .30$). This set of results indicates that the leadership models included in this study do not provide adequate prediction of the Theoretical Influence factor, while also indicating that the level of influence on the theory base in a given field may be largely due to the type of work a leader of scientific efforts chooses to engage in, with a focus on lab work leading to the largest influence on theory.

Discussion

Before discussing the broader implications of these findings it is important to discuss the limitations of the study, as these limitations must be acknowledged to frame the findings in the proper context. First, by selecting eminent scientists as the population of interest we are likely introducing range restriction to each of the constructs included in the study. We would generally expect these scientists, given their status, to be at the high end of the scale in terms of creative output and many of the other constructs examined, as compared to a population of average scientists. Additionally it is important to note that the range restriction may have occurred with only specific leadership or performance constructs, potentially changing the necessary interpretation of our results. For example, the constructs related to the theoretical area of Climate may be relatively stable at the highest levels of science due to professional norms and standards, leading to a reduced effect of the Climate constructs on performance. While range restriction is a concern there was enough variability across the scientists included in this study that we were able to conduct the described analyses and draw meaningful inferences, with ratings ranging across the entire range of each scale.

Bearing on this point, the selection of high-level scientists as our population of interest also necessarily limits the generalizability of our conclusions. This study was designed to examine how the extant leadership theories applied to this high-level population and the discussion of all results is framed as such, however it still bears emphasizing that these results may not generalize to average scientists or lower level scientists (O'Connor et al., 1995; Simonton, 1990). There is a significant body of research examining the effects of the leadership theories included in this study on lower-level scientists and in many cases the results conflict with those found in this study, likely as a result of the group being studied, and the unique characteristics of highly creative individuals (Mumford & Gustafson, 1988). Additionally, these scientists are generally working in highly functioning labs and organizations which may restrict the effects of the models presented here. For example, climate and motivation may be at generally high levels in these labs and thus there is little effect on performance if climate and motivation are at a sufficient level. Any conclusions based on this study should be restricted to high-level scientific leaders and the highly functioning labs or organizations they work with.

Another limitation of this study from two standpoints is the use of biographies to examine the occurrence of behaviors related to the relevant models and performance of the scientist and their followers. First, the use of biographies of eminent scientists did result in a relatively small sample size of 93 biographies. While this is a relatively small sample it was essentially as exhaustive as we could be while maintaining a high standard of quality for the biographies and due to the generally limited number of biographies available of relatively modern scientists. Additionally we limited our analyses and conclusions based on these analyses to take into account the small sample size in this study. Beyond the sample size issue the biographies present another potential problem in terms of the actual information contained in scholarly biographies. While these biographies generally provide substantial amounts of information on each scientist's behaviors, we are limited to events the author deems important for inclusion in the biography and the amount of detail they provide in describing each event. Due to this issue we may be missing information on potentially relevant events from each scientist's career. Additionally, the nature of academic biographies may have some inherent bias in the types of information presented. For example motivating behaviors might not appear as frequently as behaviors bearing on the leader's control of followers.

However, based on the generally high levels of documentation, coverage of career periods, and quality of the biographies as determined by each scientist's field, we believe these biographies provide high quality, unique, and extensive data on a population normally difficult to gain access to. The leadership events identified generally spanned multiple points in each scientist's career, involved the scientists working with and leading different groups, and described multiple types of problems, qualities generally regarded as critical for this type of study (Kazdin, 1980). With regard to the selection of events, those events described by the authors are likely to be critical events in each scientist's career, events which we would expect to have the greatest implications for the scientists, their followers, and the organizations they worked with, making these the events most critical for inclusion in this study (Hunt, Boal, & Dodge, 1999; Mumford, 2006). Additionally, each construct included in the ratings appeared regularly in the biography excerpts based on the ratings, with constructs appearing on average in 85% of the biography excerpts, and only three constructs appearing in less than 70% of the biography excerpts.

The final limitation we must note is with regard to our analyses. For the purpose of providing summary analyses and comparing the predictive value of each leadership model for the performance factors, constructs from each model were initially analyzed in aggregate to the model level, rather than at the level of each individual construct included in the models. While we have aggregated a number of different constructs for each model, we feel aggregating to the model level is appropriate here given that the aggregation is specified by theory and prior studies in each area.

Bearing these limitations in mind, we do feel that the results of this study have a number of important implications for our understanding of leadership processes leading to high levels of success in highly creative populations. The first set of implications comes from our hypotheses regarding the relationships, or lack of relationships, between each leadership model and leadership performance. The first hypothesis stated that leadership outcomes, with regard to leading creative efforts, would be positively related to the Control model, a hypothesis not supported by our analyses. Of our five performance factors, none were significantly related to the Control model, with only the Technical Influence factor approaching significance. These results seem to provide evidence that Control may not be closely related to leader performance on creative efforts at the highest levels, and if there is a relationship it is only with regard to the leader's influence on standard technical practices and standard field practices.

Hypothesis 2, a hypothesis stating that the Climate leadership model would be related to leadership outcomes on creative efforts, was also not supported. The Climate ratings were not significantly related to any of our performance factors and generally produced small regression weights. This is a somewhat surprising finding given the breadth of literature indicating the importance of climate for creative performance (Hunter, Bedell-Avers, & Mumford, 2007). However, as stated previously, many of the prior studies of the effects of climate on creativity have been conducted on lower level samples. Our findings seem to indicate that the relationship between climate and creativity is not as strong in high-level creative populations. This could be due to a number of factors, including the possibility that climate is relatively stable across high-level scientists due to professional standards and norms acting to create a climate conducive to creative output in a given field.

Our third hypothesis, stating that the Motivation model would be positively related to leadership outcomes on creative efforts, was also not supported by our results. Similar to Climate, the ratings of Motivation were not significantly related to the performance factors and the regression weights produced by Motivation were generally small. Again, this is an unexpected finding given the existing work on the link between motivation and creativity, a relationship that consistently appears (e.g., Baer, Oldham, & Cummings, 2003; Mumford & Hunter, 2005). The results of our analyses indicate that motivation, or at least the leader's influence on motivation, does not have an especially strong impact on creative output. In this case, we may again have an example of the difference between high-level and low or average-level creative populations. One potential explanation for the difference between our results and those of other studies of motivation and creative output is that motivation at the highest levels of science, similar to climate, is relatively stable at a high, or at least sufficient, level.

Hypothesis 4, stating that the Interactions model would be related to leader performance on creative efforts, was not supported by our analyses. The performance factors were unrelated to Interactions ratings and regression weights for the Interactions model were generally quite small. This pattern of results indicates that the Interactions model is not closely related to creative performance in high-level scientific efforts. This result may again be a case of differences between lower-level scientists and high-level scientists, with high-level scientists having more operational autonomy and generally higher levels of organizational support, reducing the need to engage in championing behaviors (Tierney, Farmer, & Graen, 1999). In lower level groups there may be a much higher impact of championing given a relative scarcity of resources, while in higher level groups resources may be easily accessible, placing more of an emphasis on other leadership processes.

Hypothesis 5, focusing on the relationship between the Team leadership model and leader performance on creative efforts, was not supported by our results. Team leadership ratings were not significantly related to leader performance, even with regard to the two team performance factors. Promoting team processes does not seem to have an influence on overall performance at the highest levels of science. This may again be a case of professional standards and norms dictating the way that teams function within each field and organization, limiting the impact of leaders on these teams, and thus on performance, via team processes. Teams at lower levels may operate in environments in which team structure and functioning is more flexible. Additionally, these teams may not be as experienced as high-level scientific teams and thus may not be as familiar with standard practices within a field in terms of teams, leading to the influence of leadership on performance in previous studies focused on team processes and creativity (e.g., Taggar, 2002).

Our final hypothesis, bearing on the relationship between the Systems Exchange model and leader outcomes on scientific efforts, was the only hypothesis to receive substantial support from our results. Systems Exchange provided significant prediction of three out of the five performance factors, specifically the Technical Influence, Professional Influence, and Team Performance factors. While the performance factors for Team Leadership and Theoretical Influence were not predicted by Systems Exchange, the overall pattern does seem to indicate that for high-level scientists the Systems Exchange model generalizes from low-level creative populations to high-level creative populations, as evidenced by the generally good prediction of leader performance on creative tasks. The potential reasons this is the only model to generalize from previous studies of low-level creative samples to the high-level sample in this study include the fundamentally cognitive nature of Systems Exchange, an element that may prevent it from being standardized in high-level populations via professional and organizational norms and best practices. Additionally, the specific constructs within Systems Exchange which predicted performance generally centered around modifying the work being done to fit the nature of the task and the organization, aspects of projects that could not be easily accounted for by field or organizational standards.

Before discussing the other implications of this study, it must be noted that the majority of our hypotheses were not supported, with only our hypothesis regarding

Systems Exchange having strong support, and none of the models included in the study predicted all five factors of leader performance on creative efforts. This points to the first major implication of our study: the existing models of leadership processes leading to creative performance, which were generally developed with individuals at lower levels of creativity, do not seem to generalize to a highly creative population. This is an important point to consider for a number of reasons. For example, interventions based on these models may not be effective in improving creative performance in highly creative populations. Leadership training programs based on these models likely still have value at lower levels, but the current approaches to training leaders of creative efforts may need to be rethought for high-level leaders. Additionally, the general lack of support for these models in this study points to the need for further development of leadership theory with regard to leading creative endeavors, particularly leading high-level creative efforts. While it seems clear from the results of this study that the current models meant to explain leadership of creative efforts may not be sufficient to explain leadership in highly creative populations, why might this be the case and why does Systems Exchange seem to generalize from low and average creativity populations to highly creative populations?

Among all of the models seeking to explain leadership of creative efforts, only Systems Exchange was supported by the results of this study. Systems Exchange, with constructs focused primarily on leader championing and strategic planning, provided fairly strong prediction of creative performance in terms of Technical Influence, Professional Influence, and Team Performance factors. With regard to Technical Influence, this relationship may be explained as a two way relationship. We would expect that influence on professional standards in field and organizations might result from recognizing which products are most creative and should be a point of focus, an idea supported by the strongest construct in the relationship between Systems Exchange and Technical Influence, perceptions of creativity. Additionally, the ability to direct individuals efforts to focus on these particularly important or creative projects, rather than potentially less fruitful products, may explain the strong relatively strong relationship between the Control construct, directing others, and the Technical Influence factor. After gaining a certain level of influence in a field or profession, we might expect a leader to be able to engage more successfully in future planning operations and championing of projects, leading to higher levels of Systems Exchange. The direction of this relationship is an open question and could benefit from future study examining whether the relationship is two-way as proposed here, or if it is a one-way relationship, identifying the direction of the relationship.

Along similar lines, we found that Systems Exchange was related to the level of Professional Influence achieved by the scientists in this study, with the constructs of project risk and structuring work around organizational needs having the largest influence on the predictive value of Systems Exchange. Again, we may explain this relationship as a two-way relationship, in which higher levels of Systems Exchange lead to higher levels of Professional Influence, which allows scientists to engage in more Systems Exchange. Leaders of creative efforts that are able to identify and focus on projects with an appropriate level of risk, and structure these projects around organizational needs or requests, seem to achieve the highest levels of influence within their organizations and are better able to produce a final creative product, whether that product is an intellectual product or an actual physical product. By identifying the level of risk for a project, leaders of creative efforts may achieve a higher overall rate of success in the projects they pursue and may be better able to plan projects based on the risks they present. This could lead to higher levels of influence within organizations as these leaders may be viewed as being a “better bet” than those with lower success rates. The higher success rate of projects will also lead to a higher level of output of creative products for these leaders. Structuring projects around organizational needs may enable leaders to more successfully champion these projects, leading to higher levels of resources and influence within an organization and higher rates of production. Again, the direction of this relationship bears examination.

Finally, Systems Exchange seemed to provide good prediction of the Team Performance factor, with the leader’s ability to account for project costs, maintain a network of professional connections, and manage competition within their team having the strongest effects on this relationship. In general, we would expect that leaders able to successfully engage in Systems Exchange would be able to procure higher levels of resources and plan projects more effectively, leading to higher levels of the Team Performance factor. The results of this study indicate that these effects may stem specifically from a leader’s ability to effectively manage team resources in terms of planning for the costs of a given project. By effectively managing costs the leader may be more likely to complete a given creative project, as they will be less likely to cancel the project due to a lack of funding. Additionally, over time, the leader may gain a reputation for effectively managing project costs and working within budgets, making them more effective at championing a project to an organization and a more attractive candidate to lead a project. Adding to the leader's ability to procure resources for the team are the professional connections they have within their network, particularly those within a given funding organization. Maintaining an appropriate level of competition within a group of high-level scientists would also be expected to improve Team Performance, as many high-level scientists on these projects may need to engage in high levels of collaboration, and inappropriate levels of competition may hurt these collaborative efforts.

While we would expect Systems Exchange to effectively predict leader success in terms of leading creative projects based on the extant literature, we would also expect our other five leadership theories to explain the success of scientist leaders. Why then were these other leadership theories not related to our leader performance factors? The explanation may lie within the properties of the sample itself as compared to the samples used in previous studies of leading creative or scientific endeavors. Much of the work done investigating these models, as we have discussed, was conducted on lower level scientists and people with lower levels of creativity than what we would expect in a sample of eminent scientists. While motivation and climate seem to consistently produce effects on creative performance in these low level samples (Hunter, Bedell, & Mumford, 2005; Baer, Oldham, & Cummings, 2003), these effects were not found in the present study. This may be due to range restriction in the population of eminent scientists and those they work with, in terms of climate and motivation. We would generally expect those engaged in work at the highest levels of a scientific field to be highly motivated individuals. Additionally, climate in these highly functioning work groups may be largely a result of professional norms and standards from the fields and organizations these scientists work in, with these norms and standards focused on creating a climate conducive to creative work.

If this is the case, with range restricted to very high levels of motivation and climate in the sample, then climate and motivation may essentially be functioning as hygiene factors. It may be the case that, as a leader, you must induce motivation and climate up to a certain level to allow for creative production in lower level populations. However, in a population of high level scientists, where motivation and climate are already maintained at a level sufficient to allow for creative performance, the leader may have little influence on these processes. Rather than needing motivation or the creation of a climate, high level scientists may instead need their motivation to be directed to appropriate tasks, leading to the effects of the Systems Exchange model and potential effects of the Control model. The lack of predictive value of the Team model for leadership of creative efforts may also be due to similar issues of range restriction within the population of high-level scientists, with team functioning largely being a result of professional norms and field standards. Norms and standards meant to produce consistently high functioning teams may obviate the need for a leader to focus on team processes. The Interaction model may not work well to explain leader performance with high-level scientists simply due to the fact that high-level scientists are not especially social and the collaboration scientists do engage in is largely structural and is based on the work they are engaged in vis-à-vis functional work demands (Zuckerman, 1977). Again, if interactions are largely a product of the work itself, leaders would likely have little influence on these interactions, and what influence they did have might be disruptive to normal functioning of these high-level scientists.

Based on the results of this study it seems that, of the available models, the Systems Exchange model, with a focus on strategic planning and the championing of projects, is relatively accurate for predicting the performance of leaders at the highest levels of science. Additionally it seems that there may be some added value from the Control model. The results of this study, as compared to those from studies of lower level scientists, seem to indicate that for leaders of scientific efforts to succeed their work group must have high motivation, team functioning, interactions, and a climate conducive to creativity, but once an adequate level of each of these factors has been achieved the leader should then focus on strategic planning and project championing, as well as directing the work group's activities. In high-level scientists, where motivation, interactions, teams, and climate may all be dictated by professional norms, leaders should focus their efforts on effective systems exchange. Most scientific leadership models do not differentiate between hygiene and performance factors, and this study may provide some guidance on making these differentiations, and at which levels these leadership processes begin to function as hygiene factors.

The results of this study seem to indicate that there is too much focus on interactions and their importance to leadership when it comes to high-level scientists. Rather, we should be focusing on leadership in terms of planning and control. Much of the work on creative leadership may be unintentionally focusing on how to create and environment for "normal" people to be creative and ignoring the unique attributes of highly creative people. The models of leading creative people developed thus far have been developed with lower creativity samples and generalized to higher creativity populations, a practice that seems to be inappropriate based on the results of this study.

Creative people are unique (Mumford et al., 2002) and we need to think about the unique aspects of creative people and how they need to be led. We may be losing sight of the other processes going on (e.g., professional norms) with our focus purely on leadership models. This study points to the need to study the leadership of creative people as a whole, not just in terms of the effects of leadership and leader behaviors.

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Appendix A: Tables

Table 1: Promax Rotated Factor Matrix Showing Factor Loadings of Scientist Leader Performance Criteria

Variable	Factor 1: Technical Influence	Factor 2: Professional Influence	Factor 3: Team Leadership	Factor 4: Team Performance	Factor 5: Theor. Influence
Dyadic influence	0.654	*	*	*	*
Group influence	*	*	0.769	*	*
Organizational influence	0.432	0.731	*	*	*
Field influence	0.655	*	*	*	0.641
Public policy influence	*	0.595	0.442	*	*
Theoretical influence	*	*	*	*	0.947
Technical influence	0.798	*	*	*	*
Number of creative products	*	*	0.728	*	*
Number of major awards	*	*	*	0.853	*
Number of groups/organizations led	*	*	*	0.791	*
H-index	*	0.724	*	*	*

Note: only loadings of 0.40 and above are included in matrix

Table 2: Intercorrelations of Leadership Models with Performance Factors

	1	2	3	4	5	6	7	8	9	10	11
1.Control	1.00										
2.Climate	0.59	1.00									
3.Motivation	0.73	0.72	1.00								
4.Interactions	0.59	0.72	0.63	1.00							
5.Teams	0.69	0.66	0.67	0.51	1.00						
6.Sys. Exch.	0.11	0.52	0.25	0.23	0.20	1.00					
7.Tech. Infl.	0.19	0.22	0.13	0.16	0.10	0.18	1.00				
8.Prof. Infl.	0.10	0.17	0.01	0.05	0.11	0.33	0.30	1.00			
9.Team Ldr.	0.13	0.10	0.01	0.26	0.03	0.03	0.33	0.16	1.00		
10.Team.Perf.	0.04	0.20	0.08	0.19	0.01	0.26	0.15	0.27	0.05	1.00	
11.Theo. Infl.	0.09	0.14	0.14	0.07	0.15	0.15	0.02	0.10	0.13	0.22	1.00

Note: $r > .21$ significant at .05 level

Table 3: Intercorrelations of Controls

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Author Opinion	1.00																		
2. Documentation	-0.48	1.00																	
3. Time on Projects	-0.36	0.16	1.00																
4. Time in Lab	-0.02	-0.02	0.01	1.00															
5. Event Detail	0.03	0.07	-0.16	0.15	1.00														
6. Lab Work	-0.19	0.14	0.20	0.25	0.13	1.00													
7. Field Work	0.11	-0.15	-0.05	-0.13	-0.11	-0.83	1.00												
8. Project Support	-0.25	0.10	0.23	0.29	0.01	0.30	-0.15	1.00											
9. Focus on Field	-0.12	0.02	0.10	0.56	0.21	0.13	0.07	0.30	1.00										
10. Group Size	-0.06	0.26	0.23	-0.03	0.04	-0.33	0.31	0.12	-0.03	1.00									
11. Organization Size	0.05	0.10	-0.01	0.11	0.05	0.12	-0.18	0.25	0.14	0.04	1.00								
12. External Commitments	0.03	-0.06	0.06	-0.04	-0.03	-0.01	0.13	0.16	0.23	0.15	0.19	1.00							
13. Professional Commitments	-0.22	0.10	0.10	0.05	-0.09	0.25	-0.23	0.21	0.13	-0.25	0.20	0.28	1.00						
14. Primary Field	0.24	-0.07	-0.27	0.05	0.03	-0.04	-0.05	-0.15	-0.03	-0.04	0.13	0.08	-0.01	1.00					
15. Secondary Field	-0.15	-0.15	0.13	0.28	-0.31	0.05	0.16	0.35	-0.03	0.01	0.25	-0.25	0.16	-0.13	1.00				
16. Education Level	-0.17	0.05	-0.05	-0.15	-0.14	0.11	-0.23	0.05	-0.08	-0.03	0.02	-0.01	0.10	0.15	-0.01	1.00			
17. Country	0.01	-0.04	0.09	0.08	0.05	0.08	-0.03	-0.05	0.13	0.04	0.07	0.01	0.12	0.07	-0.27	0.01	1.00		
18. Year of Publication	-0.09	0.14	0.15	-0.11	0.15	0.23	-0.38	0.02	-0.13	-0.13	0.11	-0.14	-0.05	-0.10	-0.52	-0.06	0.12	1.00	
19. Length of Book	-0.03	0.19	-0.10	0.04	0.10	0.05	-0.06	-0.03	-0.01	0.08	0.01	0.13	0.07	0.06	-0.16	-0.04	0.04	0.28	1.00

Note: $r > .23$ significant at .05 level

Table 4: Hierarchical Regression of Leadership Models on Performance Factors

Factor 1: Technical Influence	*β*	*Sig.*
1. Control	.251	.057
2. Climate	.105	.483
3. Motivation	.141	.302
4. Interactions	.209	.115
5. Teams	.148	.272
6. Systems Exchange	.279	.038
$R^2 = .35, p \leq .05; R^2_c = .44, p \leq .05$		

Factor 2: Professional Influence	*β*	*Sig.*
1. Control	.134	.282
2. Climate	.036	.799
3. Motivation	.156	.243
4. Interactions	-.063	.621
5. Teams	.077	.570
6. Systems Exchange	.271	.035
$R^2 = .45, p \leq .05; R^2_c = .39, p \leq .05$		

Factor 3: Team Leadership	β	*Sig.*
1. Control	.137	.315
2. Climate	-.034	.802
3. Motivation	-.033	.811
4. Interactions	.112	.409
5. Teams	-.025	.856
6. Systems Exchange	.091	.498
$R^2 = .04$, $p > .05$; $R^2_c = .13$, $p > .05$		

Factor 4: Team Performance	β	*Sig.*
1. Control	-.168	.269
2. Climate	-.053	.756
3. Motivation	-.029	.851
4. Interactions	.070	.648
5. Teams	-.095	.539
6. Systems Exchange	.327	.035
$R^2 = .11$, $p \leq .05$; $R^2_c = .35$, $p \leq .05$		

Factor 5: Theoretical Influence	β	*Sig.*
1. Control	.088	.560
2. Climate	.157	.308
3. Motivation	.045	.769
4. Interactions	.033	.828
5. Teams	.139	.367
6. Systems Exchange	-.030	.841

R^2 = .12, $p \leq .05$; R^2_c = .11, $p > .05$

Appendix B: Figures

Figure 1: Scientists and Associated Biographies

Name (Last, First)	Book Name
Adorno, Theodor	Theodor W. Adorno: One last genius
Allport, Gordon	Gordon Allport: The man and his ideas
Andrews, Roy Chapman	Dragon hunter: Roy Chapman Andrews and the Central Asiatic…
Appleton, Edward	Sir Edward Appleton
Aron, Raymond	Raymond Aron: The philosopher in history
Baade, Walter	Walter Baade: A life in astrophysics
Bailey, Liberty	Liberty Hyde Bailey: An informal biography
Bardeen, John	True genius: The life and science of John Bardeen…
Barthes, Roland	Roland Barthes: The professor of desire
Bay, Zoltan	Zoltan Bay, atomic physicist: A pioneer of space research
Beadle, George Wells	George Beadle, an uncommon farmer: The emergence of genetics…
Bell, Alexander Graham	Reluctant genius: Alexander Graham Bell and the passion for invention
Bell, Daniel	Daniel Bell
Bethe, Hans Albrecht	Hans Bethe and his physics
Bhabha, Homi Jehangir	Homi Jehangir Bhabha, 1909-1966
Bjerknes, Vilhelm Frimann	Appropriating the weather: Vilhelm Bjerknes and the construction of…
Blackett, Patrick	Patrick Blackett: Sailor, scientists, and socialist
Boas, Franz	Franz Boas
Bohr, Niels	Harmony and unity: The life of Niels Bohr
Bok, Bart	The man who sold the milky way: A biography of Bart Bok
Bowlby, John	John Bowlby: His early life
Bowman, Isaiah	The life and thought of Isaiah Bowman
Braun, Wernher von	Wernher von Braun: The man who sold the moon
Bruner, Jerome	Jerome Bruner: The cognitive revolution in educational theory
Bunau-Varilla, Phillipe-Jean	Phillipe-Jean Bunau-Varilla: The man behind the Panama Canal
Burbank, Luther	A gardener touched with genius: The life of Luther Burbank
Carrel, Alexis	The immortalists: Charles Lindbergh, Dr. Alexis Carrel, and their daring…
Chadwick, James	The neutron and the bomb: A biography of Sir James Chadwick
Chain, Ernst	The life of Ernst Chain: Penicillin and beyond

Coase, Ronald	Ronald Coase
Cockcroft, John	Cockcroft and the atom
Crawford, OGS	Bloody old britain: OGS Crawford and the archaeology of modern life
Crick, Francis	Francis Crick: Discoverer of the genetic code
Curie, Marie	Obsessive genius: The inner world of Marie Curie
De Forest, Lee	Electronics pioneer: Lee De Forest
Dewey, John	The education of John Dewey: A biography
Dubos, Rene Jules	Rene Dubos: Friend of the good earth
Einstein, Albert	Albert Einstein: A biography
Fermi, Enrico	Enrico Fermi: His work and legacy
Fleming, Alexander	Penicillin man
Foucault, Michel	The lives of Michel Foucault
Franklin, Rosalind	Rosalind Franklin: The dark lady…
Freud, Anna	Anna Freud: A biography
Godel, Kurt	Logical Dilemmas: The life and work…
Gramsci, Antonio	Antonio Gramsci
Hawking, Steven W.	Stephen Hawking: A life in science
Hubble, Edwin	Edwin Hubble: The discoverer of the big…
Innis, Harold	Marginal man: The dark vision of Harold Innis
Jacobs, Jane	Urban visionary
Jensen, Arthur	Arthur Jensen
Jordan, David Starr	David Starr Jordan: Prophet of freedom
Keynes, John Maynard	John Maynard Keynes: A personal biography…
Kinsey, Alfred	Kinsey: A biography
Lawrence, Ernest	Lawrence and his laboratory: A history of…
Lockyer, Joseph	Science and controversy: A biography of Sir Norman…
Mannheim, Karl	Karl Mannheim: The development of his thought
Marconi, Guglielmo Marchese	Thunderstruck
Mauss, Marcel	Marcel Mauss: A Biography
Mawson, Sir Douglas	Douglas Mawson: The life of an explorer
McLuhan, Marshall	Escape into understanding
Mead, George H.	The making of a social pragmatist
Meitner, Lise	Lise Meitner: A life in physics
Milgrim, Stanley	The man who shocked the world
Mills, C. Wright	An american utopian

Mincer, Jacob	A founding father of modern labor economics
Murray, Henry A	Love's story told: A life of Henry A. Murray
Myrdal, Alva	Alva Myrdal: The passionate mind
Neumann, John von	The scientific genius who pioneered the modern computer...
Oppenheimer, Robert J.	American prometheus: The triumph and tragedy of J. Robert Oppenheimer
Park, Robert E.	Robert E. Park: Biography of a sociologist
Parsons, Talcott	Talcott Parsons
Pavlov, Ivan Petrovic	Ivan Pavlov
Perls, Fritz	Fritz
Perutz, Max	Max Perutz and the secret of life
Porter, Russell	Russell W. Porter: Arctic explorer, artist, telescope maker
Rank, Otto	Acts of will: The life and work of Otto Rank
Richards, Ivor Armstrong	I.A. Richards: His life and work
Robbins, Lionel	Lionel Robbins
Rostow, Walt	America's Rasputin: Walt Rostow and the Vietnam War
Russell, Bertrand	Bertand Russell: A life
Sagan, Carl	Carl Sagan: A life
Salam, Abdus	Abdus Salam: A nobel laureate from a Muslim country
Tarski, Alfred	Alfred Tarski: Life and logic
Teller, Edward	Edward Teller: A giant of the golden age of physics
Tesla, Nikola	Tesla: Man out of time
Volcker, Paul	The making of a financial legend
Watson, JB	Mechanical man: Joan Broadus Watson and the beginnings of behaviorism
Watson-Watt, Robert	The radar man
Webb, Beatrice	The socialist with a sociological imagination
Wells, Ida B.	To keep the waters troubled
Wiley, Harvey	Politics and purity
Woolley, Leonard	Woolley of Ur: The life of Sir Leonard Woolley
Zermelo, Ernst	Ernst Zermelo: An approach to his life and work

Figure 2: Example Ratings Scale

1. Sales – the degree to which the leader focuses on selling and promoting creative ideas or products to others in the organization

1	2	3	4	5
Absence of any discussion regarding sales, or the leader rarely if ever tries to sell creative efforts		The leader spends some time trying to sell creative ideas or products, spending more time on ideas perceived as high value		The leader is constantly selling creative ideas or products, spends most of his or her time promoting creative efforts to the organization

2. Strategy – how closely the leader matches the creative efforts being worked on to the overall strategy of the organization

1	2	3	4	5
Absence of any discussion regarding strategy, or the leader displays little or no concern about the organization's strategy or goals		The leader makes sure most ideas fit within the organization's strategy, some efforts may fall outside of the strategy		All creative efforts undertaken by the leader closely match the organization's strategy, the leader rejects or highly modifies ideas outside of the strategy

3. Top management recruitment – the amount of time and effort the leader spends on gaining support from top management

1	2	3	4	5
Absence of any discussion regarding top management recruitment, or the leader spends little or no time gaining top management support		The leader tries to gain support from a few top managers, spends more time and effort on gaining support for high value projects		The leader spends much of his or her time trying to gain management support for creative projects, tries to gain support of most of the top management in an organization

Figure 3: Leadership Models and Constructs

Control

Direct supervision
Input into projects
Presence
Decision making
Directing
Directing from experience
Directing with authority
Clarity of mission
Requests creative or innovative solutions
Broad task definition
Encourage information gathering
Encourage debate
Calls attention to strange occurrences
Points out restrictions

Climate

Positive peer group
Positive supervisor relations
Resources
Challenge
Clarity of mission
Autonomy
Positive interpersonal exchange
Intellectual stimulation
Top management support
Reward orientation
Flexibility and risk taking
Product emphasis
Participation
Organizational integration

Motivation

Self-selection to projects
Concrete rewards
Work complexity
Role modeling
Verbal persuasion
Encouraging identity investment in mission
Leader engagement
Network activity

Interactions

Encourage risk taking
Provides operational autonomy
Promotes non-routine activity
Eliminates work constraints
Challenging and relevant tasks
Provides resources
Recognition for innovation
Advocates on behalf of members

Teams

Team citizenship
Performance management
Effective communication
Involving others
Providing feedback
Reaction to conflict
Averting conflict
Diversity of experience
Communication/information exchange
Shared mental models
Selection of team members

Systems Exchange

Sales
Strategy
Top management recruitment
Risk
Cost
Connections
Integration with other programs
Perception of creativity
Climate for creativity
Organizational knowledge
Organizational need
Competition

Figure 4: Performance Criteria

Performance Construct	Definition
Dyadic influence	The level of influence the leader evidenced in one-on-one relationships
Group influence	The level of influence the leader evidenced in groups directly reporting to them
Organizational influence	The level of influence the leader had on an organization as a whole, particularly with respect to organizational strategy
Field influence	The level of influence the leader had on standard practices or norms within their field
Public policy influence	The level of influence the leader had on public policy with respect to laws and regulations as well as governmental agendas and specific individuals within governments
Theoretical influence	The level of influence the leader had on the overall theory base in their field
Technical influence	The level of influence the leader had on methods, techniques, and technology within their field
Number of creative products	The number of creative products attributed to the leader and the leader's teams
Number of major awards	The number of major awards received by the leader
Number groups/organizations led	The number of groups and organizations the leader was in charge of throughout their career
H-index	A measure of scientific productivity and impact based on publications

Figure 5: Controls

Rated by judges

Author opinion
Documentation
Leader time on projects
Leader time in lab
Event detail
Amount of lab work
Amount of field work
Level of project support
Focus on primary field
Group size
Organization size
Extent of external commitments
Extent of professional commitments

Drawn from documents/databases

Primary field
Secondary field(s)
Education level
Nationality
Primary country in which work took place
Year of book publication
Length of book