PIVOT THINKING
AND THE DIFFERENTIAL SHARING OF INFORMATION
WITHIN NEW PRODUCT DEVELOPMENT TEAMS

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ABSTRACT

Functionally diverse team members bring unique sets of cognitive styles to team interaction; it is less clear how these differences affect the exchange of critical, mutually required team information. This cognitive diversity in new product design (NPD) teams increases the likelihood that individual team members will perceive the team’s task differently, leading to “cognitive representational gaps” between teammates’ interpretations of both the task and potential solution.

This research shows that cognitively diverse NPD teams develop representational gaps based on individual cognitive preferences between convergent and divergent information types and these cognitive preferences influence both task definition and solution. A second experiment shows that team leadership that bridges cognitive preferences, called “pivot thinking,” can overcome this limiting behavior. Understanding these general mechanisms deepens understanding of group information processing and conflict in cognitively diverse NPD teams. Implications for design education are discussed.
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If everyday design were ruled by aesthetics, life might be more pleasing to the eye but less comfortable; if ruled by usability, it might be more comfortable but uglier. If cost or ease of manufacture dominated, products might not be attractive, functional or durable. Clearly, each consideration has its place. Trouble occurs when one dominates all the others. (Norman, 2002, p. 151)

Don Norman

The Design of Everyday Things

CHAPTER 1 – Innovation is a Team Sport
Why Teams Matter to Innovation

There exist two opposing models that describe the process of invention. The individual defines the first model. It is often called a “flash of genius” or “divine inspiration” or the “AHA! Moment.” In this framework an individual has an idea, a new concept, a novel thought and from this experience a new product emerges; the world is changed. Many well-publicized examples of this form of invention exist ranging from the profound, like Watson or/and Crick’s conception of the structure of DNA (Moffett, 2006) to mundane, like Kearn’s invention of the intermittent windshield wiper (Seabrook, 2008). The “individual
model” of invention begins and ends with a lone person, who has a single, discontinuous idea, seemingly from nowhere.

The second model of invention involves the team and the model practiced broadly within industry. In the team approach to innovation, invention is hard, iterative work done by a “collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in one or more larger social systems (for example business unit of the corporation) and who manage their relationships across organizational boundaries” (Cohen & Bailey, 1997, p. 241). Increasingly, invention is a big corporation game. Patents are an imperfect but telling indicator of this trend. In 2009, a total of 167.3K US patents were granted. Foreign and US Corporations were granted 154.0K patents or 92% of total patents granted, while individual inventors were granted only 12.6K patents, just 7.5% of the total. IBM, Samsung and Microsoft together were granted 11.4K patents almost equaling the total of all individual inventors worldwide (Patenting by Organization, 2010).

In today’s working world, innovation is a team sport. The complexity of the innovation process, the broad range of necessary skills and the resources required to practice innovation increasingly require the capabilities found in a multi-functional work team. Effectively blending these skills in a team environment can be a significant challenge.

**NPD Teams: The benefit and curse of Functional Specialization**

Within these corporations, the composition of innovation teams, which are called New Product Development (NPD) teams, has been a subject of much study. Typically, NPD teams are multi-functional, meaning that they are
comprised of employees from different functional work areas of the company, arriving to the team with a broad range of experiences and skills. The organizational principle is that multi-functional teams have individual team member representation from each of the major functional areas that define the work of the corporation and therefore mirror the interests of the corporation at the team level. This is a benefit to the work of a team in that it naturally blends work skills and perspectives that reflect the overall business model of the corporation. It can also be a curse in that these differing perspectives flow from the differing functional work that often reflects a specific perspective that is most suited to that particular work. These differences may be a source of team conflict.

Kelley and Littman describe the NPD team as “people creating value to the implementation of new ideas.”

“Innovation is definitely not self-starting or self-perpetuating. People make it happen to their imagination, willpower and perseverance. And whether you’re a team member, a group leader, or an executive, your only real path to innovation is through people. You can’t really do it alone.” (Kelley & Littman, 2005, p. 17).

Kelley and Littman describe a variety of “personas” which can populate an NPD team. These personas are divided into three areas: learning personas, organizing personas and building personas. An example of an organizing persona is “The Collaborator” who helps bring “eclectic groups together, and often leads from the middle of the pack to create new combinations of multidisciplinary solutions.” An example of a building persona is “The Experience Architect,” a person who designs compelling experiences that go “beyond mere functionality
to connect at a deeper level with customers latent or expressed needs.” In total, Kelley and Littman identify ten separate personas that populate successful NPD teams.

These colorful descriptions of personas are helpful in describing roles but sometimes difficult to identify in the real world. NPD team members are more easily identified by the corporate work function they represent, such as sales, manufacturing, R&D or marketing. Further, when NPD teams are assembled, rarely are they constructed by persona, but more likely by a typical mix of functional backgrounds under the assumption that representing all interests of the corporate supply chain is the best way to ensure the ideation and implementation of successful new product ideas.

A type of job or functional discipline is often associated with a particular cognitive style or reference for solving problems. Corporate functional disciplines have been defined by many characteristics such as a preference for analysis (finance) over intuition (marketing) (Allinson & Hayes, 1996) or as information maximizers (R&D engineers) versus information satisfiers (human resources) (Driver & Streufert, 1969). It is less clear if these are acquired behavioral differences, reinforced by membership in a functional group or if an underlying cognitive difference drives the career choice.

Psychologist and psychometrician Raymond Cattell put forward the theory that these differences are result of an individual’s lifelong pursuit of neurocognitive advantage (Cattell, 1986). Cattell believed that individuals are born with a unique fluid intelligence capability to solve particular problems. As they go
about life solving problems, they acquire crystallized intelligence that helps solve those same problems more successfully. In turn, the individual seeks more of the problems they solve successfully and acquires more of the successful problem solving skills. Cattell refers to this as the cognitive “investment theory” where individuals gravitate towards problem-solving situations where they have skill and have seen success in the past.

Therefore, it is reasonable to assume that individuals seek jobs that reflect their underlying skills and in those jobs continue to improve those same skills. For example, consider a person that is good with numbers and gets a job in the finance department working, where they succeed and are promoted to higher level jobs where they solve increasingly complex number oriented problems. This builds a numerical skill and reinforces a desire to explain problems with numbers, regardless if a numerical solution is the preferred way to a particular solve problem. This personal strength can become a liability in the context of a multi-functional team where each team members brings a different set of functionally specific cognitive strengths (J. S. Bunderson & Sutcliffe, 2002).

Shared Mental Models and Representational Gaps
The concept of “mental models” has been used as an explanatory mechanism in a variety of disciplines over the years (Wilson & Rutherford, 1989). A mental model is defined as an individual mechanism “whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future states” (Cannon-Bowers, Salas, & Converse, 2001). Not surprisingly, it has been demonstrated that when team members explicitly share individual mental models of problem states, team results improve (Marks, Sabella, C. S. Burke, & Zaccaro, 2002).
The problem, of course, is not where individual mental models coincide; the problem is when mental models diverge and these differences are not shared. Cronin and Weigert term this a “representational gap” and define it as “rooted in individual-level problem representations - the framework that guides the way an individual solves problems.” They hold that individuals are limited to perceiving a problem only from their own vantage point and “default beliefs of others are difficult to inspect because they are often not verbalized.” Joint problem representation and problem solution at the team level are “difficult to implement and less reliable” and that “any inconsistencies across these tacit non-verbalized beliefs can easily go undetected and uncorrected” (Cronin & Weingart, 2007, p. 763).

**Cognitive Style: Meta-Types … Convergent and Divergent**

Theoretically, there can be as many cognitive styles as there are people. Practically, cognitive styles tend to group. The underlying premise of this research is that there are two fundamental meta-types of cognitive problem solving styles: convergent and divergent.

The terms “convergent” and “divergent” are derived from J. P. Guilford’s model of the Structure of Intellect (Guilford, 1967). Guilford proposed that performance on cognitive tests was a function of some underlying cognitive ability or intelligence factor. Through item examination and factor analysis of a broad range of specific intelligence tests, Guilford eventually concluded that there were 180 separate categories that comprised human cognitive ability (Guilford, 1988).
Guilford organized these categories of cognitive ability into three broad areas: Content, Product and Operation. Content related to the preference for the form of input such as visual, auditory, symbolic or behavioral. Product is defined as the structure or type of information, like units, classes, relationship or systematic data. Operation describes cognitive action, what the brain does with content and production input, and includes activity like storing to memory, evaluation, convergent production and divergent production. This final area, Operation, comes closest to describing cognitive problem solving styles.

Guilford defines convergent production as “in the area of logical deductions” and “is the prevalent function when the input information is sufficient to determine a unique answer” (1967, pp. 170-171). This aligns with the classic interpretation of logic or deductive reasoning. Guilford defines divergent production as “the generation of information from given information, where the emphasis is upon variety and quantity of output from the same source; likely to involve transfer” and is often associated with inductive reasoning. Guilford summarizes by stating, “… in divergent production we are generating the logical possibilities from given information, whereas in convergent production we are generating the logical necessities” (1967, p. 220).

A convergent style is a preference to problem solve in a deductive manner where “the problem, if properly structured may call for a unique solution.” A divergent style is a preference to problem solve in an inductive manner where there is the possibility of multiple correct answers.
Differential Information Sharing: Conceptual Model and Hypotheses

NPD teams complete their task through regular multifunctional meetings of the team members. In these meetings, NPD team members exchange information through updates and progress reviews. The NPD meeting can be considered a “marketplace” of team decision-making, as shown in Figure 1.

Within this marketplace, project information is “sold” and “bought” by individual team members as they proceed through the process of making decisions. Each team member makes implicit decisions about the information they chose to bring to the team marketplace. Individual NPD team members share information through a “trading zone” which is a series of both formal and informal conversations with other team members. This is all in service of the process of developing a joint problem representation for the entire team. As NPD team members discuss the problem information flows back to the individual team members through a “discovery zone” which is an opening moment for new learning on an individual level. This flow of information outward from the individual through trading zone and back to the individual for discovery zone is affected by an individual's ability to both listen and accept new information. In a healthy team sharing environment information will flow from the individual through the “trading zone” and back to the individual through the “discovery zone” in a iterative process.
The first moderating effect of this model is individual level problem representation and values, which is the “framework that guides the way an individual solves a particular problem” (Cronin & Weingart, 2007, p. 762). On an NPD team, this may be why finance managers like to see “the numbers,” sales managers like to know “the customer,” and marketing managers want to know “the concepts.” It is not that any one of these approaches is necessarily correct for the problem at hand, it is simply that an individual is approaching a problem with the tools and style that has afforded them the most success in the past and minimizes their personal cognitive energy required to solve problems. Within large organizations, teams working on complex cognitive tasks are typically composed of members different backgrounds (Bantel & Jackson, 1989) and represent different “thought collectives” or “departmental thought worlds” (Dougherty, 1992). It is likely that individual NPD team members bring different mental models and different values to the information sharing process and this would lead to the differential sharing of information.
It has been shown that differences in educational levels and national diversity have an impact on team information sharing, with higher levels of educational diversity enhancing team information use and higher levels of national diversity hindering information use (Dahlin, Weingart, & Hinds, 2005). This relates to NPD teams if educational diversity can be a proxy for functional domain knowledge and national diversity serves as a proxy for social or cultural differences that can occur between functions in a corporation. In this manner, teams with a diversity of domain knowledge have the capacity to share more information because each team member has unique functional knowledge that can shape a group decision. Social or cultural differences that may exist between functions are less obvious but have a significant negative impact on team information use and sharing.

I argue that functional experience over time shapes and ultimately determines an individual’s cognitive problem solving preference as either predominantly convergent or predominantly divergent. This individual preference in turn regulates how an individual both internally values information and determines their willingness to share information in a team environment.

**Hypothesis 1:** Individuals on teams exchange information moderated by cognitive problem solving preference for convergent or divergent information.

In this case, cognitive style preference is a moderator “that affects the direction and/or strength of the relation between an independent or predictor variable and
a dependent or criterion variable” (R. M. Baron & Kenny, 1986, p. 1174) with cognitive style differences between convergent and divergent style preferences as the independent variable and the type and extent of information sharing within the group as the dependent variable.

As the NPD team develops a joint problem representation through information sharing and assimilation, they begin the task of team information processing and decision-making. It is likely that individual problem-solving preferences will again moderate the information used to solve problems, which could be expressed as phrases like “I think this is important” or “we have to take this into consideration.” This exchange works through a trading zone where individual team members offer their unique perspective on the problem as the team works toward a solution. The learning about problem-solving flows back to the team through a discovery zone and influences the team shared mental model for the problem space.

Team leadership affects team learning through tacit and explicit filtering of information back to the team as team members share individual mental models of the problem representation. Hackman describes this type of leadership as the “execution skill” of a team leader and suggests that it involves decision-making skill, teaching skill and interpersonal skill. Decision-making skill is the “ability to choose among various courses of action under uncertainty, using all perspectives and data to inform the decision” (Hackman, 2002, p. 225). It is also likely that a team leader would use their own cognitive style preference to filter information, assign importance of information and shape the decision-making process.
In this scenario, convergent style preference leaders would use convergent techniques for information filtering and decision-making processes which reflect a convergent, single point approach. Similarly, divergent style preference leaders would use divergent techniques such as looking for multiple solutions and keeping problem spaces open longer to arrive at a decision. Also, a leader with no distinct style preference for either convergent or divergent problem-solving (which I call “pivot thinking,” see next section) may moderate the decision information sharing and decision-making process.

**Hypothesis 2:** Team leader behavior can offset cognitive representational gaps through a behavior called “pivot thinking” that encourages individuals of different cognitive styles to evaluate and share unique information for the purposes of group decision making.

**Seeing Both Sides: Pivot Thinkers**

Bob Johansen, a Distinguished Fellow at the Institute for the Future, describes an emerging set of skills leaders will need to deal with the future, in a world characterized by volatility, uncertainty, complexity and ambiguity. One of the most important skills is called “constructive depolarization” which is the ability “to remake polarization into dialogue.” Johansen describes it:

“In polarized situations, differences are sharply drawn and communication has disintegrated. In a chaotic world, there are often more than two points of view and there are usually many stakeholders. Constructive depolarization is a skill that all leaders will need. Leaders
need to redirect the energy of conflict and bring stakeholders towards constructive engagement and dialogue.” (Johansen, 2009, p. 89)

Team polarity can be a significant problem, particularly with NPD teams. Thomas and Schmidt found that managers of innovation teams spend on average about 20% of their time handling conflict, with the percentage increasing as teams move lower in the organization. Team polarity can have both disadvantages and advantages (K. W. Thomas & Schmidt, 1976). For example, team polarity can hobble the work process by slowing important decisions, especially if members are aware of different opinions (Pelled, 1996). On the other hand, team disagreement about tasks can be helpful in identifying and better understanding the issues involved in the discussion (Putnam, 1994); disagreement can be helpful in developing new ideas and approaches to tasks (R. A. Baron, 1991), it can increase team members tendency to internalize task issues and think more deeply (De Dreu & Weingart, 2003) and disagreement can make team members more flexible in their thinking (Carnevale & Probst, 1998). Team polarity also has a temporal aspect where differences in opinion early in a project have a positive impact on team creative performance, while differences later in the development cycle, near to production, have a negative impact on creative performance (Kratzer, Leenders, & van Engelen, 2006).

This raises the question as to the existence of a cognitive style, based on neurological structure, which might be particularly effective achieving “constructive depolarization.” This particular cognitive style must be able to see value in approaching a problem from many sides and value contribution of both divergent and convergent thinking on a team. This simultaneous use of convergent and divergent problem solving styles or the pivoting between two
very different cognitive styles reflects both the capacity for convergent/divergent problem solving styles and a lack of preference for either style in problem solving. I label this type of cognitive style is “pivot thinking.”

**Pivot Thinking:** A cognitive problem solving style that easily pivots or shifts between convergent or divergent problem solution possibilities.

The conceptual model for pivot thinking is shown in Figure 2. This model assumes that problem solving preferences are generally divided into Guildford’s two primary Operations – Convergent and Divergent. This model assumes no overlap between the two approaches, as they are mutually exclusive. For example, the search for a single, unique correct answer is exclusive of the search for multiple correct answers. A “Converger” would tend to favor convergent problem solving techniques and solutions, although retain a limited interest in divergent problem solving, while a “Diverger” would tend to favor divergent problem techniques and solutions and also retain a limited interest in convergent problem solving.

![Figure 2 - A conceptual model for Pivot Thinking that reflects both a capacity and facility to shift between Convergent and Divergent problem solution possibilities.](image-url)
A “Pivot Thinker” would display problem solving preferences that easily pivots or shifts between convergent and divergent approaches. The pivot thinker may begin the process of problem solving by looking for a single point answer but then shift to the possibility of multiple answers and the implications of a divergent approach. This pivoting may occur several times within the problem solving process, perhaps without the individual conscious of the varying problem approaches.

There is a neurological basis or mechanism for pivot thinking capability. Pivot thinking requires the neurological capability to quickly shift between convergent style neurological systems in divergent style neurological systems. This capability, called “task shifting” is a distinct neurological capability that varies with individuals based on their unique neurological characteristics.

Mental chronometry or cognitive reaction time (RT) has been recognized as a measure of individual cognitive differences since the early 1800s. RT is considered an indication of how fast a thinker can execute mental operations and it has been linked to moderate positive correlations in IQ. RT becomes a proxy for cognitive load or the amount of stress placed on cognitive systems to solve a particular problem (Jensen, 1982).

British psychologist William Hick discovered that RT varies not only by individual but also by the nature of the cognitive task (Hick, 1952). “Hick’s Law” describes the time it takes for a person to complete a cognitive task as a result of the number of possible choices presented; the more choices the longer
it takes and the higher the cognitive load. Cognitive scientists also measure time and error rates in “task switching” the control processes that “reconfigure mental resources for a change of task by requiring subjects to switch frequently among a small set of simple tasks” (Monsell, 2003). It has been shown that RT and error rates grow as the brain alternates between different cognitive systems, indicating a higher cognitive load and higher cognitive energy associated with task switching. This is most evident when switching between distinctly different cognitive tasks, like a convergent task (arithmetic) and a divergent task (alternate possible rules for geometric classification) that resulted in “switching-time costs” (Rubinstein, Meyer, & J. Evans, 2001).

Team Composition and Pivot Thinking

As individuals bring different cognitive capabilities and the freedom of choice to problem solving, they likely gravitate toward problems they find easier to solve and solve problems in ways they find easier to process. In this manner, individuals with a divergent problem solving style may seek situations that feature divergent problems (over convergent problems) and may seek to solve any problem using divergent style techniques. Similarly, individuals with a convergent style may seek convergent problems and tend to solve problems using convergent style techniques. This is simply a way of managing cognitive load and minimizing the cognitive energy needed to problem solve.

The model below (Figure 3) represents different types of five-person team composition arranged on a polar axis by their preferred cognitive problem-solving style, from a convergent style to a divergent style. The midpoint represents “no preference” between either convergent or divergent problem solving styles and this would be the position of a “pivot thinker” (®).
I posit that in this position, the pivot thinker might play a “bridging” role within the team dynamics for problem solving. Kirton describes bridging as spanning a “cognitive gap that may exist within members of the team” (Kirton, 2003). He describes two types of bridging: 1) the distance between one’s preferred style and behavior that appears to be needed, and 2) the distance in a social interaction, between preferred styles of two people or a person in a group or two groups. Kirton also notes that “bridging is not a score but a social role” and as a social role requires special interpersonal skills which may or may not be found in the pivot thinker. Kirton ultimately places the responsibility of bridging on the acknowledged leader of the group.

![Figure 3 - Possible five-person team composition displayed as a range of convergent or divergent problem solving preference styles with the Pivot Thinker aligned on the center point and the thick grey line estimating the amount of coping energy required by each team.](image-url)
The thicker gray line on each model represents the amount of “coping energy” required to generate consensus (at least three of five members) within a team, as shown in Figure 3. Coping energy is described as the cognitive and emotional energy required to bridge the gap between a preferred problem solving style and the style required to solve a problem or the predominant style of the group (R. J. Burke & Weir, 1980).

Coping energy is the personal energy required to power individual coping behavior that offsets inter-individual stress. Endler and Parker describe coping behavior as a “response to external stressful or negative events” and coping strategies fall into three broad areas: problem-focused coping (where the individual confronts the stress source directly), emotion-focused coping (where the individual self-regulates negative emotional from the stressor) and avoidance-focused coping (disengage from the stressor) (Endler & Parker, 1990, p. 845). I posit that the pivot thinker, given an inherent flexibility of problem solving styles, would be particularly capable of implementing problem-focused and emotion-focused coping behavior that form the basis of inter-individual.

Team A in Figure 3 shows a wide range of preferred cognitive problem-solving styles with the pivot thinker position in the middle of this range of styles. This range of cognitive styles may also lead to an asynchronous distribution of information within the team. I argue that a pivot thinker might play the role of a **consensus builder** given the relative proximity of their balanced style with other members of the team. A pivot thinker in this role requires less coping energy and provides the opportunity to encourage “psychological safety,” which encourages a “shared belief held by members of a team that the team is safe for interpersonal risk taking” (Edmondson, 1999).
Team B represents a polarized range of cognitive styles and requires a significant amount of coping energy by all members of the team. As Edmondson notes, top management teams tend to have a wide range of cognitive styles and confront difficult interpersonal challenges, “private information may remain unshared when individuals - deeply engaged in the discussion at hand - failed to recognize its salience for the issue under consideration. Members may also fail to share private information taken for granted and implicitly assume that others know what they know, or because they are reluctant to jump into an already active discussion” (Edmondson, Roberto, & Watkins, 2003, pp. 304-305).

Teams with a wide range of cognitive ability often generate more innovative and successful solutions (Bantel & Jackson, 1989). However, this comes with the risk of interpersonal conflict. In this case, the pivot thinker may play the role of what I term the diplomat who seeks to bridge very different points of view within the team. Scholars divide team conflict into two broad areas: “cognitive conflict,” which is generally task oriented and focused on judgmental differences and “affective conflict,” that emerges when “cognitive disagreement is perceived as a personal criticism” (Amason, 1996). The pivot thinker as a diplomat would be able to recognize the different cognitive perspectives and points of view within a team while minimizing the chance that these differences would devolve into personal criticisms.

Team C shows a skew towards one end of the cognitive style. It is likely that this team would have high intra-team satisfaction given the similarities in style and for the most part may not be aware of other potential issues and problem solving. This team composition also requires the least amount of coping energy
because members are similar in their cognitive problem-solving style. It is likely that only the pivot thinker might identify gaps in cognitive coverage and, as a result, play the role of what I call the devil's advocate. Research has shown that a devil's advocate position can be effective in improving team problem-solving processes, if the devil's advocate remains objective, non-emotional in decision-making situations (Schwenk & Cosier, 1980).

Team C is a single cognitive style team and the team structure for this research. Subjects were screened for their convergent and divergent style and organized into like-style groups of six. In one half of the groups, one convergent or divergent subject was replaced with a balanced pivot thinker. This places the pivot thinker in team situations that requires the minimum amount of coping energy. Pivot thinkers were not screened on the basis of their interpersonal skills; so adjusting the research situation to require a minimum amount of coping energy seemed appropriate.

Team D illustrates the role of an outlier or what Hackman refers to as the team “deviant” (Hackman, 2009). This type of team requires a significant amount of coping energy particularly from the outlier because, as Hackman states, “the deviant veers from the norm at great personal cost.” Teams benefit from deviant cognitive styles only when discussion can remain objective and non-emotional. Often the conversation becomes emotional because, as Hackman points out, the deviant says things that “nobody on the team wants to hear, which is precisely why many team leaders crack down on deviance and try to get them to stop asking difficult questions, maybe even knock them off the team.” (p. 174)
In this research, pivot thinkers were placed in the role of team leader. The pivot thinkers were pre-selected based on the balance of their preference for convergent and divergent thinking and played the role of a “tacit leader” whose first responsibility was to “enhance team effectiveness” (Hackman, 2002). The pivot thinker was a tacit leader because they appeared to be randomly chosen by the research leader and given nominal responsibilities - timing of the group discussion, recording a group decision, speaking first and ensuring that every team member had the opportunity to speak. The paradox of team leadership relative to team democracy was not discussed with the subjects; rather they were allowed to manage any inherent contradictions explicitly (Murnighan & Conlon, 1991).

**Why This Research Matters**

The NPD team is a rich environment for representational gaps. Often, team members come from different functional backgrounds with very different cognitive style sets. In such an environment, individuals may assume a common problem representation (i.e., developing a successful new product for marketplace introduction) yet the representation process of achieving this problem solution may be quite different. In fact, even the language used by team members may be affected by individual problem representations, such as the value of sharing facts over observations or feelings. Therefore, it is important to understand how cognitive problem solving preference might predict how an NPD team member may value information and share it for consideration by the team in a group discussion.

This research contributes to three broad domains of interest – design thinking, groups and team dynamics and cognitive assessment. The generally accepted
descriptions of “design thinking” have long been associated with the interplay between convergent and divergent cognitive styles. Arthur Cropley describes design thinking as involving “… 2 components: generation of novelty (via divergent thinking) and evaluation of the novelty (via convergent thinking). The way in which the 2 kinds of thinking work together can be understood in terms of thinking styles or of phases in the generation of creative products. In practical situations, divergent thinking without convergent thinking can cause a variety of problems including reckless change” (Cropley, 2006, p. 391). This research attempts to show that individuals have an innate propensity for either convergent or divergent thinking and that in a design decision situation. This tendency can affect the nature of a team discussion and ultimately the outcome.

In groups and teams research, there has been much research on the effect of diversity on team dynamics and outcomes (see Mannix & Neale, 2005). However, relatively little work has been done on personality traits or cognitive styles and the impact on team discussion and decision-making. A notable exception is the work of Baer et al. and the use of personality indicators as a predictor of team creativity. Baer found that “teams exhibited higher creativity when they were composed of multiple high extraversion, high openness to experience, or low conscientiousness individuals and when team members shared a sense of creative confidence. In these circumstances, it is likely that the creative synergies arising from individuals with these personality characteristics engaging in collective idea generation efforts allowed teams to produce ideas that go beyond those that could have been generated by members individually” (Baer, Oldham, Jacobsohn, & A. Hollingshead, 2008, p. 274). In this research, convergent and divergent problem solving style preferences are considered specific cognitive traits and the impact of these traits on team discussion and decision-making is explored.
Finally, in the area of cognitive assessment, this research explores the use of an industry-oriented assessment tool – the Herrmann Brain Dominance Indicator (HBDI). The HBDI is a cognitive assessment tool that has been judged to be both valid and reliable (see Coffield, Moseley, Hall, & Eccleston, 2004, p. 162) and maintains a significant database of industry and functional subject norms. The HBDI can provide data on cognitive profiles for “engineers,” “designers,” “marketing,” and “sales” professional roles that help calibrate subjects recruited for this study strengthen the connection between laboratory and field research.
A scorpion and a frog meet at the riverbank. Both want to cross, but the scorpion cannot swim so it asks the frog for help. The frog is worried, but the scorpion promises, “I won’t sting you, because if I did I would drown.” In mid-river the scorpion stings the frog. The shocked and dying frog asks “why?” and the drowning scorpion answers “It’s just in my nature.”

The Scorpion and The Frog

(Livraghi, 2008)

CHAPTER 2 - Of Two Minds: Convergers and Divergers
Key Problem Solving Differences in Human Cognition

The Question of Problem Solving

It is in the nature of humans to solve problems and the nature of how humans solve problems has long been an area of philosophical and scientific inquiry. In the 1950s, Alan Newell and Herbert Simon studied human problem solving in the context of machine intelligence, at a time when it was thought that machines might solve problems in similar way to humans (Newell, Shaw, & Simon, 1958). They proposed criteria that any theory of human problem solving should answer:
“First, it should predict the performance of a problem solver handling specified tasks. It should explain how human problem solving takes place: what processes are used and what mechanisms perform these processes. It should predict the incidental phenomenon that accompany problem-solving, and the relation of these to the problem solving process.”

(Newell et al., 1958, p. 151)

These questions, or tests, outline the general criteria for evaluating individual and group problem-solving processes in NPD groups. This understanding begins with an appreciation of the problem solver; the specific cognitive styles, capabilities, frames of reference and decision-making criteria individuals bring to the problem-solving process. It is also important to understanding the specific meta-cognitive and personality mechanisms that describe an individual’s problem-solving processes. Finally, any theory that defines group problem solving should also predict incidental phenomenon, like the decision-making processes, of individuals in the group and the group itself.

Cognitive styles, Personality Traits and Cognitive Style

A cognitive style is a basic mental ability used to perform a specific thinking task and described in the context of the brain’s information processing structures and functions (Deary, 2000). This usually includes neural structures and functions like working memory, verbal decoding, reasoning ability and task switching.

There are many of these types of cognitive skills and psychometric testing has developed to measure these skills and form the basis for comparison between individuals. Francis Galton and later Louis Terman (Terman, 1916) attempted to calibrate cognitive ability through the use of specific verbal and non-verbal test items, summed to provide a scalable score that became known as the Stanford-
Binet Intelligence Scale or more commonly IQ score. A modern example of this kind of psychometric instrument is the ETS “French Kit” (Ekstrom & Harman, 1976) that includes tests like Word Fluency (FW), Memory Span (MS), Number Facility (N) and Logical Reasoning (RL). These tests remain valuable to researchers given their long history of data and the specific aspects of cognition they explore. However, these tests reveal little of about the “processes and mechanisms” of problem-solving reference by Newell and Simon.

A separate measure of cognitive performance is a personality trait. Personality is defined as “a dynamic and organized set of characteristics possessed by a person that uniquely influences his or her cognitions, motivations, and behaviors in various situations.” Trait extends this to a “habitual patterns of behavior, thought, and emotion” (Kassin, 2003, p. 327). Personality traits dictate behavior and are considered relatively stable over time.

A leading measure of personality traits is the Five Factor Model (“Big Five") developed by Paul Costa and Richard McCrea (Costa & McCrae, 1992). The technique uses statistical factor analysis to cluster self-assessed personality measures on 240 characteristics. Five major personality traits have emerged - Openness, Extraversion, Neuroticism, Agreeableness and Conscientiousness. Research has also linked the Big Five personality traits to job performance, where individual factors were more or less important to specific types of jobs but only conscientiousness correlated with job success across all different job types (Barrick & Mount, 1991).
Personality trait can be considered independent of cognitive skill in that reasoning ability (for example) is not related to extraversion or agreeableness (Driver & Streufert, 1969). It is possible that individuals of the same personality type may have different cognitive skills and individuals with similar cognitive skills may have very different personality traits (Schroder, Suedfeld, & Bieri, 1971).

*Cognitive style* is a blend of cognitive skills and personality trait. Samuel Messick, a leader in the field of cognitive style research and its impact on educational testing, defined cognitive styles by effect on behavior. Messick states that cognitive styles “appear to serve as high level heuristics that organize lower-level strategies, operations, and propensities – often including abilities – in such complex sequential processes as problem solving and learning” (Messick, 1984).

Cognitive style is how a person perceives and remembers information and with that information, the approach used to solve problems. Maria Kozhevnikov, a Harvard neurologist, defines cognitive style as:

"... relatively stable individual differences in preferred ways of organizing and processing information that cut across the personality and cognitive characteristics of an individual" (Kozhevnikov, 2007, p. 468).

Cognitive styles involve both the preferred skills a person brings to problem solving and the preferred behaviors they use to problem solve. The blending of cognitive styles can become quite complex in the context of a group or team, where individual team members may bring very different cognitive skills and
personality traits to the group task. The interaction of cognitive styles may be an important moderating factor for how a team problem solves, more so than other traditional factors of diversity such as demographics or tenure. Differing cognitive styles can also contribute to the development of “representational gaps” where team members frame problems completely differently based on their cognitive style and how they prefer to solve problems.

**Aristotle’s Problem Solving Foundation: ***sullogismos* and *epapôgê*

The existence of a unitary or multiple cognitive styles has been a point of contention among philosophers, scientists and intellectuals throughout the centuries. Socrates saw intelligence as basically unitary, whereas Plato and Aristotle saw intelligence as multiple. Ben Franklin adopted the former view; Thomas Jefferson the later (Snow & Yalow, 1982).

Aristotle was the first scholar to develop an organized and broad method for problem solving, which he called *sullogismos*. This forms the basis of what we know today as logic or deductive reasoning. In his treatise, *Prior Analytics* (24b 18-20), Aristotle defines *sullogismos* as a form of reasoning that shows a necessary, single conclusion follows from a set of premises. (Aristotle, 1989) These deductive arguments are valid or invalid, sound or unsound, but are never false or true. Aristotle’s classic demonstration of deductive reasoning:

*All men are mortal; Socrates is a man; Socrates is mortal.*
However, Aristotle also recognized a second valid approach to problem solving. In a related treatise, *Posterior Analytics* (71a 6-12), Aristotle defines *epapôgê* and this has come to be known as inductive reasoning. *Epapôgê* is a form of reasoning that "proves the universal by relying on the fact that a particular is already clear" (Cahn, 2006). Aristotle defines rhetorical arguments based on "examples" as a form of induction. Inductive reasoning allows for the possibility that a conclusion derived from a set of premises may be either true or false. Aristotle's demonstration of inductive reasoning:

*Socrates runs; Plato runs; All men run.*

Aristotle's model of cognition included only these two forms of thinking - deductive and inductive. As Aristotelian scholar John McCaskey writes, "Whatever exactly induction is, it is one of two, and only two, kinds of valid reasoning, and deduction is the other. In no unambiguous passage anywhere in the corpus does Aristotle waive on this" (McCaskey, 2007, p. 349).

**Spearman and Thurstone: Singular versus Multiple Cognitive Styles**

The classification of thinking styles and approaches continued throughout the centuries, through philosophers like Augustine, Locke, Descartes and Kant, all essentially revolving around the Aristotelian model of deductive and inductive thinking.

A notable breakthrough was achieved by Charles Spearman, a British psychologist working in the early 20th century, who discovered that
performance on one intellectual task positively correlated with performance on a range of other intellectual tasks. Through the use of statistical factor-analysis, Spearman concluded “that all branches of intellectual activity have in common one fundamental function” (Spearman, 1904). This “common one fundamental function” came to be known a “general intelligence” or simply g.

It is less well-known that Spearman thought of this structure as a “two factor theory” in which each mental task was influenced by both an underlying general ability (g) and “the remaining or specific elements of the activity” that he concluded are “wholly different from that in all the others” which he termed “specific information” or s. Statistically, this is appropriate because the g factor typically accounts for 30-50% of performance variance so other cognitive factors, specific information (s) in combination must account for the remaining and significant 50-70% of variation (Deary, 2000).

As Spearman developed his theory of g, he actually became more interested in s. Influenced by the work of early neuroscientists like Pierre-Paul Broca and Korbinian Brodmann, Spearman adopted the internal combustion engine as a metaphor for cognitive functioning, where g is the “energy” or “power” and s is “engine” or individual bundles of neurons relating to specific cognitive performance (Spearman, 1923).

“Each different operation must necessarily be further served by some specific factor peculiar to it. For this factor also, a physiological substrate has been suggested, namely the particular group of neurons specifically serving the particular kind of operation. These neural groups would serve
as alternative “engines” into which the common supply of “energy” could be alternatively distributed. Successful action would always depend, partly on the potential of energy developed in the whole cortex, and partly on the efficiency of the specific group of neurons involved. The relative influence of these two factors could vary greatly according to the kind of operation; some kinds would depend more on the potential of the energy, others more on the efficiency of the engine” (Spearman, 1923, pp. 5-6)

If Spearman represented the British approach to the measurement of cognitive processing and ability, then Louis Thurstone represented the American view where cognitive ability was varied, complex and distinctly egalitarian (Gould, 1981). Thurstone (a mechanical engineer by training) held that intelligence was less a function of one overriding capability and more the result of "Primary Mental Abilities" (PMAs) of which he claimed seven: verbal comprehension, word fluency, number facility, spatial visualization, associative memory, perceptual speed and reasoning (Thurstone, 1938). Thurstone analyzed cognitive test data from subjects with similar overall IQ scores and found very different profiles of primary mental abilities, supporting his cognitive model. However, when Thurstone administered his PMA tests to an intellectually heterogeneous group of subjects, he failed to find that the PMAs separate; rather he found evidence of g.

Later in life, both Spearman and Thurstone saw value in the others’ work. Cognitive theory turned toward a reconciliation of the competing points of view, diversity of cognitive ability and the result was the development of a single
structural model, which is the hierarchical organization of mental abilities (Martinez, 2000).

Cattell to Carroll: Fluid (and Crystallized) Intelligence

Raymond Cattell was a student of Spearman's in the 1920's and became a lifelong proponent of factor-analysis as a method to find patterns from dispersed and seemingly unrelated data sets. Cattell proposed that thinking ability or g was a function of two separate but related cognitive abilities - "fluid intelligence and crystallized general abilities" (Cattell, 1963). Later, in partnership with John Horn, Cattell refined this theory (Horn, 1964).

“Crystallized ability loads more highly on those cognitive performances in which skilled judgment habits have become crystallized (whence its name) as the result of earlier learning application of some prior, more fundamental general ability to these fields” (Cattell, 1963, pp. 2-3). Crystallized cognitive ability is a function of the facts, techniques and experiences that one can bring to bear on problem solving and typically grows with age and experience. “Fluid general ability, on the other hand, shows more in tests requiring adaptation to new situations, where crystallized skills are of no particular advantage” (1963, p. 3). Cattell later described fluid intelligence as the ability to problem solve when someone "... does not have recourse to the answers to such complex issues already stored in memory” (Cattell, 1986, p. 7).

John Carroll advanced the case for hierarchical organization of cognitive ability through a massive factor analysis of 461 data sets, some of which were originally built by Spearman and Thurstone (Carroll, 1993). Carroll’s statistical model
places a factor called Stratum III General Intelligence (3G), which is “conceptually equivalent to Spearman’s $g$,” in a superordinate position, as shown in Figure 4. Below Stratum III lies Stratum II that includes eight broad factor items, reminiscent of Thurstones’ PMA’s. Below Stratum II is Stratum I that include the more narrow, specific cognitive test that most significantly correlate with the Stratum II factors.

![Figure 4 – Carroll’s Structure of Cognitive Abilities that illustrates the hierarchical nature of cognitive abilities and the importance of Fluid Intelligence (2F) to both convergent and divergent thinking.](image)

Stratum II factors include Fluid Intelligence (2F), Crystallized Intelligence (2C), General Memory and Learning (2Y), Broad Visual Perception (2V), Broad Auditory Perception (2U), Broad Retrieval Ability (2R), Broad Cognitive Speediness (2S) and Processing Speed (2T). Importantly, the Stratum II factors are arranged (from left to right) in the order in which they contribute to Stratum III or General Intelligence. The first Stratum II Factor, with the most significant loading to General Intelligence (3G) in Fluid Intelligence (2F), while the second
Stratum II Factor is Crystallized Intelligence (2C), aligning with Cattell's hierarchy on cognitive processing. Together, these two Stratum II Factors (2F and 2C) explained over 65% of the variance in General Intelligence (3G).

Carroll's definition of Stratum II Fluid Intelligence (2F) has the largest single factor loading onto Stratum III General Intelligence (3G). Fluid Intelligence (2F) is comprised of Stratum I level factors General Sequential Reasoning (RG), Quantitative Reasoning (RQ) and Induction (I). While these Stratum I level factors, in combination, load to describe Fluid Intelligence, they may represent different and distinct cognitive abilities.

Carroll describes General Sequential Reasoning (RG) as operating in tasks that "require subjects to start from stated premises, rules, or conditions and engage in one or more steps of reasoning to reach a conclusion that properly and logically follows from the given premises" (Carroll, 1993, p. 245). Similarly, Quantitative Reasoning (RQ) operates in tasks that "require subjects to reason with concepts involving quantitative or mathematical relations in order to arrive at correct conclusions" (1993, p. 246) In both the case of RG and RQ, the subject is expected to converge to the one, demonstrably correct answer.

Induction (I) is described differently, as presenting "subjects with materials that are governed by one or more implicit rules, or that exhibit or illustrate certain similarities or contrasts.” The subject's task is to discover the rules that govern the materials or the similarities and contrasts on which rules can be based, and then to “demonstrate that discovery either by stating the rules or relevant stimulus attribute, or by making appropriate the choices among alternatives that
are presented" (1993, p. 245). With Induction (I) the subject must diverge and choose between multiple, potentially correct answers.

This suggests that cognitive ability is largely about two behaviors: how a person thinks (2F – Fluid Intelligence) and what a person knows (2C – Crystallized Intelligence). In complex organizations, like large, multi-national companies, workers are screened for what they know before hiring, which is usually a result of level of formal education and relevant work experience. This leaves how a person thinks as the major discriminating cognitive ability in these environments. “How you think” is just another way of saying “cognitive style” and as research from Cattell to Carroll has shown, splits between a convergent preference for reasoning (R) or a divergent preference for induction (I).

There is further evidence from the field of educational assessment that divergent thinking ability is distinct from convergent thinking ability. For example, Magnusson and Backteman tracked 1,000 Swedish students from age 13 to age 16 while conducting a battery of cognitive skill assessments over this time (Magnusson & Backteman, 1978). Cronbach’s analysis of the results showed that convergent skill assessment tests predicted later performance on convergent tests at the .50 to .65 correlation level, while convergent skill assessment tests predicted divergent skills at only the .20 correlation level (Cronbach, 1990). Also, while divergent skill assessment tests tended to predict later performance, the .40 correlation level was much lower but better than the .20 correlation with convergent tests. Therefore, divergent and convergent cognitive skill assessments appear to predict performance independently suggesting they are separate and distinct abilities.
Kirton, Driver and Herrmann: Business Problem Solving

Within the business community, the opportunity to improve problem solving effectiveness has long been a goal. In the 1960’s and 1970’s, as the use of psychometric testing expanded and new neurological measurement tools where developed, several researchers turned their attention to improving decision making and problem solving process within a business environment. Three such tools, representative of this effort, are the Kirton’s Adaption-Innovation Inventory (KAI), Driver’s Dynamic Decision Style Model (DDSM) and Herrmann’s Brain Dominance Indicator (HBDI).

These tools have several characteristics in common, perhaps because they are tailored to a business audience. First, they are very simple; simple to administer, simple to take (usually completed within 20 minutes) and incorporate only one or two scales to characterize results. Second, the results easily translate into behavior descriptors making implementation attractive in the structured environment of a business or team unit. Finally, all of the instruments measure the preference for problem solving behavior and not ability or skill of problem solving. It has been noted that task preference often correlates with task skill, and these instruments only claim to measure preference for problem solving (Ellis & Siegler, 1994).

The Kirton Adaption-Innovation Inventory (KAI) is a 32-item self reported instrument that returns a single preference score on a bi-polar scale ranging from “adaptor” to “innovator,” as shown in Figure 5 (Kirton, 1976). Adaptors are drawn to “do things better” and exhibit behaviors like seeking “solutions to problems in tried and understood ways” and “resolving problems rather than finding them,” with work habits that value “precision, reliability, efficiency’
methodicalness, prudence, discipline, conformity.” Kirton’s Adaptors have more of a convergent style.

Kirton, a British occupational psychologist, describes the differences between Adaptors and Innovators as “a problem solving style” and this aligns closely with the characteristics of convergent and divergent thinking. Over time, Kirton has adopted an orthogonal, second axis which is called task competence “level,” which is reflective of the experience with either problem solving style. For example “High Level Adaptors” who understand the benefit of adaptive behavior
so well that they know “exactly when its most valuable to break a rule” (Kirton, 2003, p. 155). Similarly, “High Level Innovators” who value change may best understand when it's not “wise to break certain rules” (2003, p. 156).

Kirton believes that the problem solving style Adaptors and Innovators is a trait in that it is set early in life and becomes immutable. Flexibility around style becomes a function of “level” with more experience within a style opening up the possibility of (at times) breaking the pattern and using the opposite style. In this construct, pivot thinking is more of a state (versus trait), a temporary state of mind triggered by a specific situation and available to only individuals with “level” experience. This is, indeed, a form of pivot thinking but suggests that only individuals capable of pivoting are those with more experience. I reject this concept, rather suggesting that all individuals have the ability to pivot think regardless of experience.

The KAI is reminiscent of the Cattell-Carroll construction of intelligence where Kirton’s “problem solving level,” a result of experience, is evocative of Crystallized Intelligence (2C) while “problem solving style” aligns with Fluid Intelligence (2F). Similarly, Kirton divides the world into Adaptors, who favor convergent thinking and may use Reasoning (R) as a preferred cognitive tool, while Innovators favor divergent thinking and may use Induction (I) as a preferred cognitive tool.

Michael Driver developed the Driver Decision Style Exercise (DDSE), an American professor of management and organization during the 1960's and
It is based on a two-axis model of decision-making behavior, as shown in Figure 6.

The first scale defines information use and separates subjects into two groups - maximizers or satisficers. Decision maximizers favor an analytic, information intensive approach; while decision satisficers balance time, energy and quality, often satisfied with decisions that are "good enough." The second axis relates to problem focus. Some subjects naturally seek to one best answer and Driver calls this "unifocus" while other subjects look for a range of answers, which Driver calls "multifocus." In this model, "maximizers with unifocus" have a convergent style, while "satisficers with a multifocus" have more of a divergent style.

The DDSE presents subjects with a small-scale personnel case that contains six pieces of information. The reader decides what the case means and how to use
the information provided. Results are computer scored and subject preferences are identified as a satisfier or maximizers with a preference for unifocus or multifocus problems. Dominant and backup styles are identified.

Driver also connects these decision styles to occupations and professions. For example, Driver associates the “maximizer/unifocus” decision style preference with professions like engineering, finance and accounting (Driver et al., 1990, p. 153). On the other end of the spectrum, “satisfier/multifocus” decision style is often found in professions like sales, marketing and human resources. The relationship between two very different kinds of decision preferences (unifocus versus multifocus) and it’s impact on career choice is an indication that neural competency may guide people to certain kinds of work and then affords success which reinforces the underlying neural competency and diminishes other competencies.

The third instrument of interest is the Herrmann Brain Dominance Instrument (HBDI), developed by Ned Herrmann (Herrmann, 1989). Herrmann was a 35-year employee of General Electric, and during his career he held a wide variety of staff and line management roles. Herrmann became interested in the difficulty and low success rate of successful managers switching between different functional jobs.

The HBDI provides, on the basis of 120 items, a four-category classification of mental problem solving preferences, as shown in Figure 7. Herrmann’s inspiration was MacLean’s (1990) model of the triune brain (cortex, limbic system and r-complex) and Sperry’s (1964) 1981 Nobel Prize winning research
on split-brain (right-left) specialized functions. This resulted in a four-quadrant model (cerebral-limbic, left-right) that formed the metaphorical basis for describing problem solving preferences.

Herrmann’s four quadrants (counter clockwise from upper left) are described as Quadrant A “theorists,” Quadrant B “organizers,” Quadrant C “humanitarians,” and Quadrant D “innovators.” Subjects have stronger and weaker problem solving preferences within each quadrant with a “whole brain” preference resulting in roughly equal preference for each problem solving style that is applicable to only about 3% of the population (Herrmann, 1989, pp. 89-90). Herrmann also shows that various profiles align with various professions: Quadrant A (cerebral-left) tend to be technical problem solvers such as engineers and accountants who are convergent thinker, while Quadrant D
(cerebral-right) designers, psychiatrists or musicians, who are more divergent thinkers.

In summary, it is highly likely that any four-category or two-dimensional model of approaches to thinking and problem solving styles will be over simplistic for clinical purposes. However, as tools to separate two very fundamental cognitive approaches (convergent and divergent thinking) and then sort out the implications for both individual and group achievement, these instruments prove valuable. The HBDI is particularly interesting, given its metaphorical link to brain functioning and its concern with thinking, feeling and doing as an individual and in social contexts (Coffield et al., 2004).

Neurological Implications of Cognitive Style

In the future, functional magnetic resonance imaging (fMRI) neurological research will look just a bit more sophisticated than phrenology appears today, which is both the curse and triumph of neuroscience - it is constantly reinventing itself, disproving the proven and opening new avenues of inquiry (Panksepp, 2004).

The idea that the brain is composed of many different subsystems and that these subsystems in combination shape behavior has been a part of science and philosophy for thousands of years (Aunger & Curtis 2008). For example, Plato, in The Republic argues that humans have two distinct parts of the soul - one part “reflects, rational thought” and the other part is distracted by “irrational appetite” (Loptson, 1998).
Cognitive psychologist and cognitive neuroscientists are beginning the process of identifying these neural subsystems and connecting them with both thought and behavior. There is a growing consensus that cognitive processing falls into two types of activity - System 1 and System 2 - also called the “dual-process” theory (J. S. B. T. Evans, 2008). System 1 cognition is characterized as “fast, automatic and unconscious” while System 2 cognition is described as “slow, deliberative and conscious” (2008, p. 255) System 2 thinking is a form of thinking “under intentional level control, supported by unconscious processes in System 1 that deliver percepts, memories, and so on” (2008, p. 258)

Keith Stanovich, a cognitive psychologist at the University of Toronto, elaborates further by splitting System 2 cognition into two fundamental groups - algorithmic (Type I) and reflective (Type II) cognition, as shown in Figure 8 (Stanovich, 2010). Describing humans as “cognitive misers,” Stanovich suggests that most thinking is done on an algorithmic level, which the less cognitively intense process of applying previous experience, rules and boundaries to a solution space as a way to conserve cognitive energy. In contrast, reflective cognition involves “simulation or hypothetical reasoning” in an open-ended unstructured process, and therefore requires more cognitive energy (Stanovich, 2009).
In the context of Guilford’s model of cognition, the Algorithmic Mind is more closely associated with a convergent style of problem solving. This supposes that the algorithmic mind is seeking a pattern or rule, based on previous experience, that provides a unique solution. In contrast, the Reflective Mind is more closely associated with the divergent style of problem solving. The process of cognitive simulation, defining and redefining a problem space while seeking multiple answers is a cognitively intensive activity, which Stanovich describes “of a higher order.”

The differences between the Algorithmic Mind and the Reflective Mind can be shown with the following examples. The first question illustrates the algorithmic mind, seeking a pattern and problem solving to a single correct answer. This is a “nonsense syllogism” from the Manual for Kit of Factor Reference Cognitive Tests RL-1/8 (Ekstrom & Harman, 1976).
All elephants can fly. All giants are elephants. Therefore all giants can fly.

Is this an example of “good reasoning” (G) or “poor reasoning” (P)?

In this example, cognition involves applying rules about equivalency and transference. Cognitive solution testing reveals that there is only one correct answer.

A second example illustrates the reflective mind through the use of “disjunctive reasoning” (Toplak & Stanovich, 2002). Consider this question:

Jack is looking at Anne but Anne is looking at George.  
Jack is married but George is not.  Is a married person looking at an unmarried person?

a) Yes  b) No  c) Cannot be determined

The question was answered incorrectly by 86% of respondents (c), while only 13% selected the correct answer a). To correctly answer this problem the subject needs to consider multiple states (for Anne’s marital status) and then simulate different scenarios considering all possibilities. This is a cognitively intensive task and Toplak and Stanovich hypothesize that subjects default to algorithmic thinking and choose the cognitively “easy answer” of (c).

(Note: a simple way to solve this problem is to draw the physical relationships between Jack, Anne and George and then note the known marital status of Jack and George. This makes to options of Anne’s marital status obvious and the
answer is obvious. This also underscores the importance of drawing or sketching to practice of design thinking and may be a trigger for simulative or Reflective Mind thinking.)

Stanovich suggests the greater mystery is what triggers the shift between the cognition of the Algorithmic Mind and the Reflective Mind. Research has shown that this shift to the Reflective Mind may be caused “metacognitive experiences of difficulty or disfluency during the process of reasoning” such as anomaly detection (Alter, Oppenheimer, Epley, & Eyre, 2007, p. 569) This would suggest that pivoting between convergent and divergent thinking, while being an inherent quality of cognition, may be purposely triggered by certain types of intervention and perhaps developed as a learned cognitive behavior.

This tendency to resort to well-known or repeated answers is also called the Einstellung Effect (A. S. Luchins, 1942). The Einstellung Effect describes the human behavior of solving a new problem in the same way a problem has been previously solved without regard to the appropriateness of the solution process. In effect, the brain defaults to known, previously correct ways of solving a problem as a means of cognitive efficiency, regardless of the correct way of solving the problem (A. S. Luchins & E. H. Luchins, 1959). In neurological terms, this is called the "Hebb’s Law" named after psychologist and neurologist Donald Hebb. Hebb theorized then proved that an increase in synaptic effectiveness is a results of the presynaptic cell’s "repeatedly and persistently takes part in firing" the postsynaptic cell (Hebb, 1949). This has been reduced to the shorthand phrase "neurons that fire together, wire together" and is a neurologically based theory and mechanism that supports the human tendency to default to algorithmic/convergent processing over simulative/divergent processing.
Returning to Spearman's hypothesis of 80 years ago ... the question remains about the existence of a specific “physiological substrate” of a “particular group of neurons” serving a “particular kind of operation.” Neurology and brain system mapping has largely been focused on finding common systems of cognition and not on individual differences. Therefore, most research is focused on finding the neurological system that drives a “convergent style” or the neurological system that drives a “divergent style” and not on how these systems may be different.

Barbey and Barsalou conducted a meta-review of over 60 empirical neuroscience research studies that inform theories of reasoning and problem solving (Barbey & Barsalou, 2009). They found broad support for the dual process (System 1 and System 2) theory of cognition, indicating that different neurological systems perform different types of reasoning. They also found that “deductive reasoning does not appear to recruit a unitary neural system but instead engages different brain regions based on the particular reasoning task and materials employed” (2009, p. 42) They also found that “inductive inferences drawn from familiar categorical syllogisms and conditional statements engage a left hemisphere language and knowledge network implemented in the frontal and temporal regions” (2009, p. 42). This provides further evidence in support of Spearman's earlier hypothesis that different parts of the brain do indeed perform different types of reasoning.

The discipline of psychology has spent over 100 years examining differences in human behavior; neuroscience is just beginning to understand the differences between human brain processing. A recent study using structural magnetic
resonance imaging measured cortical thickness to explain differences in personality as measured by the NEO–FFI “Big Five” personality trait instrument (DeYoung et al., 2010). In this study, researchers found that differences in cortical volume by specific region predicted performance on four of the five “Big Five” personality indicators. For example, Extroversion covaried with the cortical volume of the medial orbitofrontal cortex, a brain region involved in processing reward information. Similarly, Neuroticism (also referred to as emotional stability) covaried with volume of brain regions associated with threat, punishment and negative affect.

The only “Big Five” measure that did not correlate with cortical differences was Openness, which is both surprising and confirming. It is surprising because the Openness measure has been consistently associated with a specific mode of cognition – creativity and divergent thinking – in psychometric studies (McCrae & Ingraham, 1987). It is confirming because it indicates that a divergent style may require many different brain systems working in concert. As DeYoung comments on the lack of correlation for Openness, “We hypothesized that Openness/Intellect would be associated with structural variation in some or all of the brain systems involved in the regulation of working memory, attention, and reasoning, including dorsolateral [prefrontal cortex] PFC, anterior PFC (frontal pole), and anterior parietal cortex” (DeYoung et al., 2010, p. 3).

**Cognitive Style and Design Thinking**

Design thinking may be as old as humanity itself. Anthropologist Tim Ingold, discusses the hunting habits of the Orochon people of North Central Sakhalin in the Russian Far East. The Orochon travel through their territory on both "saddle trails" and "sledge trails" (Ingold, 2007). As they hunt, the Orochon use winding
saddle trails where they are "ever attentive to the landscape that unfolds along the path, and so too its living animal inhabitants. Here and there, animals may be killed" (2007, p. 76). Ingold refers to this purposefully wandering, hunting behavior as "wayfaring."

When an animal is killed, it is buried on the spot in the permafrost. The Orochon use sleds to retrieve their kills. Ingold states, "The sled path, by contrast, is a line of transport. It has a starting point and ending point, and connects the two." He refers to this second behavior as “transport,” as shown in Figure 9.

Figure 9 – An interpretation of Ingold’s description of the Orochon method of hunting that separates cognitive states of the hunters into Wayfaring to find and kill the prey and Transport to bring it back to the village.

In this manner, the Orochon hunting process is an iteration of “wayfaring” and “transport.” Wayfaring requires divergent cognitive skills, reading signs, interpreting evidence, and looking for something where many possible solutions
exist. In design terms this is often referred to as “attending to the flow.” On the other hand, transporting is more of a convergent cognitive skill requiring a sense of geometry; the shortest distance between two points, where the parameters are known and efficiency is the goal. Again, in design terms this is referred to as “attending to the plan.”

In the design community, the actual cognition that describes design thinking has been a source of discussion for the past 50 years. Much of the debate revolves around the process of design thinking not the cognition of design thinking. Through this debate it is clear that design thinking is not one cognitive skill, its many cognitive skills applied simultaneously.

Henry Dreyfuss, a leading product designer from the 1930s to the 1960s who designed such iconic products as the 20th Century Limited locomotive, Westclox “Big Ben” alarm clock and the classic John Deere tractor, imagines “design thinking” as a juggling act of competing cognitive and personality skills not all that dissimilar from the range of skills sitting around a NPD meeting room table (Dreyfuss, 1955).

_It might seem to some that the designer lays claim to a special omniscience, an infallibility, through which he blithely presumes to offer a solution to any problem. He makes no such claim. He takes pride in his skill based on experience and an alertness sometimes interpreted as vision he approaches every problem with the willingness to do painstaking study and research and to perform exhaustive experimentation. He is equipped to work intelligently with the engineer, the architect, the physicist, interior_
decorator, the colorists, and the doctor. He must know how far to go and when to stop. He must be part engineer, part businessman, part salesman, part public-relations man, artist, and almost, it seems at times, Indian chief.

He operates on the theory that it is better to be right than to be original; therefore he steers a course somewhere between daring and caution. (Dreyfuss, 1955, p. 24)

Dreyfus is describing the act of pivot thinking by a designer. The “course somewhere between “daring and caution” is reminiscent of the balance between a divergent style, where there are many possible answers but no assurance of a correct answer, and a convergent style, where there is much information but only one right answer. Steering a course between “daring and caution” is one illustration of the behavior of pivot thinking.

Others have sought to define design thinking by the problem rather than the process. Richard Buchanan commenting on the earlier work of Horst Rittel, defines design thinking in the context of “wicked problems” (Buchanan, 1992). Wicked problems are a “class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision-makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing” (1992, p. 15). Buchanan points out that the difference in thinking demanded by wicked problems lies in the relationship between determinacy and indeterminacy.
Determinate problems allow for a linear model of design thinking, where the designers task is to identify the appropriate conditions and precisely calculate a solution. For these kinds of problems, a convergent style of thinking is not only useful, but also necessary. On the other hand, “wicked problems” are fundamentally indeterminate; implying that there are no definitive conditions or limits to the problem itself. In this case, the designer must use a divergent style, considering many possible constraints and many possible solutions through cognitive simulation to successfully produce any answer.

Tim Brown, CEO and president of the design firm IDEO, describes design thinking as feeling “chaotic to those experiencing it for the first time.” (Brown, 2008a, p. 4) He describes design thinking as a series of “divergent and convergent steps,” where divergent thought is the process of “creating choices” while convergent thought is “making choices.” Brown’s description and sketch of the “feeling” of design thinking, taken from his personal blog site, is shown in Figure 10 (Brown, 2008b).
Brown also sees a second axis to design thinking that involves analysis and synthesis; breaking problems apart and put ideas together. He describes synthesis as “… hard because you're trying to put things together which are often in tension. Less expensive, higher quality for instance.” This process of design thinking is the difficult task of “the uncertainty of divergence and the integrated head-hurting complexity of synthesis” (Brown, 2008b).

Clearly, the practice of design thinking requires both a convergent style and a divergent style, in large part to match the design problem being solved. Roger Martin describes this process as an “opposable mind” and the process by which design problems are solved is called “integrated thinking” (Martin, 2007). Martin describes integrative thinking as “the ability to face constructively the attention of opposing ideas and, instead of choosing one at the expense of the
other, generate a creative resolution of the tension in the form of a new idea contains elements of the opposing ideas but is superior to each” (2007, p. 15). In a sense, this is concurrently employing both a convergent and divergent styles to solve a problem.

**Pivot Thinking: Trait or State?**
The behavior of pivot thinking is defined as “a cognitive problem solving style that easily pivots or shifts between convergent or divergent problem solution possibilities.” This prompts the question … is pivot thinking a trait or a state?

Fridhandler distinguishes between the psychological constructs of “trait” and “state” in this manner: “The conditions that are most typically conceptualized as states (e.g., moods and emotions) are generally presumed to be short-lived. Traits, on the other hand, are universally defined as highly enduring, even lifelong” (Fridhandler, 1986, p. 169). In this context, I would define convergent and divergent problem solving style preferences as traits. These problem solving preferences likely begin with some type of neurological structural processing advantage and through Cattell’s “investment theory” and Hebb’s synaptic effectiveness observation become an enduring cognitive behavior.

However, convergent and divergent cognitive styles are not exclusive, like any trait, in that individuals possess a range of cognitive behaviors and can exhibit deviations from their underlying traits given the appropriate circumstances. Nonetheless, like a trait, convergent and divergent represent the “default behavior,” the starting point for problem solving under most circumstances.
Therefore, if an individual’s underlying cognitive problem solving style preference is a trait, can they change over time? Recent research in neurology and brain functional imaging indicates that individuals possess a surprising amount of neural plasticity or the ability to change the way the brain works through learning (Poldrack, 2002). Techniques such as meditation can facilitate a significant change in long-term brain function (Davidson & Lutz, 2008). I posit that individuals can change their problem solving preferences over time through learning, training and a change of environment and reward systems.

Pivot thinking, the ability to easily shift between convergent and divergent problem solving, may be more aligned with the psychological construct of “state.” The psychological construct of state is typically associated with temporal definition – states are short-lived or temporary. While clearly some individuals will show no long-term preference for either convergent or divergent problem solving, others are able to flex into an opposing role depending on mood, emotion or circumstance. For example, time and deadline pressure may encourage a divergent thinker to be more likely to accept convergent problem solutions and frustration or failure may make a convergent thinker more interested in a divergent range of possible solutions.

Similarly, the emotion of fear may moderate an individual’s willingness to pivot to another problem solving style. Perceptions of risk and failure consequences all impact on individual choice (see Lerner & Keltner, 2001), which suggest that the ability to pivot between convergent and divergent problem solving styles may be less of a cognitive ability and more a factor of emotional self-awareness and regulation.
If pivot thinking is a state which can be triggered through environment, reward systems and coaching, this has broad and positive implications for teaching both engineering and design. The ability to flex problem solving styles, the willingness to accept the risk of adopting an opposite problem solving style can be encouraged and taught as a behavior.
CHAPTER 3 - Team Currency: Open and Close Ended Conversations
Experiment #1: Testing the Information exchange Differences between Facts and Questions in Group Discussions

The NPD team is widely recognized as the primary setting for new product information exchange as well as the central vehicle for collective decision-making. The NPD team can be described using the metaphor of a marketplace, where bits of information as the currency and decision making within the team a marketplace. One central characteristic of the NPD team decision-making process is that the group proceeds with minimal constraints on the give-and-take of information; there are few formal guidelines (beyond general organizational norms) dictating who may talk to whom and what may be said (Stasser & Davis, 1981).

The NPD team is usually comprised of multi-functional representatives. As each functional representative considers the problem-solving space, they bring to it a
mental model based on their experience and functional demands. For example, the manufacturing representative on a NPD team may be thinking about the manufacturing implications of new product, even as the discussion revolves around an unrelated topic such as consumer acceptance. This is an elemental contributor to “representational gaps” (Cronin & Weingart, 2007).

Stasser (1985) has extensively documented this differential sharing of information is experienced by teams. He found that privately held information tends not to be shared with other team members even when team members share a common goal. There are many reasons individual team members may take for granted what they know or decide that information is not important to others on the team. For example, psychological safety or the shared belief within a team that the climate is safe for interpersonal risk-taking can have a significant effect on information sharing (Edmondson, 1999).

As a result, in a group information exchange both tacit and explicit filtering of information often occurs. It has been shown that this differential sharing of information can be affected by not only functional experience but also variables such as experience levels, demographic differences and rank within the organization (J. S. Bunderson & Sutcliffe, 2002). There is less evidence that information is shared on the basis of cognitive problem-solving preference, which is a more fundamental and basic filter than either experience or demographics.

This research involves two experiments of six-member groups sharing asynchronously distributed information. Each group participated in both
experiments. The Shoe Design Discussion (Experiment #1) is an open-ended discussion (no group decision required) where information is presented as either a fact or in question form and all information is unique and not repeated among subjects. This experiment is designed to show differential passing of information with a group based on the type of information (question or fact) and the cognitive preference style (convergent or divergent) of the group.

The Shampoo Prototype Discussion (Experiment #2) is a closed-ended discussion (a group-level decision is required) and most information in the group is common to all members of the group and only certain information is unique to each individual. This experiment is design to illustrate how “hidden profiles” (Stasser & Stewart, 1992) are revealed within a group, again based on preference type and the presence of a pivot thinker.

**Measuring Convergent and Divergent Style Preference**
The research design for this study required that participants be identified as having either a convergent style preference, divergent style preference or as a pivot thinker (no preference) prior to acceptance as a research subject and assignment to a specific group. The screening tool used was the Herrmann Brain Dominance instrument (HBDI). The HBDI has been judged to be both a valid and reliable psychometric instrument for the measurement of four factors (C. V. Bunderson, 1989). Further, in an independent evaluation of 16 different learning style instruments, Coffield’s review states “the psychometric properties of the HBDI appear to be sound” and concludes that “there are good reasons to recommend the use of the HBDI as a means of individual and group reflection on thinking and learning preferences” (Coffield et al., 2004, p. 168)
The HBDI provides, on the basis of 120 items, a four-factor classification of mental preferences or cognitive styles (Herrmann, 1989). The HBDI-A factor (HA) reflects a preference for solving analytical and factual problems using logical and reason, while the HBDI-B (HB) factor shows a preference for temporal and sequential reasoning, sequencing content and the application of rules. The HBDI-C (HC) factor reflects a problem solving preference for interaction with others, sensing and reacting to input from others, while the HBDI-D (HD) factor shows a preference for imaginative or conceptual problem solving, synthesizing input and viewing problems in a holistic manner.

Herrmann states that about 60% of the population have two dominate problem-solving preferences and an additional 30% have three dominate preferences. Scores of HA and HB, and HC and HD have positive correlation while scores HA and HC and HB and HD have negative correlation. (C. V. Bunderson, 1989, p. 34)

The HBDI was chosen as a screening instrument for several reasons. First, both the HA and HD factors seem to fully describe a preference for either convergent problem solving or divergent problem solving. Scores on factors HB and HC were not part of the subject selection process. Second, the HBDI has an extensive occupational database of scores that help align this instrument with the purpose of this research, which is a better understanding of the problem dynamics of an NPD team that includes a range of functional skills from engineering and finance to marketing and human resources. Finally, the HBDI could be administered on-line, which facilitated the screening and selection of participants at remote locations.
HBDI scores by occupation are shown in Table 1. Professions like engineer, financial officer and radiologist have high HA scores reflecting the convergent problem solving required for those jobs. These occupations have a lower HD score reflecting less of a preference (or need) for divergent problem solving. In contrast, occupations like psychiatrist, creative director or human resource manager have high HD scores indicating a preference for divergent problem solving; and they have correspondingly lower HA scores showing less interest in convergent problem-solving. The difference between these problem-solving style preferences can be shown in the difference between HA and HD scores, ranging from a high of .67 for a radiologist to a low of -.42 for a psychiatrist.

<table>
<thead>
<tr>
<th>Occupation/HBDI Factor:</th>
<th>HA</th>
<th>HB</th>
<th>HC</th>
<th>HD</th>
<th>HA-HD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Convergent Styles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiologist</td>
<td>0.83</td>
<td>0.58</td>
<td>0.21</td>
<td>0.17</td>
<td>0.67</td>
</tr>
<tr>
<td>Engineer</td>
<td>0.80</td>
<td>0.51</td>
<td>0.39</td>
<td>0.30</td>
<td>0.50</td>
</tr>
<tr>
<td>Financial Officer</td>
<td>0.76</td>
<td>0.64</td>
<td>0.35</td>
<td>0.27</td>
<td>0.49</td>
</tr>
<tr>
<td>Stock Broker</td>
<td>0.65</td>
<td>0.62</td>
<td>0.39</td>
<td>0.28</td>
<td>0.37</td>
</tr>
<tr>
<td><strong>Divergent Styles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychiatrist</td>
<td>0.34</td>
<td>0.35</td>
<td>0.32</td>
<td>0.76</td>
<td>-0.42</td>
</tr>
<tr>
<td>Creative Director</td>
<td>0.43</td>
<td>0.35</td>
<td>0.38</td>
<td>0.71</td>
<td>-0.28</td>
</tr>
<tr>
<td>Pediatrician</td>
<td>0.41</td>
<td>0.36</td>
<td>0.66</td>
<td>0.67</td>
<td>-0.26</td>
</tr>
<tr>
<td>Human Resource Manager</td>
<td>0.34</td>
<td>0.51</td>
<td>0.83</td>
<td>0.57</td>
<td>-0.23</td>
</tr>
<tr>
<td><strong>Balanced Styles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Estate Agent</td>
<td>0.51</td>
<td>0.43</td>
<td>0.60</td>
<td>0.52</td>
<td>-0.01</td>
</tr>
<tr>
<td>Middle Manager</td>
<td>0.52</td>
<td>0.62</td>
<td>0.49</td>
<td>0.43</td>
<td>0.09</td>
</tr>
<tr>
<td>R&amp;D Manager</td>
<td>0.73</td>
<td>0.65</td>
<td>0.30</td>
<td>0.62</td>
<td>0.11</td>
</tr>
<tr>
<td>School Superintendent</td>
<td>0.55</td>
<td>0.65</td>
<td>0.49</td>
<td>0.43</td>
<td>0.12</td>
</tr>
<tr>
<td>All Females</td>
<td>0.42</td>
<td>0.56</td>
<td>0.66</td>
<td>0.53</td>
<td>-0.11</td>
</tr>
<tr>
<td>All Males</td>
<td>0.63</td>
<td>0.54</td>
<td>0.48</td>
<td>0.48</td>
<td>0.15</td>
</tr>
</tbody>
</table>

HBDI raw scores have been norm-referenced to the instrument mean (.50) for each factor.
The NEO-FFI (also known as the “Big Five Factors”) was collected post research for additional insight on subject personality differences between groups (Costa & McCrae, 1992). The NEO-FFI is a 60-item instrument that measures five domains of personality: neuroticism (Ne), extraversion (Ex), openness (Op), agreeableness (Ag) and conscientiousness (Co). The NEO-FFI is in booklet form and requires 5-10 minutes to complete. The results are hand scored by the researcher with different scales for males and females (McCrae & Costa, 2010). The resulting raw score for each factor was converted to a calibrated T-score and then norm-referenced for comparison to the HBDI scores.

Previous team research with the NEO-FFI instrument suggests that teams composed of members with different levels of each of the Big Five Personality dimensions have the potential to exhibit higher levels of team performance (Neuman, Wagner, & Christiansen, 1999). This performance is often relative to a specific team task. For example, successful advertising agency creative teams (teams in charge of conceiving and executing advertising) have higher levels of neuroticism and openness than non-creative (teams that handle media placement and account services), somewhat more extroverted and less conscientious (Gelade, 1997). Baer found that student team creativity performance increased quadratically as the number of team members who scored high on extroversion, high on openness or low on conscientiousness increased (Baer et al., 2008). In other research, conscientiousness was a “consistently valid predictor for all occupational groups studied and for all criterion types” (Barrick & Mount, 1991). Unfortunately, few studies have examined the link between convergent and divergent cognitive styles and the mechanisms of both team information exchange and decision-making processes. This research was designed to address this gap in the literature.
Subject Demographics and Style Preference

Participants were recruited from both industry and student populations. Industry groups were recruited from companies that included a large Midwest insurance underwriter, a multinational software company, design consultancy and a satellite manufacturing company. Students were recruited from a masters-level product design-engineering course, undergraduate business management and art design classes. The two populations of participants were not mixed – industry groups contained all work-experienced participants while student groups were comprised of only students. As participants were assembled into research groups, an effort was made wherever possible to break-up existing work group patterns for both industry and student participants.

The Stanford University Institutional Review Board (IRB) has approved this research for Human Subjects Research, Protocol #20057, IRB Number 349. All participants reviewed the approved IRB Informed Consent Statement before participation in this study.

In total, 143 participants were screened using the HBDI to identify the 96 participants in this research - a 67% acceptance rate. The acceptance rate might have been higher because in several groups additional participants need to be screened to replace last-minute dropouts or no-shows.
The 96 participants were arranged in 16 groups, as shown in Table 2. Of the 16 groups, 9 were comprised of students and 7 were from industry. On average, 41% of participants were female with team composition ranging from 83% female to 0% female. In general, the participants were highly educated with an average of 18 years of education experience (masters-level). The average work experience was .5 years for student groups and 12 years for industry groups. There was no statistically significant demographic difference between groups with a pivot thinking leader and groups without a pivot thinking leader.

The raw scores for both the HBDI and NEO-FFI were converted to differentiated norm-referenced scores, ranging from .00 to 1.00 (Cronbach, 1990). For all nine factors (four for HBDI and five for NEO-FFI), each subject’s raw scores were converted to a differentiated norm-referenced equivalent using one-dimensional scaling and a stretched scoring scale. The median raw score for each factor was
equated to .50 and one-dimensional scaling was used to convert raw scores to conform to the published instrument high and low raw scores.

The HA-HD score difference was used to select and group participants for this research. An HA-HD score difference of .30 or higher was the threshold for selecting convergent problem-solving style participants while a score difference of negative .30 or lower was the threshold for divergent problem-solving style participants. Pivot thinkers were selected on the basis of an HA-HD score between .10 and negative .10. The 96-person subject pool was composed of convergent (n=44), divergent (n=44) and pivot thinkers (n=8), respectively as shown in Figure 11 and Table 3.

![Figure 11 - HBDI Mean Scores by Subject Group. Error bars are 2 SEM.](image-url)
Table 3 - HBDI Mean Scores by Subject Group

<table>
<thead>
<tr>
<th>Subject Groups:</th>
<th>n</th>
<th>HA</th>
<th>HB</th>
<th>HC</th>
<th>HD</th>
<th>HA-HD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergent</td>
<td>44</td>
<td>0.76</td>
<td>0.52</td>
<td>0.37</td>
<td>0.39</td>
<td>0.36</td>
</tr>
<tr>
<td>Divergent</td>
<td>44</td>
<td>0.41</td>
<td>0.36</td>
<td>0.54</td>
<td>0.70</td>
<td>-0.29</td>
</tr>
<tr>
<td>Pivot Thinker</td>
<td>8</td>
<td>0.64</td>
<td>0.41</td>
<td>0.42</td>
<td>0.57</td>
<td>0.07</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>0.59</td>
<td>0.44</td>
<td>0.45</td>
<td>0.55</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Convergent thinkers, with a HA mean score of .76 were significantly higher than divergent thinkers with a mean score of .41 score on this same measure, t(86) = 13.34, p<.000. Similarly, divergent thinkers with a HD mean score of .70 were significantly higher than convergent thinkers with a mean score of .39 score on the same measure, t(86) = -14.65, p<.000. However, pivot thinkers scored almost as well on HA as convergent thinkers (.76 vs .64, t(50) = 3.06, p<.004) and almost as well on HD as divergent thinkers (.70 vs .57, t(50) = 4.55, p<.010), perhaps indicating enough of a capacity in each cognitive style that would allow pivot thinkers to connect with either convergent or divergent thinking styles.

Scores of HB and HC were not used for subject selection. In general, these scores were lower for all participants with slightly higher scores for HB among convergent thinkers and slightly higher scores for HC among divergent thinkers, which is a predicted pattern for general population results as stated in the HBDI instrument professional manual.

A correlation analysis between HBDI and NEO-FFI factors for this research sample is shown in
Table 4. HA and HD negatively correlate ($R = -.71$), which is not surprising given the process used to select participants for this research. Similarly, HA-HD positively correlates with HA ($R=.94$) and negatively correlates with HD ($R=-.91$) indicating that this data item is a useful single indicator for separating participants throughout the balance of this analysis.

<table>
<thead>
<tr>
<th>Factor</th>
<th>HA</th>
<th>HD</th>
<th>HA-HD</th>
<th>Ne</th>
<th>Ex</th>
<th>Op</th>
<th>Ag</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HD-HD</td>
<td>-.71</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA-HD</td>
<td>.94</td>
<td>-.91</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ne</td>
<td>-.08</td>
<td>-.07</td>
<td>-.10</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex</td>
<td>-.16</td>
<td>.12</td>
<td>-.16</td>
<td>-.10</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Op</td>
<td>-.49</td>
<td>.61</td>
<td>-.59</td>
<td>.02</td>
<td>.17</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag</td>
<td>-.13</td>
<td>.09</td>
<td>-.12</td>
<td>-.43</td>
<td>.16</td>
<td>.17</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Co</td>
<td>.23</td>
<td>-.27</td>
<td>.27</td>
<td>-.29</td>
<td>.04</td>
<td>-.22</td>
<td>.24</td>
<td>--</td>
</tr>
</tbody>
</table>

Factors
HA – HBDI Factor A
HD – HBDI Factor D
HA-HD – Difference HA and HD
BOLD - significant at p<.05

Table 4 - Correlation among HBDI and NEO-FFI Measures

The HA factor scores, which is synonymous with convergent thinking, has a strong negative correlation with openness ($R=-.49$) and a positive correlation with conscientiousness ($R=.23$). This is consistent with the literature that shows convergent thinking is motivated to seek single point solutions, thereby showing less interest in new or multiple solutions. Convergent thinking is also positively linked to conscientiousness, “described by a tendency to engage in systematic and rigid task strategies and by a tendency to adhere to established ways of thinking and doing things (dependability) rather than by a propensity to exert high levels of task-directed efforts (achievement)” (Baer et al., 2008).
The HD factor score, which is synonymous with divergent thinking, has a strong positive correlation with openness (R=.61) and a negative correlation with conscientiousness (R=-.27). Openness has long been associated with divergent thinking (McCrae & Ingraham, 1987) and team creativity (Schilpzand, Herold, & Shalley, 2011). Further, openness has a negative correlation with conscientiousness (R=-.22), which may be an indication of the underlying tension that exists between convergent and divergent thinkers.

A principle component analysis of the seven observed scores for each factor confirms the underlying integrity of the subject selection this research, as shown in Table 5. The six factors include HA and HD, the primary markers for convergent and divergent thinking, as well as the five items (Ne, Op, Ex, Ag and Co) of the NEO-FFI “Big Five” personality indicator. A factor analysis of the convergent and divergent participants (n = 88) shows a two-component solution. The first component, described as “C or D thinker,” illustrates the key differences in the participants as either being a convergent thinker (HA -.85) or a divergent thinker (HD .89) along with the openness (Op .81) factor that has been shown to correlate HD. The second component, described as “Team Player,” is an aggregation of agreeableness (Ag .76) and conscientiousness (Co .59) that could be an indication of important interpersonal and team skills.

<table>
<thead>
<tr>
<th>Component</th>
<th>Descriptive</th>
<th>Eigenvalue</th>
<th>Factor</th>
<th>Variance</th>
<th>Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>“C or D Thinker”</td>
<td>2.44</td>
<td>HA (-.85)</td>
<td>34.9%</td>
<td>34.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HD (.89)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Op (.81)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>“Team Player”</td>
<td>1.78</td>
<td>Ag (.76)</td>
<td>25.5%</td>
<td>60.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Co (.59)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 - Factor Analysis: Convergent and Divergent Participants
A principle component analysis of the eight pivot thinkers reveals a different profile, as shown in Table 6. The first component explains over half the variance and has a positive correlation with both HA (.92) and HD (.81) as well as the Ag (.85) agreeableness factor. This “balanced and agreeable thinker” component suggests that pivot thinkers not only have a balanced problem-solving preference between convergent and divergent thinking and combine this with a supportive interpersonal style.

<table>
<thead>
<tr>
<th>Component</th>
<th>Descriptive</th>
<th>Eigenvalue</th>
<th>Factor</th>
<th>Variance</th>
<th>Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>“Balanced and Agreeable Thinker”</td>
<td>3.77</td>
<td>HA (.92)</td>
<td>52.8%</td>
<td>52.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HD (.81)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ag (.85)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>“Follow the Rules”</td>
<td>1.60</td>
<td>Co (.86)</td>
<td>23.9%</td>
<td>76.7%</td>
</tr>
</tbody>
</table>

Table 6 - Factor Analysis: Pivot Thinkers

It is equally important to note that openness (Op) does not appear as a significant factor among pivot thinkers. Openness strongly correlates with HD and these pivot thinkers have above-average HD scores. Instead, the second component features conscientiousness (Co .86) that suggests that if thinkers may be more interested in accomplishing the task over any particular problem-solving path.

**Experimental Design and Research Process**

The experimental design for this study compares convergent problem solving style participants to divergent problem solving style participants with either the presence of a pivot thinker leader or no pivot thinker leader. This results in a 2x2 matrix, as shown in Figure 12. A total of four groups of six participants each
were conducted for the four conditions, resulting in a total of 16 groups and 96 participants.

After participants were screened and assembled into appropriate groups, the research process involved four steps, as shown in Figure 13. The first step was group-level instruction on how to participate in a role-play exercise and group leader (referred to as a “moderator” with the group to minimize authority) selection, which is shown in Appendix A. Leader selection was conducted by a seemingly random process (confirmed by post session interviews) and resulted in the pivot thinking member selected as the group leader in the groups that included a pivot thinker.
In groups that did not contain a pivot thinker, leader selection was entirely random. Participants would then engage in one of two experiments - shoe design discussion or shampoo prototype selection discussion. The order of the experiments was alternated to diminish order bias (Krathwohl, 2009). The final step in the research process was the completion of a group satisfaction rating survey and the NEO-FFI. The total time for each research session was about 70 minutes. Group-level data was collected via audio and paper surveys, transferred to Microsoft Excel and stored within a password protected University server; all statistical calculations were completed using SPSS 19.

The group satisfaction rating question is shown in Appendix A. The group satisfaction question was taken from Edmondson’s study of group psychological safety (Edmondson, 1999). Group closeness was measured using a reverse coded question and the Aron Scale of Closeness as a means of measuring group familiarity (A. Aron, E. N. Aron, & Smollan, 1992). The concern was that participants in groups who were very familiar might assume pre-determined
roles and exchange information in a different manner than participants in groups with a lower sense of familiarity.

Experiment #1 - Shoe Design Discussion
Subject groups were separated into either all convergent problem-solving thinkers or all divergent problem-solving thinkers, either with or without a pivot thinker, resulting in a 2 X 2 (style x pivot thinker) factorial design. It was not expected that a pivot thinker would play any role in this experiment, so the principal unit of measurement is either convergent or divergent dominant groups.

The first experiment, the “Shoe Design Discussion,” presents a case study where subjects are expected to play a role. In this case, each subject is described as a peer-level member of a well-known footwear company’s top design team that meets once per quarter to discuss potential new product designs and make an individual “go/no go” decision for further development. Footwear was chosen as a product focus because subject experience with the product is universal and yet design experience for footwear is relatively limited.

The group size of six was chosen for two reasons. First, a considerable body of research shows that group member interaction is a function of group size, with larger groups affording less individual interaction. However, it is been shown that this has an impact up to a group size of about six members after which larger group size does little to impact group decision-making processes (Bass & Norton, 1951). A meta-review of group size has also shown that the quality of group judgment levels off at groups of five to six members (E. J. Thomas & Fink,
It has also been shown that group satisfaction is maximized in groups of about five members (Hackman & Vidmar, 1970). The second reason a group size of six was selected is that 6 to 9 members is roughly the size of most cross-functional NPD teams (Ancona & Caldwell, 1992; Sarin & McDermott, 2003).

Each participant received identical background information, with the exception of a four-item set of information specific to the design, which was unique to each subject. The participants were also given a multi-view simulated 3D CAD drawing of the design (Figure 14) to encourage a more animated conversation and add to the realism of the experience. The specific shoe company was familiar to the participants and while the specific shoe design is an actual product of the company, post research discussion indicated the participants had no sense that it was currently in the marketplace. The subject role-play information is shown in Appendix B.
The factual items about the shoe design used in this experiment were taken from manufacturer's specifications for this particular shoe (i.e., color assortment, weight, reflective materials) or other similar shoes. The question items about the shoe design were summarized from the marketing materials found on the manufacturer's website and marketing materials from companies that make similar types of shoes.

The focus of this experiment was the tacit and explicit differential decisions each individual team member makes when sharing information. Participants were given the instruction that "some information may be helpful for this discussion, some information may not be helpful – you as a designer decide what you think..."
is important to share with the group.” Respondents were allowed to keep a copy of their information throughout the experiment and refer to it as needed, making item recall not an issue. As a result, it was expected that every information item would be shared in the discussion at different times and in different order depending on the relative personal importance of the item to each respondent.

Information Items and Distribution
All information about the shoe design discussion experiment was in the form of either “fact” items or “question” items. Facts items were designed to be “close ended” in that they were simple statements of specifications about the shoe design. The precedent for this taxonomy comes from the study of Deep Reasoning Questions (DRQ). A DRQ encourages the subject to consider specific components of the problem, specific mechanisms and to integrate content to a single conclusion (Sullins, Craig, & Graesser, 2010). DRQs often yield to “yes” or “no” answers to relatively shallow inquiries like “Does the CPU use RAM when running an application?” (Graesser & Person, 1994). In this manner, DRQs have the characteristic of convergent thinking, where the questioner is attempting to converge on “the facts.” An example of a shoe design discussion fact was “The weight of this shoe is 482g/pair.”

Questions items were designed to be “open-ended,” in a way that might encourage additional conversation and additional avenues of inquiry. Eris (Eris, 2002) proposes an alternative label for this type of question, called Generative Design Questions (GDQ). GDQ questions can have multiple alternative known answers as well as multiple unknown possible answers. The questions intent is to disclose both known answers and generate unknown answers. Such
questions are characteristic of divergent thinking, such as “How does the CPU use RAM when running an application?” (Graesser & Person, 1994). An example of a shoe design discussion question was “What if shoes are a statement about who you are as a person?”

It was hypothesized that convergent problem-solving thinkers would be more attracted to facts, while divergent problem-solving thinkers would be more attracted to questions.

Fact items were taken from the product website for the actual shoe design and represented real specifications for the shoe. The question items were also taken from the company website and inferred from product selling messages. Fact and question items were presented to a separate subject group (n=97) who were asked to categorize them as either facts or questions and each item received about 90% agreement on its categorization, as shown in Appendix C.

In total, there were 24 information items randomly distributed among the six participants in each group. Each subject had two facts and two questions for a total of four unique information items. In the information set, eight facts aligned with eight questions, while four facts had no corresponding question and four questions had no corresponding fact.

The participants were given approximately two minutes to read their information sheet and then a 20-minute countdown timer was started. Of the 16 research groups, 14 groups used the entire 20-minute time for discussion and two groups
used approximately 18 minutes for their discussion. Following the discussion, each subject individually completed a survey which recorded their “go/no go” decision and ask them to rate each information item on the basis of how important was to them making their decision about the shoe design. The item survey is shown in Appendix D.

A discussion time of 20 minutes was selected through pilot testing of the case studies. Two groups of six participants were allowed to discuss the two case studies “for as long as they wanted” and one group ended their discussion in 21 minutes and the second group ended their discussion in 18 minutes indicating that a 20 minute discussion time was about right for the complexity of this experiment.

Data Collection
Each session was recorded using audio and coded for response using VCode (Hagedorn, Hailpern, & Karahalios, 2010). VCode enables the specific tracking of the person speaking, which can then be linked to role position and a specific information set within the team. This also allows for the recording of the exact moment an information item was introduced into the team conversation. If an information item was introduced more than once, the earliest introduction time was used for analytical purposes.

Results: Convergent and Divergent Problem-Solving Groups
The data collected from the 16 groups shows that convergent style thinking groups traded a total 15.2 facts and questions (of a possible 24 items) versus 17.0 facts and question items for divergent thinkers, which is a nonsignificant
difference of -1.8, \( t(14) = -0.582, p < .570 \), as shown in Table 7. Convergent and divergent thinking groups, in total, traded an average of 9.1 facts and 9.4 questions, respectively, indicating an equal preference for these effects. Convergent thinking groups traded 6.1 questions versus 7.6 questions for divergent groups, a nonsignificant difference of -1.5, \( t(14) = -0.715, p < .487 \).

<table>
<thead>
<tr>
<th>Items Shared in Group</th>
<th>n</th>
<th>Fact</th>
<th>Question</th>
<th>Total</th>
<th>Min</th>
<th>Max</th>
<th></th>
<th></th>
<th>Item Importance Rating</th>
<th>n</th>
<th>Fact</th>
<th>Question</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergent</td>
<td>8</td>
<td>9.1</td>
<td>6.1</td>
<td>15.2</td>
<td>7</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td>44</td>
<td>3.54</td>
<td>3.56</td>
<td>.02</td>
</tr>
<tr>
<td>Divergent</td>
<td>8</td>
<td>9.4</td>
<td>7.6</td>
<td>17.0</td>
<td>10</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td>44</td>
<td>3.21</td>
<td>3.45</td>
<td>.24</td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td>-.3</td>
<td>-1.5</td>
<td>-1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.33</td>
<td>.11</td>
<td></td>
</tr>
<tr>
<td>Pivot</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>3.39</td>
<td>3.67</td>
<td>.28</td>
</tr>
<tr>
<td>All Participants</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>96</td>
<td>3.38</td>
<td>3.52</td>
<td>.14</td>
</tr>
</tbody>
</table>

**Table 7 - Item Sharing and Importance Rating by Cognitive Style Group**

Each team member was also asked to rate the importance of every information item to their decision-making process on a five-point scale from 5 (very important) to 1 (not very important) as shown in Appendix A. This was intended to be an individual measure, how important the item was to their specific decision-making process, and the information is analyzed on an individual basis. All participants rated questions (3.52) as more important that facts (3.38), a significant difference of .14, \( t(95) = 2.304, p < .023 \).

Convergent thinkers (n=44) rated facts (3.54) equal to questions (3.56), a nonsignificant difference. Divergent thinkers (n=44) rated questions (3.45) higher than facts (3.21), a significant difference of .24, \( t(43) = 2.461, p < .018 \). This is surprising in that the original hypothesis was that convergent thinkers would be
more attracted to facts than questions. It appears that convergent thinkers highly value all types of information, while divergent thinkers were more attracted to “open-ended” questions than “close-ended” facts.

This difference is also indicated, but not significant, among pivot thinkers (n=8) for whom rating of questions (3.67) is higher than facts (3.39), a nonsignificant difference of .28, t(7) = 1.61, p<.161. A one-way analysis of variance (ANOVA) also indicates that facts ratings are the only areas where these three groups differ (F(2,95) = 3.21, p<.045), specifically between convergent and divergent ratings.

In reviewing the research group audio recordings, it was noted that group style tended to vary by work experience. Student teams, with less work experience, tended to approach the experiment in a very structured manner, often times purposely soliciting specific feedback from each member of the group before open discussion began. In this manner, most facts and questions were eventually brought into the conversation, but as simply statements of “what I know” and not as a part of any on-going group discussion. On the other hand, teams comprised of more experienced participants tended to begin the conversation without much review of the facts and questions provided. Eventually, facts and questions would work their way into the conversation, but in a less regimented and structured process.

This is evident when viewing the facts and questions shared by groups with less work experience (mostly students) versus groups with more work experience, as shown in Table 8. For example, groups with less experience (n=9) on average had 1.2 years of work experience within average 23.5 years subject age, in
contrast to groups with more work experience (n=7) that had on average 14.5 years of work experience and an average 39.7 years subject age. In total, the groups with less work experience shared 18.7 items versus 12.7 items for the groups with more work experience, a significant difference of 6.0, $t(14) = 3.145$, $p<.041$, items per group. Differences in fact sharing (10.3 versus 7.8, +2.5) was significant ($t(14) = 2.578$, $p<.022$) and differences in question sharing (8.4 versus 4.9, +3.5) was somewhat significant ($t(14) = 1.860$, $p<.084$).

<table>
<thead>
<tr>
<th>Experience Level</th>
<th>Mean-Years Work</th>
<th>Mean-Age</th>
<th>n</th>
<th>Fact</th>
<th>Question</th>
<th>Total</th>
<th>n</th>
<th>Fact</th>
<th>Question</th>
<th>Total</th>
<th>Diff</th>
<th>Fact</th>
<th>Question</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less</td>
<td>1.2</td>
<td>23.5</td>
<td>9</td>
<td>10.3</td>
<td>8.4</td>
<td>18.7</td>
<td>54</td>
<td>3.46</td>
<td>3.58</td>
<td></td>
<td>.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More</td>
<td>14.5</td>
<td>39.7</td>
<td>7</td>
<td>7.8</td>
<td>4.9</td>
<td>12.7</td>
<td>42</td>
<td>3.27</td>
<td>3.45</td>
<td></td>
<td>.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td></td>
<td></td>
<td><strong>2.5</strong></td>
<td><strong>3.5</strong></td>
<td><strong>6.0</strong></td>
<td></td>
<td><strong>.19</strong></td>
<td><strong>.13</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 8 - Item Sharing and Importance Rating by Work Experience**

Item importance rating varied by level of work experience. Less experienced participants tended to rate facts and questions equally (3.46 and 3.58) while more experienced groups tended to favor questions over facts (3.45 to 3.27), a significant .18 difference, $t(41) = 1.869$, $p<.069$. Also, less experienced participants tended to value all information (both facts and questions) over more experienced participants, which is particularly true in facts, where less experienced participants rated facts (3.46) higher than more experienced participants (3.27) a nonsignificant .19, $t(94) = 1.470$, $p<.145$.

The paradoxical difference in more work experience groups, which shared fewer question items than fact items but rated questions as more important, may be explained by confidence. Experienced teams were more likely to invent their
own questions, in most cases based on their prior work experiences, than less experienced participants who had little relevant crystallized knowledge to draw upon. This would explain why experienced teams shared less of the provided questions overall, but still valued questions in the process of problem solving.

Subject work experience had an impact on how groups performed. Groups with less work experience showed very little difference between convergent and divergent thinking styles in the amount of items shared or the mix between fact and question items, as shown in Table 9. Convergent and divergent subject groups both shared 18.8 information items with the differences between facts and questions and significant.

<table>
<thead>
<tr>
<th>Less Experience</th>
<th>Items Shared in Group</th>
<th>Item Importance Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Fact</td>
</tr>
<tr>
<td>Convergent</td>
<td>5</td>
<td>10.6</td>
</tr>
<tr>
<td>Divergent</td>
<td>4</td>
<td>10.0</td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td>.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>More Experience</th>
<th>Items Shared in Group</th>
<th>Item Importance Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Fact</td>
</tr>
<tr>
<td>Convergent</td>
<td>3</td>
<td>6.7</td>
</tr>
<tr>
<td>Divergent</td>
<td>4</td>
<td>8.8</td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td>-2.1</td>
</tr>
</tbody>
</table>

Bold p<.05, Italic p<.10

Table 9 - Item Sharing and Importance by Experience and Cognitive Style
On the other hand, subject groups with more experience traded substantially fewer information items, with convergent groups trading only 9.3 information items, while divergent groups traded 15.2 total items, a significant difference of -5.9, t(2) = -4.038, p<.056. ANOVA shows that significant differences exist between less experienced participants and more experienced participants in the area of facts (F(3,95) = 4.306, p<.007) and questions (F(3,95) = 7.806, p<.000) and total items (F(3,95) = 9.304, p<.000)

Among subject groups with more work experience, predicted differences in information sharing appear. Convergent thinking groups shared 6.7 facts and 2.6 questions, a somewhat significant difference of 4.1 items (t(2) = 2.306, p<.148) Divergent participants shared 8.8 facts and 6.4 questions, a difference of 2.4 items, not a significant difference.

Item important ratings also showed a difference between the work experience level of participants. In the less work experienced groups, convergent thinkers had the same overall rating for information items (3.65 for facts and 3.59 for questions). Less work experienced divergent thinkers favored questions (3.60) over facts (3.23), a significant difference of .37, t(23) = 3.589, p<.002. Also, less experienced convergent thinkers rated fact items (3.65) higher than less experienced divergent thinkers (3.23), a statistically significant difference of .42, t(29) = 3.743, p<.001. Again, these differences may relate to work place confidence, with less experienced convergent thinkers comfortable with known facts in the absence of the ability to supply their own facts based on prior experience, while less experienced divergent thinkers are more comfortable with questions and seeking new information.
Among more work experienced participants, the difference between the importance of fact and questions diminishes. Experienced convergent thinkers rated the importance of facts (3.38) and questions (3.58) the same (a nonsignificant difference) essentially the same pattern as with less experienced convergent participants. More experienced divergent thinkers found both facts (3.18) and questions (3.31) of the same importance, which is different than their less experienced counterparts. ANOVA shows a statistically significant difference among groups on fact item ratings, where less experienced convergent thinkers rated facts significantly higher than more experienced divergent thinkers (F(3,95) = 3.563, p = .017). There is not a similar pattern in question item ratings where all groups rated the importance of questions at the same level (F(3,95) = .457, p = .253).

General Liner Modeling (GLM) also illustrates the affect of work experience on information sharing. For example, each subject had four items of information, unique to their role in the discussion, so they could share between 0 – 4 items in the conversation. If item sharing is the dependent variable, while convergent/divergent thinking and work experience are the independent variables, work experience becomes a defining factor in prediction of item sharing, as shown in Table 10. Convergent and divergent participants with more work experience shared less information items than comparable participants with less (or no) work experience. Pivot thinking participants shared about the same information items regardless of work experience level.
A review of timing patterns of how groups shared information item revealed no significant differences but did show some interesting trends, as shown in Table 10. For example, convergent groups started discussion after an average of 132 seconds had elapsed, whereas divergent groups started with an average of 65 seconds elapsed. The difference of 57 seconds was not statistically significant (p = .230) but does suggest that convergent groups were more interested in first understanding their individual data. Similarly, both groups continued introducing information items well into the discussion with the last information...
item with convergent and divergent groups introducing the last information item after an average of 901 and 887 elapsed seconds, respectively.

<table>
<thead>
<tr>
<th>Group Mean (elapsed seconds)</th>
<th>Item Mention</th>
<th>First Item Mention</th>
<th># Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>First</td>
<td>Last</td>
<td>Fact</td>
</tr>
<tr>
<td>Convergent</td>
<td>8</td>
<td>132</td>
<td>901</td>
</tr>
<tr>
<td>Divergent</td>
<td>8</td>
<td>65</td>
<td>887</td>
</tr>
</tbody>
</table>

Table 11 - Temporal Sharing by Cognitive Style Group

For both convergent and divergent thinking groups, the first item mentioned tended to be a fact. Convergent thinking groups introduced a fact on average after 161 elapsed seconds, which was marginally but not significantly sooner than a question was introduced. Divergent thinkers introduced a fact item on average after 76 elapsed seconds, which again was marginally but not significantly sooner than a question was introduced. It seems most groups initiated conversation with the statement of fact, perhaps because the “closed ended” nature facts makes them less controversial and easier to begin a conversation.

Discussion exchanges were also tracked in-group. A discussion exchange is when one subject stops carrying the narrative of the conversation and a second subject begins talking continuing the narrative the conversation. In convergent groups there was an average of 117 exchanges of conversation versus 139 exchanges for divergent groups, a +22 exchange differential but not statistically significant. It was hypothesized that divergent thinkers might have more discussion exchanges than convergent thinkers, but this data is inconclusive.
Correlation analysis showed that no personality factor of the NEO-FFI translated to discussion dynamics. For example, the extraversion (Ex) factor showed no correlation with either individual talk time ($R=.049$, $p = .638$) or the number of talk opportunities ($R=.106$, $p = .303$). There were no significant individual correlations between Openness (Op), Agreeableness (Ag) or Conscientiousness (Co) and with talk time or talk opportunities or items shared. Emotional Stability (Ne) showed a modest negative correlation ($R=-.190$, $p=.064$) with talk opportunities perhaps indicating that the more emotionally grounded a subject feels, the less likely they are to speak up in a group situation.

Following the shoe design discussion, all participants were asked one question regarding future development of the shoe design. The question was open-ended: "Would you proceed with further development of the Kinetic shoe design?" (Yes-No) The intent was to determine individual commitment to the design and its potential, as a measure of openness to additional changes. It was assumed that divergent style thinkers, who rate highly on the openness factor (NEO-Op), would be most receptive to the design and the potential for future changes.

Convergent style thinkers ($n=44$) said “yes” 59% of the time, divergent thinkers ($n=44$) said “yes” 41% of the time and pivot thinkers said yes 50% of the time, as shown in Table 12. This difference of 18 points is modestly significant, $t(86) = 1.715$, $p<.090$. 
"Finally, would you proceed with further development of the Kinetic shoe design?" (Yes-No)

<table>
<thead>
<tr>
<th>Individual profile</th>
<th>n</th>
<th>% Yes</th>
<th>Work Experience</th>
<th>n</th>
<th>% Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergent</td>
<td>44</td>
<td>59%</td>
<td>Less - Convergent</td>
<td>30</td>
<td>43%</td>
</tr>
<tr>
<td>Divergent</td>
<td>44</td>
<td>41%</td>
<td>Less - Divergent</td>
<td>24</td>
<td>33%</td>
</tr>
<tr>
<td>Pivot</td>
<td>8</td>
<td>50%</td>
<td>More - Convergent</td>
<td>18</td>
<td>89%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>More - Divergent</td>
<td>24</td>
<td>46%</td>
</tr>
</tbody>
</table>

Table 12 - Further Development by Cognitive Style and Experience

However, when the results are analyzed by work experience a different pattern emerges. There is less willingness to proceed with the design among less experienced participants, with convergent thinkers (n=30) voting "yes" 43% and divergent thinkers (n=24) voting "yes" 33% of the time, a nonsignificant difference between the two. However, among participants with more work experience, convergent style thinkers (n=18) voted "yes" 89% of the time, and divergent thinkers voted "yes" 46% of the time. This difference of 43% points is significant, t(40) = 2.615, p<.013.

These results were initially surprising, but a careful review of the group audio conversation provides insight. The less experienced groups tended to discuss only the facts available or their personal preferences. The more experienced groups provided examples and metaphors from other categories of information, which was available to them through their experiences. Similarly, more divergent style thinkers tended to reject the design because the feeling was that the designers “could do better,” reflecting an intuitive feeling that more (and better) options existed beyond what was presented. Convergent thinkers had less perspective on what was possible, tended to be more constrained by the
information on hand and ultimately more forgiving to the shoe designers by generally encouraging the design process to proceed.

A correlation analysis was performed to determine if other factors might be related to the decision to continue development on the shoe design, as shown in Table 13. The level of work experience positively correlated ($R=.22$, $p=.052$) with the decision to continue design development, consistent with previous results. Women were less likely to proceed with development with a negative correlation ($R=-.23$, $p=.041$) between a further design development and gender.

<table>
<thead>
<tr>
<th>Further Dev</th>
<th>Gender</th>
<th>Work Exp</th>
<th>Fact avg</th>
<th>Question avg</th>
<th>Openness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>-.23</td>
<td>.22</td>
<td>.25</td>
<td>.22</td>
<td>-.28</td>
</tr>
<tr>
<td>Work Exp</td>
<td>-.15</td>
<td>-.09</td>
<td>.01</td>
<td>.06</td>
<td>.05</td>
</tr>
<tr>
<td>Fact avg</td>
<td>-.06</td>
<td>.49</td>
<td>-.30</td>
<td>-.07</td>
<td></td>
</tr>
<tr>
<td>Question avg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 13 - Further Development Decision Correlation Analysis*

Participants that rated the importance of information higher, either facts ($R=.25$, $p=.038$) or questions ($R=.22$, $p=.045$), were also more likely to vote “yes” on further development. Finally, participants who rated highly on openness (NEO-Op) were less likely to vote “yes” on further development ($R=-.28$, $p=.031$), which is surprising. Review of the group recording shows that group with high levels of openness (divergent groups) sensed more opportunities and upside and were therefore willing to discontinue this design in preference for another, separate design alternative.
Results: Pivot Thinkers

The shoe design discussion experiment was not constructed in a way to isolate the impact of pivot thinkers on group decision-making. Convergent style thinking groups without a pivot thinker moderator shared 12.3 items of information compared to 18.3 items of shared information in convergent groups with a pivot thinker moderator, as shown in Table 14. This difference of -6.0 less total information shared by convergent groups without a pivot thinker leader is not significant, t(6) = -1.332, p<.2.31.

<table>
<thead>
<tr>
<th>Items Shared in Group</th>
<th>n</th>
<th>Fact</th>
<th>Question</th>
<th>Total</th>
<th></th>
<th>Item Importance Rating</th>
<th>n</th>
<th>Fact</th>
<th>Question</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergent wo/PT</td>
<td>4</td>
<td>7.3</td>
<td>5.0</td>
<td>12.3</td>
<td></td>
<td>3.40</td>
<td>24</td>
<td>3.56</td>
<td></td>
<td>-.16</td>
</tr>
<tr>
<td>Convergent w/PT</td>
<td>4</td>
<td>11.0</td>
<td>7.3</td>
<td>18.3</td>
<td></td>
<td>3.70</td>
<td>24</td>
<td>3.62</td>
<td></td>
<td>.08</td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td>-3.7</td>
<td>-2.3</td>
<td>-6.0</td>
<td></td>
<td>-30</td>
<td></td>
<td>-.30</td>
<td></td>
<td>-.06</td>
</tr>
<tr>
<td>Divergent wo/PT</td>
<td>4</td>
<td>10.2</td>
<td>7.8</td>
<td>18.0</td>
<td></td>
<td>3.24</td>
<td>24</td>
<td>3.44</td>
<td></td>
<td>-.20</td>
</tr>
<tr>
<td>Divergent w/PT</td>
<td>4</td>
<td>8.5</td>
<td>7.5</td>
<td>16.0</td>
<td></td>
<td>3.17</td>
<td>24</td>
<td>3.46</td>
<td></td>
<td>-.29</td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td>1.7</td>
<td>.3</td>
<td>2.0</td>
<td></td>
<td>.07</td>
<td></td>
<td>-.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 14 - Impact of Pivot Thinker on Shoe Design Discussion

In the divergent groups, the split between less and more work-experienced teams was balanced. The divergent style teams without a pivot thinker shared 18.0 items while the divergent style teams with the pivot thinker shared 16.0 items, a nonsignificant difference. If anything, the pivot thinker may have encouraged a more robust discussion between facts and questions, highlighting the difference to divergent thinkers. As a result, divergent style thinking groups with the pivot thinker rated the importance of facts (3.17) significantly lower than questions (3.46), a significant difference of -.29, t(22)=-2.068, p<.053.
There is also limited evidence that pivot thinkers, as individual team members, may have had a moderating effect on their groups, as shown in Table 15.

<table>
<thead>
<tr>
<th></th>
<th>Pivot Thinkers</th>
<th>Balance Group (/Person)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Items</td>
</tr>
<tr>
<td>Convergent Groups</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>Divergent Groups</td>
<td>4</td>
<td>2.3</td>
</tr>
<tr>
<td>Less Exp – Convergent</td>
<td>3</td>
<td>3.7</td>
</tr>
<tr>
<td>Less Exp – Divergent</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>More Exp - Convergent</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>More Exp - Divergent</td>
<td>2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 15 - Pivot Thinker and Balance Group Item Sharing

In convergent groups, pivot thinking individuals tended to share more of their individual items (3.3) than the average for the balance of the group (2.5), a nonsignificant difference of 0.8 items. Conversely, in divergent groups pivot thinkers (n=4) shared less of their individual items (2.3) than the average for the balance of the group (2.9), a nonsignificant difference of -0.6 items. This pattern of over sharing of items in convergent groups and under sharing of items in divergent groups continued when the groups were divided by level of work experience.

Discussion

The results of the shoe design discussion experiment provide conditional support for Hypothesis 1:

Hypothesis 1 (H1): Individuals on teams exchange information moderated by cognitive problem solving preference for convergent or
*divergent information and not on the likelihood of successfully solving the problem.*

The conditional support is based on the effect of work experience; experience has a significant impact on the way in which information is assimilated and shared in a group setting.

Convergent thinking style groups tend to share more facts overall and tend to rate the factual information of equal importance to questions, in the context of problem solving. Divergent thinking style groups tend to share more questions overall and value questions over factual information. Divergent thinking groups also share more total information items in the discussion and decision-making process than convergent thinking style groups.

In addition, work experience has an important moderating effect. Although not always statistically significant, subject groups with work experience, either divergent or convergent thinking style groups, tended to share less information, either facts or questions, than groups with less work experience. This would indicate that learned experience interacts with cognitive style in a way that shapes information assimilation, transmission and understanding. This aligns with Cattell's theory of cognition where learned experience forms the basis for "crystallized ability." As Cattell states, crystallize ability guides "skilled judgment habits ... as a result of earlier learned application of some prior, more fundamental general ability to these fields" (Cattell, 1963).

Participants with work experience, and either a convergent or divergent cognitive style preference, tend to rely on prior “learned application” more so
than participants with less work experience and this has a significant and overwhelming affect on information sharing. The practical implications suggest that tools and techniques for exploring both cognitive styles may need to be scaled to the novice and experienced workers within a field. It is possible that some techniques like “listening skills” could apply to both the novice and expert, but higher order evaluation skills probably need to be adjusted to reflect subject skill level.

This research is also supportive of the distinction between dominant function diversity and intrapersonal functional diversity as identified by Bunderson and Sutcliffe (J. S. Bunderson & Sutcliffe, 2002). In this research, no subject had dominant functional diversity, a measure of work experience, because there was little or no experience with the designing shoes. However, work experience may have formed the basis for intrapersonal functional diversity, given the many more experiences and practical learning which could be brought to bear in the conversation by participants with more work experience. In these discussions, participants with more work experience used examples and metaphors to make discussion points and had to rely less on the facts and questions supplied by the research materials. Intrapersonal functional diversity has been identified as a positive effect on information sharing and unit performance for these reasons.

There are several limitations to this research. First, the application of facts and questions in conversation was not universally or consistently applied. In some cases, respondents presented questions as “facts” and in other situations presented facts as “questions.” For example, the question item "Will leather be “in fashion” this year?" was often stated as “Leather is “in fashion” this year, so a leather upper is a good thing.” Similarly, the fact item "The weight of this shoe
is 482 grams/pair” was stated as “These shoes weigh 482g/pair; is that a lot or a little, is that a good thing or a bad thing?” This convolution of facts and questions may cloud the actual behavior of the participants as they interpret the information and pass it into group conversation.

Individual reinterpretation and sharing of a known (fact) as unknown (question) or the unknown (question) stated as known (fact) are the very earliest signs of the development of Cronin and Weigert’s representational gaps in teams. Presenting an open-ended, unknown item (question) as a close-ended known item (fact) leads to misinterpretation and ultimately flawed decisions. This would have been important to track in this research as a way to determine if this relates to cognitive style or is a more universal human characteristic.

The concluding question about future development of the shoe design was confusing to some participants. It was not clear what was meant by "future development" and the commitment it represented, which caused confusion on the decision by some participants. This question could have been written more clearly by more specifically describing the impact on the design team with something like “Would you encourage the design team to continue with this design, including the changes you've talked, or would you encourage the design team to discard this prototype and start all over again?”

Finally, it was important to balance the groups by experience level. Initially, this was considered a secondary design characteristic behind balance for cognitive style preference, gender, inclusion of a pivot thinker and order effect. In hindsight, the two most important sample characteristics for this research design
are cognitive style preference and level of work experience and should be balanced for each experimental condition.
CHAPTER 4 - Team Marketplace: Pivot Thinkers and Group Decisions

Experiment #2: Testing the Differences in Problem Solving Style Preference on Group Decisions

The benefit of a multi functional NPD team is the potential for a broad range of problem-solving styles and perspectives to achieve a solution that exceeds what any individual member may be capable of. The challenge of a multifunctional NPD team is both the blending of individual level problem representations and sharing entire data sets of information that are unique to a specific discipline. For example, a manufacturing representative on a multifunctional team may know that a certain producing plant faces labor problems because of overtime regulations, while other members of the team, oblivious to this situation, may unknowingly recommend solutions that require manufacturing overtime.
Without a sharing of uniquely held information, the group will make either suboptimal or incorrect decisions.

As stated earlier, Cronin and Weigert refer to the diversity of problem-solving styles as differences in “individual level problem representations” which ultimately lead to group level “representation gaps” (Cronin & Weingart, 2007). The unique information that each team member possesses is often referred to as a “hidden profile” and presents an entirely different cognitive problem. In this case, it is less of an issue of problem representation and more an issue of relevance and importance that causes individual information to surface as part of group problem solving.

Stasser and Stewart define a hidden profile as a “pattern of unshared information that exists on the individual level and affects group decision-making” (Stasser & Stewart, 1992). Hidden profiles underpin a process where, at the onset of a group discussion, individual members tend to favor a certain alternative because they only have information that favors this alternative. This individual alternative may be a suboptimal because it does not reflect all information about the alternative. The group can discover the superior option by pooling knowledge held by individual members. The discovery of a hidden profile depends on consideration of unshared information by each individual during the group discussion and the extent to which the group discussion focuses on commonly shared information, unique individual information is often overlooked or discounted by the individual.
A pivot thinker, in a leadership role within the group, may provide a unique catalyst to encourage better dissemination of individually held, unique information. As individual members bring their individual problem representations to group-level problem solving task, they may be encouraged to explore “alternative possibilities” by the relatively unbiased nature of the cognitive problem-solving style of a pivot thinker.

In this context, it might be expected that groups with the pivot-thinking leader would do a better job of uncovering hidden profiles and therefore arriving at a better, more correct group decision. This leads to the hypothesis for a second experiment designed to identify the impact of team leader behavior:

**Hypothesis 2 (H2):** Team leader behavior can offset cognitive representational gaps through a behavior called “pivot thinking” that encourages individuals of different cognitive styles to evaluate and share unique information for the purposes of group decision making.

As evidenced in group behavior, it could be expected that a pivot thinker group leader might speak more frequently (intervals) and longer (talk time) than other group members in an effort to facilitate exposure of hidden profiles. Similarly, a pivot thinker leader might seek to keep the problem space open longer, delaying an ultimate decision until necessary, which has been associated with more successful problem solving (Getzels & Csikszentmihalyi, 1976). Finally, it is possible that a pivot thinker may facilitate a particular type of decision process, for example, completing a rank decision task by first eliminating the least
desirable alternative before selecting the best alternative or selecting the best alternative while allowing the subsequent alternatives to fall in place.

Experiment #2 - Shampoo Prototype Discussion
This hidden profiles experiment is a test of asynchronously distributed information and modeled similar work by Stasser and Hollingshead. In Stasser’s original work four-subject groups were given information about three political candidates (Stasser & Titus, 1985). In total, 16 information items were shared about each candidate, for a total of 54 information items. The information items for Candidate A were more positive than for either Candidate B or Candidate C. The experimental design created hidden profiles, in that information favoring each candidate was equally shared, but unique information favoring Candidate A was given to only one subject. A pre-and-post individual rating of each candidate showed that preference for Candidate A was less than Candidate B or Candidate C and actually declined after group discussion, indicating sub optimal decision-making and inefficient information sharing.

In Stasser’s follow-up work, group size and information priming were introduced as variables (Stasser & Stewart, 1992). This experiment modeled a homicide investigation that included three suspects. Participants were asked to read a 27-page booklet containing 24 clues; 6 clues each (18 total) incriminated a particular subject, 3 clues exonerated one subject and 3 clues exonerated a second subject. To create a hidden profile, the six clues exonerating participants were not shared equally. In addition, this research was conducted under two conditions: 3 and 6 subject groups and information priming which led some groups to believe they had sufficient information to solve the crime and other groups to believe they had insufficient information to solve a crime. A pre-and-
post individual rating of each suspect was collected as well as a group decision following the discussion. Stasser found that when critical clues were unshared, 67% of the participants who believed they had sufficient information correctly solve the problem, while only 35% of the participants who believed they had insufficient information to solve the problem. Stasser also found that group sharing of critical information was substantially lower in 6-subject groups over 3-subject groups.

Hollingshead explored the value of rank ordering within group decision-making, using a hidden profiles technique, including the variable of either a face-to-face subject group or a distributed, computer connected group (Hollingshead, 1996). The decision task involved an investment decision in stock for three companies (Alpha, Beta and Gamma). Participants were given 8 information items about each company: 6 information items were common to all participants and 2 information items were unique about each company, for total of 24 information items within the group. A separate rating of just the commonly distributing information indicated a preference for Companies Alpha and Beta, while a separate rating of all 24 information items favored Company Gamma. Therefore, the ability of the group to make a “correct” decision depended on the sharing of unique information. Hollingshead found that groups required to make a rank order decision (1-2-3) between the alternatives did a better job of disseminating unique information. Also, face-to-face groups did a better job overall of sharing information than computer mediated groups where there was “general information suppression and no effect of group decision procedure.”

In this experiment, the Shampoo Prototype Discussion, subject groups were separated into either all convergent problem-solving thinkers or all divergent
problem-solving thinkers, either with or without a pivot thinker as a group leader, resulting in a 2X2 factorial experimental design. In this case, it was expected that the pivot thinker would play a role in the experiment outcome.

The subject experience is that of a case study where participants are expected to play the role of a member of the “product development team” for a well-known personal care products company and the group decision was to “to launch one of three new shampoo hair care prototypes.” The shampoo product prototypes were developed by geographically dispersed research laboratories in Toronto, Canada, Trebbin, Germany and Tianjin, China - and the products became known as “Toronto,” "Trebbin" and "Tianjin." Shampoo products were chosen as a focus area because subject experience with the product is universal yet evaluation experience on a product feature set is relatively limited.

Subject groups were composed of 6 participants, with one participant selected as a moderator who would record the group decision. In subject groups that contained a pivot thinker, the pivot thinker was selected as group moderator through a seemingly random process that did not indicate that they had any particular or special attribute.

Each participant received near identical background information, which included 21 information items; 7 types of information for each of the 3 products. For 6 of the information types, the information was common among all participants; one information type was unique to each participant. The subject role-play information is shown in Appendix E.
The participants were also given a simulated 3D CAD drawing of the Prototypes (Figure 15) to encourage a more animated conversation and add to the realism of the experience. The specific personal care products company was familiar to the participants and the product prototypes are merely representations and do not describe known product in the marketplace.

Figure 15 - Shampoo Prototypes CAD Representation. These are product views of unbranded stock bottles that contain colored liquid. They are photographic quality to appear as real prototype options and add realism to the discussion. A footnote indicates that all products contain the same amount of product to negate this as a variable in the group discussion.

**Information Item Validation**

The information item set was independently validated to ensure the individual items led to a specific decision outcome. As shown in Appendix F, common information item sets (C1-C6) were shown to an independent group of participants (n=63), who were asked to rate the products on how successful they
would be in the marketplace. Scoring was recorded using a five-point Likert-like scale (1-very successful, 5-very unsuccessful). Participants were asked one close-ended question to choose the one “most successful product” in the marketplace (Toronto, Trebbin or Tianjin).

Results show that with only the common information item set, respondents rated the “product success” of Toronto (1.46), somewhat favored over Tianjin (1.71) (t(62)=-1.674, p<.099). Both Toronto (t(62)=-8.253, p<.000) and Tianjin (t(62)=-4.009, p<.000) were rated statistically better than Trebbin (2.38). In terms of the “most successful” choice, results were about equally split between Toronto (44%) and Tianjin (51%) and statistically higher than Trebbin (5%), as shown in Table 16.

<table>
<thead>
<tr>
<th>Item Set</th>
<th>n</th>
<th>“Product Success” Rating</th>
<th>“Most Successful”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Toronto</td>
<td>Trebbin</td>
</tr>
<tr>
<td>Common Only</td>
<td>63</td>
<td>1.46</td>
<td>2.38</td>
</tr>
<tr>
<td>Common and Unique</td>
<td>54</td>
<td>2.70</td>
<td>1.31</td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td>1.24</td>
<td>-1.07</td>
</tr>
</tbody>
</table>

Table 16 - Shampoo Prototype Information Item Validation

A different, second group of respondents (n=54) were shown the complete item set, with both common items (C1-C6) and unique items (U1-U6). The unique information set contains information items that have a negative influence on Toronto and Tianjin for a positive influence on Trebbin.

Respondents rated “product success” for the Toronto (2.70) and Tianjin (2.72) statistically equal. Trebbin’s success rating (1.31), was substantially better than
Toronto \((t(53)=-6.788, p<.000)\) or Tianjin \((t(53)=-6.816, p<.000)\) and significantly improved \((\text{mean } -1.07, t(53)=-9.544, p<.000)\) versus the common item only test. “Most successful” product ratings flipped, with Trebbin favored by 85% of respondents while Toronto and Tianjin were favored by 6% and 9%, respectively.

It is anticipated that early conversation within the group would center on common information as this represents 86% (6 of 7 information types) known by any subject. The extent to which unique information entered the conversation would be a factor of the group decision-making process and the influence of the pivot thinking leader.

**Results: Convergent and Divergent Problem Solving Groups**

Overall, six of eight convergent teams arrived at the correct product prototype answer (Trebbin), while seven of eight divergent teams arrived at the correct answer, as shown Table 17. In total, 13 teams arrived at the correct solution, while only three teams arrived at an incorrect solution. This relatively high level of correct solutions was not anticipated.

<table>
<thead>
<tr>
<th>Team Answer</th>
<th>Items Shared/Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Convergent</td>
<td>8</td>
</tr>
<tr>
<td>Divergent</td>
<td>8</td>
</tr>
<tr>
<td>Diff</td>
<td>-1</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
</tr>
</tbody>
</table>

*Table 17 - Team Answer and Information Sharing by Group*
Analysis of the dynamics of information sharing in each group begins to reveal some important differences in problem solving styles. For example, convergent groups, on average, shared 5.1 common information items and 4.7 unique information items for a total of 9.8 information items. In contrast, the divergent groups shared 5.6 common information items and 4.9 unique information items, for total of 10.5 information items. The difference of -0.7 information items shared by convergent versus divergent problem-solving groups is a significant difference when evaluated on an individual level (t(94)=−2.037, p<.044) indicating that convergent individuals tended to share less of the available information with their groups.

However, this may be a difference without distinction because the increased sharing of divergent groups was among common information items, not unique information items, which would not necessarily lead to a better decision. Also, unique information items were part of each individual’s hidden profile and they were shared at equal rates between groups, a further indication that there was no difference between convergent and divergent information sharing.

Analysis of the decision timing within each group type revealed some surprising and significant differences. Within each group discussion, several key events were time stamped with the elapsed time in the group discussion. The first time a group member mentioned that a final decision was required (First Mention) as part of the task, this was considered the beginning of the group decision-making process. Typically the discussion before this point included a discussion of the roles, discussion of information items and sharing of points of view, but with no mention of the need to make a specific group decision.
Elapsed time was noted when a group made their first choice (First Choice), which meant a specific the prototype alternative had group agreement. This choice was not always the group’s #1 Ranked Choice (#1 Choice), as some groups made their First Choice a discarding of the #3 Ranked Choice (#3 Choice). When the group had completed their decision making process and all members were satisfied with the final ranking, the elapsed time was noted. For perspective, each group had 20 minutes of discussion (1,200 seconds) that was monitored with a countdown timer and audible signals.

Groups with a divergent problem-solving style made their first mention of the need for decision with a mean of 556 seconds elapsed in group discussion compared to a mean of 674 seconds elapsed for convergent problem-solving style groups, as shown in Table 18. This earlier start by divergent groups into the decision-making process (+118 seconds earlier, \( t(94)=2.314, p<.023 \)) is significant and surprising. It was believed that divergent problem-solving style groups would delay decision-making, but this shows that they initiate the process earlier.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>First Mention</th>
<th>First Choice</th>
<th>#1 Choice</th>
<th>Finish Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Seconds</td>
<td>Diff</td>
<td>Seconds</td>
<td>Diff</td>
</tr>
<tr>
<td>Convergent</td>
<td>8</td>
<td>674</td>
<td>900</td>
<td>226</td>
<td>950</td>
</tr>
<tr>
<td>Divergent</td>
<td>8</td>
<td>556</td>
<td>799</td>
<td>243</td>
<td>1004</td>
</tr>
<tr>
<td>Diff</td>
<td></td>
<td><strong>-118</strong></td>
<td>-101</td>
<td>17</td>
<td>54</td>
</tr>
</tbody>
</table>

*Bold p<.05*

**Table 18 - Decision Timing by Group**

The time elapsed between the first mention of making a choice to the actual first choice of the group was a mean of 226 seconds for convergent groups and 243
seconds for divergent groups, a nonsignificant difference. This indicates that while divergent groups started the choice making process earlier, both convergent and divergent groups took about the same elapsed time to arrive at their first group choice.

However, the mean lapsed time from the first mention of a decision to the actual #1 Choice of the group differed significantly by convergent and divergent groups. In convergent groups, a mean of 276 seconds had elapsed between first mention and first choice compared to 448 seconds for divergent groups. This difference of 172 seconds is significant \( t(94) = -3.505, p < .001 \) and indicates that divergent groups took a longer period of time to arrive at their number one choice. Decision process analysis (which follows) also shows that divergent groups were more likely to decide their last choice first, while divergent groups almost exclusively chose their first choice first.

It should also be noted that both convergent and divergent groups used about the same amount of time for the entire discussion (1,070 seconds versus 1,113 seconds). The divergent groups spent a significantly longer time (+161 seconds, \( t(94) = -2.962, p < .004 \)) on the decision-making process, in essence keeping the problem space open longer. This behavior is consistent with the literature on emergent problem-solving styles (Getzels & Csikszentmihalyi, 1976).

The manner by which groups set about solving this problem was also revealing. The first pattern involved making the #1 Choice for prototype expansion first and then the #2 and #3 Choices (termed 1-2-3 or 1-3-2). The second approach made
the least desirable or #3 Choice first and then either the #1 or #3 choice (termed 3-1-2 or 3-2-1). Results from these choice patterns are shown in Table 19.

In this experiment, 11 of the total 16 teams used a #1 Choice first pattern and only 5 teams used a #3 Choice first pattern. Of note, 7 of the 8 convergent groups used a #1 Choice first pattern, while only 4 of the 8 divergent groups used #3 Choice first pattern, compared to only 1 of the convergent groups. This indicates that divergent groups were more likely to make the #3 choice first, keeping the problem space open longer and consistent with the longer amount of time divergent groups spent in the decision-making process.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>n</th>
<th>#1 Choice First Patterns</th>
<th>#3 Choice First Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1-2-3</td>
<td>1-3-2</td>
</tr>
<tr>
<td>Convergent</td>
<td>8</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Divergent</td>
<td>8</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Correct</td>
<td>13</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Less Experienced</td>
<td>9</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>More Experienced</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>With Pivot Thinker</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Without Pivot Thinker</td>
<td>8</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 19 - Group Decision Process by Group Type

The decision making choice pattern did not seem to have an impact on making the correct choice, as of the 13 teams that did make the correct choice, eight teams used a #1 Choice first pattern and 5 teams used a #3 Choice first pattern. However, of the three teams that made an incorrect choice, all three used a #1
Choice first pattern indicating that early selection of the "optimal choice" has a higher likelihood of leading to an incorrect choice.

Work experience also seems to have a significant impact on decision choice pattern. In the 9 teams of less work experienced participants, eight teams used a #1 Choice first pattern, while in the 7 teams of more work experienced participants more than half (4 teams) used a #3 Choice first pattern. This is an indication that work experience and, perhaps, the confidence from work experience may encourage a team to lengthen the time they spend in problem solution by discounting obviously poor choices before they make their final selection.

Finally, there was little indication that the existence of a pivot thinker within a group changed the decision choice pattern. For example, in the 8 groups with a pivot-thinker leader, 6 groups used a #1 Choice first pattern for making a decision, while in the 8 groups without a pivot thinker, 5 groups used the #1 Choice first pattern. This would seem to indicate that the decision choice process within the group was more reflective of the problem-solving styles of the group members than the existence of a pivot-thinking leader.

The correct group decision largely depends on the appropriate dissemination of unique information items to the group and this displayed a distinctive pattern by convergent and divergent problem-solving groups. As shown earlier (Table 17), groups shared 4.8 of the 6 unique information items and there was little difference by convergent and divergent problem-solving groups. However, when the items are measured by the time in which they entered into the conversation,
an interesting pattern emerges. It is assumed that the earlier a unique information item enters into the conversation, the more important it is to group discussion and the decision outcome.

Overall, there was no difference in timing between convergent and divergent groups entered unique information items into the conversation. On average, convergent teams entered information items into the conversation with 382 elapsed seconds versus 279 elapsed seconds by divergent group, as shown in Table 20. However, differences did emerge when specific information items were examined. For example, convergent problem-solving groups entered the unique information items U3, U4 and U6 into the conversation on average 89 seconds before divergent problem-solving groups entered them into the conversation.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>n</th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
<th>U5</th>
<th>U6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Groups</td>
<td>16</td>
<td>12</td>
<td>15</td>
<td>14</td>
<td>11</td>
<td>12</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Convergent - Groups</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Convergent - Time (s)</td>
<td>447</td>
<td>355</td>
<td>338</td>
<td>526</td>
<td>484</td>
<td>207</td>
<td>382</td>
<td></td>
</tr>
<tr>
<td>Divergent - Groups</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Divergent - Time (s)</td>
<td>382</td>
<td>253</td>
<td>395</td>
<td>550</td>
<td>353</td>
<td>380</td>
<td>379</td>
<td></td>
</tr>
<tr>
<td>Overall Difference (s)</td>
<td>+65</td>
<td>+102</td>
<td>-57</td>
<td>-24</td>
<td>+131</td>
<td>-173</td>
<td>+5</td>
<td></td>
</tr>
<tr>
<td>Convergent Earlier (s)</td>
<td>8</td>
<td></td>
<td>-57</td>
<td>-24</td>
<td></td>
<td>-173</td>
<td>-89</td>
<td></td>
</tr>
<tr>
<td>Divergent Earlier (s)</td>
<td>8</td>
<td>+65</td>
<td>+102</td>
<td></td>
<td>+131</td>
<td></td>
<td>+100</td>
<td></td>
</tr>
</tbody>
</table>

Table 20 - Unique Information Items Shared by Group

These information items are special in that they contain uniquely factual and numerical information that discounts the Toronto and Tianjin prototypes, while
supporting the Trebbin prototype. (see Appendix F for the information items) The unique information item U3 provides information on the cost of ingredients and uses a numerical percentage to express the necessary changes in retail pricing. The unique information item U4 has to do with lead-time for ingredients, which again is expressed in factual terms. Finally, the unique information item U6 explains the hair color stripping characteristics expressed as number. This seems to indicate that convergent groups were more interested in the hard, concrete facts about the differences in the prototypes and entered these into conversation earlier.

Divergent problem solving groups entered the unique information items U1, U2 and U5 into the conversation on average 100 seconds before convergent problem solving groups. The unique information item U1 is a conceptually strategic consideration indicating that not all prototypes are compatible with a shampoo-conditioner combination. The unique information item U2 discloses the need for a FDA mandated label on one product prototype (Toronto). Finally, unique information item U5 discussed the formula performance on different hair types, which is again an open-ended consideration for choosing the top-performing prototype.

In this experiment, both factual based and conceptual based unique information items lead to the correct decision, which may be one reason why there was no differentiation between convergent and divergent problem solving style groups. However, the pattern of convergent groups favoring facts and divergent groups favoring concepts or questions, which was revealed in the first experiment, continued through this experiment.
Results: Pivot Thinkers

It is hypothesized that pivot thinkers would have a moderating influence on the way in which groups shared information. The study design involved 8 convergent problem-solving groups, 4 groups had a pivot thinker leader, and 4 groups had a randomly selected leader with a convergent problem-solving style. Similarly, within the 8 divergent problem-solving groups, 4 groups had a pivot thinking leader and 4 groups had a randomly selected leader with a divergent problem solving style.

A way to measure the impact of a pivot thinking group leader is to track the amount of unique information items shared within the groups. For example, within the problem solving groups without a pivot thinking leader 18 unique information items were shared out of a possible 24 items (4 teams x 6 items per team). Within the 4 divergent problem-solving groups without a pivot-thinking leader, only 16 unique information items were shared, as shown in Figure 14.

![Figure 16 – Unique Information Item Sharing With and Without Pivot Thinkers. A total possible 6 Unique Information Items could be shared within any group and there are four groups in each condition.](image-url)
However, within groups that had pivot thinking leadership in the number of unique information items shared increased for both convergent and divergent problem solving groups. Convergent problem-solving groups with the pivot thinker shared 20 unique information items, compared to 18 without a pivot-thinking leader. Divergent problem solving groups with a pivot thinking leader shared all 24 information items, compared to only 16 without ever thinking leader. While the base sizes of this analysis make it difficult to determine a statistical significance, the increase of unique information items shared by groups with a pivot thinking leader is consistent with the hypothesis that a balanced problem solving leader will make a difference in the way information is shared.

General Liner Modeling (GLM) also illustrates the affect of a pivot thinking leader on the likelihood of a subject sharing their unique information within a group. For example, each subject had one Unique Information item critical to the conversation and ultimate group decision as shown in Table 21.

If the likelihood of the subject sharing their Unique Information item is the dependent variable, while convergent/divergent thinking and the presence of a Pivot Thinking Leader are the independent variables, the presence of a Pivot Thinking leader becomes a defining factor in prediction of item sharing. The corrected GLM shows that the presence of a Pivot Thinking leader has a significant affect on a participants likelihood of sharing their Unique Information item, \( F(3,96) = 3.397, p=.021 \).
Another measure of the impact of a pivot-thinking moderator on groups was the talk time within the group, as shown in Table 22. In convergent groups a pivot thinking moderator seemed to speak less; the pivot thinking moderator spoke 192 seconds while a randomly selected moderator spoke for 249 seconds, a nonsignificant difference of 57 less seconds, \( t(7) = -1.705, p < .240 \). In divergent groups the pivot thinking moderator seemed to speak more; the pivot thinking moderator spoke 253 seconds, a nonsignificant +38 seconds more, \( t(7) = .369, p < .570 \) more than a randomly selected divergent thinking moderator.

![Graph showing likelihood of sharing unique items with and without a pivot thinker.](image)

### Table 21 - GLM Test Between-Participants Effects comparing the likelihood of a subject sharing Unique Information by cognitive type (convergent or divergent) within groups without and with a Pivot Thinking Leader.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>1.458</td>
<td>3</td>
<td>.486</td>
<td>3.397</td>
<td>.021</td>
</tr>
<tr>
<td>Intercept</td>
<td>63.375</td>
<td>1</td>
<td>63.375</td>
<td>442.823</td>
<td>.000</td>
</tr>
<tr>
<td>Type (C or D)</td>
<td>.042</td>
<td>1</td>
<td>.042</td>
<td>.291</td>
<td>.591</td>
</tr>
<tr>
<td>Group (woPT, wPT)</td>
<td>1.042</td>
<td>1</td>
<td>1.042</td>
<td>7.278</td>
<td>.008</td>
</tr>
<tr>
<td>Type*Group</td>
<td>375</td>
<td>1</td>
<td>.375</td>
<td>2.620</td>
<td>.109</td>
</tr>
<tr>
<td>Error</td>
<td>13.167</td>
<td>92</td>
<td>.143</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>78.000</td>
<td>96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>14.625</td>
<td>95</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 21 - GLM Test Between-Participants Effects comparing the likelihood of a subject sharing Unique Information by cognitive type (convergent or divergent) within groups without and with a Pivot Thinking Leader.
In a separate review of the group recording, it appears that in divergent groups, pivot thinking moderators spent more time keeping the group on task as they tended to wander, while in convergent groups less effort was required by the pivot thinking moderator to keep the group on task.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>n</th>
<th>Talk(s)</th>
<th>Inter</th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
<th>U5</th>
<th>U6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Groups</td>
<td>16</td>
<td>227</td>
<td>24</td>
<td>12</td>
<td>15</td>
<td>14</td>
<td>11</td>
<td>12</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>w/o Pivot Thinker</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convergent</td>
<td>4</td>
<td>249</td>
<td>24</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Divergent</td>
<td>4</td>
<td>215</td>
<td>24</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Mean Time (s)</td>
<td>8</td>
<td>232</td>
<td>24</td>
<td>413</td>
<td>366</td>
<td>372</td>
<td>544</td>
<td>473</td>
<td>311</td>
<td>(413)</td>
</tr>
<tr>
<td>w Pivot Thinker</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convergent</td>
<td>4</td>
<td>192</td>
<td>25</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Divergent</td>
<td>4</td>
<td>253</td>
<td>24</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Mean Time (s)</td>
<td>8</td>
<td>223</td>
<td>24</td>
<td>417</td>
<td>243</td>
<td>363</td>
<td>537</td>
<td>380</td>
<td>276</td>
<td>(369)</td>
</tr>
</tbody>
</table>

Table 22 - Information Item Mention Timing by Pivot Thinking Moderators

In groups without a pivot thinking leader, either convergent or divergent problem-solving groups, the unique information items were mentioned on average at 413 seconds into the conversation. This compares to 369 seconds for the average mention time for unique information items among groups led by a pivot thinker. While this 44 second earlier mention of unique information items by groups led by a pivot thinker is not statistically significant, it is again further indication that pivot thinkers, in either convergent or divergent groups, help to extract important decision-making information earlier in the group discussion process.

**Case Study Theory: Pivot Thinker Inflection Points**

This experiment attempted to show the impact of balanced, pivot thinkers on the flow of group information and the group decision-making process. However,
given the limited number of incorrect group decisions, there is less than anticipated quantitative data to highlight these differences. As a means of extracting more learning and insight from this experiment, the data was interpreted through case study grounded theory process.

Glaser and Strauss detailed a comparative method for developing theory in qualitative environments, termed grounded theory (Glaser & Strauss, 1967). The technique involves capturing subject and environmental input, coding the data, collecting the codes into concepts and later into categories, which yield a theory of behavior. In the case of this experiment, much of this work was done through the coding of data through a conceptual framework, which built into a categorical view of behavior and the resulting theory.

This data can also be considered a series of case studies, if each subject group is considered a separate case as the unit of analysis (Yin, 2009). Case study theory development places emphasis on discovery of the “how” and “why” of subject behavior. The unit of analysis is an individual subject group, and these subject groups can be analyzed as either a single case or multiple cases. The summary of case descriptions using pattern matching can yield a theoretical proposition of how participants behave in this context.

Perhaps most helpful, is the technique described by Eisenhardt that involves with-in case and cross-case analysis (Eisenhardt, 1989). In the context of this experiment, all 16 groups were originally reviewed in the order the data was collected (essentially random) and coded on various behaviors like information items discussed, decision patterns and leadership behaviors. A second with-in
case review was completed to identify the similarities within convergent problem-solving style groups and divergent problem-solving style groups. In this analysis, three randomly selected convergent groups and three randomly selected divergent groups were separately reviewed using the frame of similarities within the group set, with paragraphs of notes collected.

This data was also examined for cross-case patterns. The first cross-case pattern examined was the three groups who incorrectly solved the problem versus three randomly selected groups (two convergent, one divergent) who correctly solved the problem, in an effort to understand the differences in decision-making processes that led to different final decisions. The second cross case pattern was groups with a pivot thinker moderator versus groups without a pivot thinker moderator. In this analysis, 8 groups were reviewed, 4 groups with pivot thinker moderators (two convergent and two divergent) and four groups with randomly selected moderators (two convergent and two divergent).

The resulting written notes, in combination with the data analysis presented earlier, form the basis for the development of a quantitative grounded theory (Glaser, 2008). Glaser considers qualitative grounded theory to be abductive in nature, combining the inductive aspect of qualitative research with the deductive techniques of quantitative research. The resulting group decision-making process is mapped in Figure 17.
Most groups, either convergent or divergent, began their session with rule setting. This involved largely two tasks - an understanding of the desired group outcome (a rank order of choices) and a general, non-specific discussion of what information each individual subject may possess. In fact, one group (convergent) spent over 5 minutes discussing how they would value input from each person and then combine that into a group decision before they began discussing any of the individual information. The rule setting phase of the group process tended to last a little longer amongst convergent groups; divergent groups tended to move more directly to information sharing.

The next phase was information sharing. In some groups, mostly the convergent groups, the group moderator led this activity in a methodical manner soliciting information from each participant. While this did a good job of uncovering hidden profiles, it was rarely completed before conversation wandered into new
areas. This proved to be an inflection point for the moderators. Pivot thinker moderators tended to let conversation flow, but returned to the individual participants for a continuation of information sharing. Randomly selected moderators either showed no interest in guiding the group (usually divergent groups) or had a mechanistic manner of exposing information (usually convergent groups). Finding the appropriate balance between free flowing conversation and continued exposure of hidden profiles seem to be a trait found in pivot thinking moderators.

At some point during information sharing, one subject would propose a #1 Choice. Typically this choice was Toronto, which is the first choice on the left side of the participants’ information sheets and with the preponderance of common information it seems like a good choice. After one individual proposes a choice the groups tended to differ in process. If there was general group agreement that this was a good choice, reinforced by review of the common information supporting the choice, group discussion moved to the #2 and #3 Choices. These types of groups made the incorrect choice. Of the three groups that made incorrect choices, two groups had a randomly selected moderator, and one group had a pivot thinking moderator (convergent group). All three groups who made the incorrect choice selected the Toronto prototype.

Most groups took a different path after one individual proposed a choice. Almost immediately, negative information from the hidden profiles about the proposed choice would surface in the group for discussion. Once a choice was proposed, all members of the group, either divergent or convergent, would search for the negatives associated with that choice. This is the second inflection point for pivot thinking moderators. In the search for negatives, participants could either
search by product prototype (vertically, on the subject information sheet) or by information category (horizontally). If the pivot thinker moderator continued the conversation on a product-by-product prototype review (vertically) then the search for negatives turned into a search for the best choice - or the #1 Choice with the less negatives.

The pivot thinking moderator could also guide the conversation by information category (horizontally) and this resulted in a comparison of negatives and a search for the option with the most negatives, resulting in the discounting of an option or #3 choice. Typically, the hidden profile information that was most negatively motivating was the "FDA warning label" (U2 - Toronto) and "color stripping" (U6 - Toronto and Tianjin). After one product prototype was discounted as the #3 Choice (usually Tianjin), the conversation turned to the choices with the most positives, with less emphasis on product negatives. This process took longer which is reflected in the quantitative analysis where divergent groups (decision pattern 3-1-2) spent more time in the decision-making process than convergent groups.

This analysis points to three characteristics of pivot thinkers that can positively impact the group decision-making process. The first characteristic is successfully balancing free-flowing conversation with the diligent collection of hidden profile information from all group members. The second characteristic relates to keeping the decision space open longer. The groups that incorrectly selected a product choice did so without a full understanding of the available data. The third characteristic of a pivot thinker that can positively impact group decision-making relates to identifying the “easy choices” and getting the group to commit. In the case of groups that identified important negatives, they viewed these
negatives as being significant, so the #1 Choice was the “easy choice.” Of course, this seems like an easy choice because all of the important information from the hidden profiles had been revealed; however, if that information had not been revealed then it is possible that the “easy choice” was also the incorrect choice. An alternative was the pivot thinking moderators who approached the choice process more cautiously by focusing the group on the least desirable choice, then settling on the most desirable choice. This two-step process of choice making affords more opportunity for hidden profile information to emerge.

Results: Group Familiarity and Satisfaction
As a post-experiment measure, data on group familiarity and group satisfaction was collected. Familiarity was measured in two ways. The first was a question asking participants how familiar they were with the other people in the group (1-not at all, 5 completely familiar) and the second was the Aron Scale of Closeness (see Appendix A). Satisfaction was measured with one question, “How satisfied are you working with this group?” (1 – “Completely satisfied,” 5 – “Not at all satisfied”).

Overall, group familiarity was above average with a mean score of 3.50 (between 3- "Somewhat familiar" and 4 - "Quite familiar"). This is not surprising as most groups were recruited from larger natural groups. For example, within the work experienced participants, project teams were often recruited to participate. Similarly, student groups were recruited from larger classes of similar students. One-Way ANOVA analysis showed no statistical differences in group familiarity between convergent and divergent groups, convergent and divergent and pivot thinking individuals, or any differences in familiarity levels between
more work experience and less work experience. Therefore, while the familiarity score was above average for all groups, it was consistent among all subject groups.

Group familiarity as measured by Aron Scale of Closeness had a mean score of 4.6 (an above average score, between the fourth and fifth level of closeness) with no statistical differences between key group measures. Surprisingly, there was also no statistically significant correlation between the Aron Scale of Closeness, group familiarity and group satisfaction.

Group satisfaction had the same results with one notable exception. Overall, the mean group satisfaction score was 1.74 (between 1 – “Completely satisfied” and 2 – “Quite satisfied”). Again, ANOVA analysis revealed no statistical differences in group satisfaction between convergent and divergent groups, convergent and divergent and pivot thinking individuals, or any differences in familiarity levels between more work experience and less work experience.

The one notable exception was between correct solution and incorrect solution decision groups, where groups that made a correct group decision scored significantly higher on group satisfaction than groups that made an incorrect group decision. (Recall, the groups have no idea if they have made a correct or incorrect decision at the conclusion of the research.) The three groups (n=18) that made an incorrect group decision had a mean group satisfaction score of 2.11, while the 13 groups (n=78) that made a correct group decision had a mean group satisfaction score of 1.65, a difference of .46, which is statistically significant (F(1,95) 6.618, p=.012).
Discussion
The results of the shampoo prototype discussion experiment provide conditional support for Hypothesis 2:

**Hypothesis 2 (H2):** Team leader behavior can offset cognitive representational gaps through a behavior called “pivot thinking” that encourages individuals of different cognitive styles to evaluate and share unique information for the purposes of group decision making.

It appears that differences in problem-solving styles can lead to differences in group decision-making processes and a balanced, pivot thinking leader can moderate this group decision-making process. This moderation is what Baron calls “the causal relation between two variables changes as a function of the moderator variable” (R. M. Baron & Kenny, 1986, p. 1174) and defines both the type and amount of information shared within a group. In this experiment, convergent problem-solving style groups shared less information than divergent problem-solving style groups. There was also a difference in how decisions are made, with divergent groups starting the process earlier and continuing it longer than convergent problem-solving style groups.

Convergent groups tended to decide in rank order, with #1 Choice first, while divergent problem solving style groups solved with both #1 Choice first and #3 Choice first. In terms of the hidden profile unique information items, convergent groups tended to share the factual information earlier than divergent groups and divergent groups tended to share the conceptual information earlier than
converging groups. This indicates that groups comprised of unique problem-solving styles can acquire, evaluate and decide upon information in very different ways.

The impact of the pivot thinker on group decision-making processes can be important to the group outcome. There is evidence that groups with a pivot thinking moderator shared more of their hidden profile unique information. These groups also shared this unique information, in both convergent and divergent groups, earlier in the discussion than groups without a pivot thinking moderator. Case study analysis indicates that a pivot thinking moderator can shape the conversation and ultimately the outcome of a group decision. Pivot thinking moderators tended to balance the free flow of discussion with a thoroughness of uncovering hidden profile information items. Pivot thinking moderators also tend to leave the problem open for a longer period of time within the groups for discussion, particularly in divergent groups. Finally, pivot thinking leaders help the group make the “easy choice,” which in the case of divergent problem-solving style groups meant discounting the #3 Choice before making the #1 Choice, which can lead to a better outcome.

There are several limitations to this experiment. First, and most notably, it was not robust enough to uncover all the potential pitfalls of divergent and convergent thinking because the information task was not complex. For example, this experiment placed 36 information items in asynchronous distribution, of which 18 information items are required to make the correct decision. Based on the work of Stasser and the work of Hollingshead, these experiment should have at least 54 asynchronously distributed information items with about one third of the items required to make the correct decision. As a
result of this lack of complexity, more groups than anticipated correctly solved the group decision process that limited the ability of this factor to determine effectiveness by problem solving style type or pivot thinker impact.

This experiment would also have been helped by doing a better job of isolating the distinct impact of the pivot thinker moderator on the group decision-making process. For example, this experiment could be conducted in a way that gives the moderator (pivot thinker or randomly selected) no information about the product prototypes, while distributing pertinent information amongst the team. The moderator would still be charged with guiding the discussion and recording the decision, and this would put pressure on the moderator to either accept input from like-minded teammates (in the case of a randomly assigned moderator) or balance input in the case of a pivot thinking moderator. This research design would do a much better job of highlighting the specific impact of the pivot thinking moderator without changing the underlying structure of the subject alignment or nature of the case study discussion.

Finally, this analytical approach does little to explain how a pivot thinking moderator affects the group. This would require a more specific language analysis to accurately capture the nature and intent of the actions of the pivot thinking moderator. As a result, the best this can do is identify that a difference exists without a real understanding of what it is about a pivot thinker that makes this difference meaningful.
CHAPTER 5 - Pivot Thinking and the Art of Good Questions
Contributions, Applications, Limitations and Asking Good Questions

This dissertation has explored the impact of cognitive problem solving styles and illustrated where group representational gaps can occur in New Product Development teams. The primary goal of this work is to identify the existence and implications of these cognitive problem solving style patterns that lead to the development of group interaction techniques that maximize the contribution of all group members, regardless of their neurological type. The secondary goal is to determine if a group leader, with a balanced cognitive problem solving pattern between convergent and divergent thinking (also known as a pivot thinker) can make a positive difference in the way groups interact and share information.
This research is premised on the assumption that individuals, particularly work-experienced individuals, have established patterns of cognitive problem solving; but this is only a starting point. Individuals may be neurologically patterned differently in ways that may not be obvious to themselves or others. The hope is that better group decisions can be made through understanding of these cognitive problem solving patterns and the use of techniques that balances group information exchange and ultimately close representational gaps leading to better decision-making.

**Contribution to Group Theory**

The key contribution of this research is the identification of underlying neurologically based patterns that can fundamentally change the way information is valued and shared within a group context. This contributes to the theory of groups and teams research because it begins to explore an important “difference that makes a difference” in groups – cognitive diversity and the impact of cognitive diversity on design team interaction and decision making.

There exist fundamentally different views of closed end information, like facts, versus open-end information like questions. These different views can be traced to a fundamental cognitive pattern, that is reinforced though life's experiences and is often coalesced by functional-type within a large corporation. Finance managers may highly value facts and discount the value of questions, while sales managers may appreciate the idea generation potential of questions and may bend facts to their point of view.
However, these cognitively influenced views are plastic or malleable, affected by life experience. In this research, participants with work experience and either a convergent or divergent style preference, tended to rely on prior learned application more so than less work experience participants. This would suggest that not only can the view of and value of certain types of information change over time and experience, but it can also be a learned response distinguishing between the novice and expert.

Group decision-making processes may also be predictable by a neurological pattern. Convergent problem-solving style thinkers will tend to seek the best solution first, which assumes there is a best solution. Divergent problem-solving style thinkers may tend to discount the worst choice first, leaving open the problem space longer while seeking an optimal solution. This trade-off between efficiency and time largely turns on the elimination of representational gaps. The bigger the representational gaps that exist within a group, either perceived or unperceived, the greater likelihood that seeking the best solution first will lead to a suboptimal decision.

Finally, there is the possibility that a group leader (a pivot thinker) who values both convergent and divergent problem-solving styles may be able to "pivot" a group process to a better, “whole brain” solution. General population HBDI data indicates that about 15% of the population has a natural balance between convergent and divergent problem-solving styles, and might be expanded through training and group management techniques. This is both the challenge and promise of design thinking education.
Application to Design Thinking

There is no common, agreed way to teach design thinking. In fact, much of design thinking has resisted classic, statistics based research choosing instead to rely on practice and application. Perhaps, research such as this might begin to influence the teaching of design thinking in ways such as the following:

Benefit Finding. Much design thinking work begins with the process of consumer, customer or user "need finding," which is often considered a divergent activity. However, the very best need finding work is convergent in the search for a simple (or simpler) answer to an existing and persistent problem. Convergent solutions are often overlooked for more expansive divergent-inspired solutions. A more complete understanding of convergent and divergent thinking techniques and a process for balancing these techniques can help the beginning design thinker and lead to better group interaction.

"I like/I wish" feedback. In Experiment #2, it was interesting to note how quickly all groups, both convergent and divergent, used negative information as an evaluative tool. This communication technique tends to lead to convergent, close-ended evaluation, as it is often more difficult to discount a negative than to support open-ended, positive information. Focusing on negatives, also leads to a close-ended evaluation process that could be called "you need/you should," meaning “you need to consider this issue” or “you should do this” to be successful. Providing feedback in the “I like/I wish” format brings a divergent, flexible and positive approach to group communication. This type of feedback also keeps the problem space open longer, making it possible to identify new and unexpected pathways to problem solution.
Iterative prototyping is the engine that drives design thinking. The process of making an idea tangible, exploring limitations and reinventing a solution through a second, third and fourth prototype is the essence of design thinking. The use of oblique prototyping (also referred to as “dark horse prototyping”), that purposely prototypes in a diagonal or slanted path to a proposed solution may add value for both convergent and divergent thinkers. For the convergent thinker, it is an obvious attempt to break out of established patterns and generate new ways of thinking. For the divergent thinker, it's a chance to condense many possibilities into one best possibility to generate learning. The fact that it is considered a purposeful diversion from a straight-line path to a solution makes it easier for both types of thinkers to embrace the technique.

3-2-1 Decisions. It is been shown that rank order decisions do a better job of uncovering hidden profiles and disseminating individual to group information. Further, it is been shown that keeping problem spaces open longer helps lead to more creative and successful solutions. Encouraging a decision process that first discounts the least desirable option, and last embraces the very best option may be a technique that helps both convergent and divergent thinkers. To the convergent thinker, this is still an organized process that leads to the desired end result. To the divergent thinker, this keeps the problem space open longer leaving room for additional information, ideas and approaches.

Future Research Opportunities
This research shows the existence of representational gaps generated by, or certainly exacerbated by, differences in cognitive problem-solving style. In the future, research might explore ways to successfully bridge this representational
gap, particularly among equally balanced teams of convergent and divergent thinkers. It might be that some of the tools mentioned in the applications section are worthy of this type of research.

More work could be done on the impact of a balanced pivot thinker in a group composed of strong convergent and divergent thinkers. In particular, this could be laboratory research similar to Experiment #2 but convergent and divergent thinkers hold all information and pivot thinker moderator has none of the information. The task of the pivot thinker moderator would be identical, to rank order choice, but in this case it would depend on fully extracting the hidden profiles from people of very different cognitive problem-solving style types. This type of research could be controlled against a similar team with a randomly selected moderator who is not a pivot thinker.

This research also hints at importance of Stanovich’s simulative thinking, or the ability to accept new information and create new possibilities within a group context. There is less known about what triggers simulative thinking, what brings an end to simulative thinking and a return to algorithmic thinking. There has been interesting research on the use of dysfunction or modest confusion as a way to trigger simulative thinking and it would be helpful to find a reliably positive method of initiating simulative thinking (Alter et al., 2007). Perhaps it is the “I like/I wish” coaching technique.

Finally, it would be interesting to explore the use of priming as a way to bridge representation, particularly as a tool of a pivot thinker. It has been shown that counterfactual priming can uncover hidden profiles and guide group decision-
making processes (Galinsky & Kray, 2004). It would be helpful to better understand what type of priming, particularly in a design thinking context, would most successfully bridge representation gaps – do convergent thinkers need/require a different kind of priming than divergent thinkers?

**Limitations**

There are several significant limitations of this research. First and foremost, the base size of this research, with only 96 participants and 16 groups, is limited in the ability to generate reliable statistical differences. This research also presupposes two types of cognitive styles - convergent and divergent - but it is well known that there are many other types of cognitive problem-solving styles. For example, the full HBDI instrument contains four factors of problem solving style (of which only two were used in this research) and NEO-FFI uses five factors to describe personality. It is entirely likely that other factors beyond convergent and divergent thinking significantly impact how an individual interprets information and makes choices about sharing in a group context.

This is laboratory research and not an exact replication of a real world NPD group environment. In situ research takes into account factors not involved in this research, such as time pressure, reporting relationships and past experience in group decision-making. This style of laboratory research helps uncover subtle differences but may not be completely representative of how NPD teams make decisions in real time.
Finally, the Art of Asking Good Questions

Perhaps the most startling and revealing aspect of this research is the markedly different way that convergent and divergent thinkers react to questions - open ended statements designed to trigger simulative thinking. Eris separated questions into Deep Reasoning Questions (DRQ's) and Generative Design Questions (GDQ's). DRQ's are comfortable spaces for convergent thinking, including questions for clarification, confirmation and the confident reduction of options. GDQ's are much more problematic, reflecting divergent thinking, opening up problem spaces and triggering simulative thinking, often when the real benefit of a GDQ is not immediately known.

Creativity exercises often preach diversion for the sake of diversion. The premise is that the simple act of opening up options and thinking about the world in new ways, will have benefits in the moment at hand or in the future. It can also be a distraction and a significant waste of time. Questions for the sake of questioning seem to have limited value.

Therefore, what makes a good question? What makes a question worth answering?

Societies are defined by the questions we ask. In the book, Guns Germs and Steel, Jared Diamond traces the ascendancy of humanity to essentially one factor – geography (Diamond, 1999). Clusters of early humans prospered based on the favorable (versus unfavorable) climate and soil conditions of their particular location on earth rather than any intellectual, moral or genetic superiority. However, cultures were also shaped by the questions they ask. Organized
agricultural practices are thought to have begun in the region known as the "Hilly Flanks," which is the western area of Fertile Crescent. In this area, there was a temperate climate and sufficient rainfall to make irrigation unnecessary. The eastern region of the Fertile Crescent, which is known as the upper Nile Valley, initially did not prosper because it was subject to irregular rainfall that produced flooding and drought.

This caused the Egyptians to ask themselves questions about water control, in a way that was not necessary of inhabitants of the Hilly Flanks. These questions about water control led to the invention of the irrigation canal and dams for the storage of water. This superior control of water, lead to superior agricultural practices and an abundance of food, which was the basis for the establishment of the Egyptian Empire which lasted for 5,000 years. Clearly, disadvantage relative to competition (Nile Valley versus Hilly Flanks) led to asking the right questions and changed a society.

The similar pattern occurred with the relative recent ascendancy of Western culture, as described by Ian Morris in Why the West Rules - For Now. (Morris, 2010) In the 13th century, the Eastern culture (primarily China) far exceeded the Western culture (primarily northern Europe) in virtually every societal measure - population, food production, technology and war making capacity. The game changer for both cultures was access to the resources of North and South America. China judged the distance (the Pacific Ocean) insurmountable and chose to ask questions about how to maximize the resources within their own territory. Northern Europe judged the distance possible and chose to ask questions about mathematics, navigation, material science which led to direct access of the Americas and eventually ascendancy over Eastern culture. In this
case, asking questions about opportunity, what is possible, made the difference in the future of these cultures.

**A Good Question - Defined**

Therefore, it seems that good questions have balance. They are rooted in relationship between the realities of today and the opportunities of tomorrow. They reflect what might be possible relative to a known standard (i.e., comparison to competition) and they are also stretching in a way that creates a balance between uncertainty and ambiguity. In this way, a good question balances the obvious productivity of convergent thinking with the upside opportunity of divergent thinking. There is something in it for both types of cognitive problem-solving styles.

The art of asking a good question may be the ultimate test of a "pivot thinker."
Appendix A – Role Play Instructions and Group Satisfaction Measures

Group Leader/Moderator Instructions:

Thank you for agreeing to be the Group Moderator!

You are a peer within this group. Your opinion is just one within the group and means no more or less than any other group member.

You have two responsibilities:

• You must make sure that the group finishes it’s discussion within the allotted time. You will monitor the time and report it back to the group while in progress.

• You will record the group decision in the Essence Shampoo Role Simulation Exercise.

In addition, you may choose to:

• Start the conversation or continue the conversation if it begins to lag.

• Prompt or solicit opinions from group members who are not participating.
Post Discussion Feedback

Name: ________________________________

How **satisfied are you** working with this group?

☐ Completely satisfied
☐ Quite satisfied
☐ Somewhat satisfied
☐ Slightly satisfied
☐ Not at all satisfied

How **familiar are you** with the other members of this group?

☐ Not at all familiar
☐ Slightly familiar
☐ Somewhat familiar
☐ Quite familiar
☐ Completely familiar

Please circle the picture below that best **describes your relationship** with the other members of this discussion:
MERRELL Footwear began in the Green Mountains of Vermont in 1984. Today, MERRELL is the leading manufacturer of high-quality, performance footwear for outdoor enthusiasts.

As the needs of the outdoor enthusiasts have changed, so too has MERRELL's approach to addressing those needs. Over time, the concept of "outdoor" has broadened to include all types of activities and environments - both natural and urban. MERRELL is driven to keep pace with this evolution of "The New Outdoor," and continues to evolve.

You are a member of the MERRELL Design Team. The Design Team is a collection of the top designers at MERRELL and you meet once a quarter to discuss potential footwear designs and make an individual go/no go decision for further development. The purpose of this meeting is to share design information that may be helpful for the group in making a decision. Some information may be helpful for this discussion, some information may not be helpful – you as a designer decide what you think is important to share with the group.

The discussion today is about a shoe design called Kinetic. This is the first time you have seen this design. Standard CAD 3-D prototypes have been produced for this discussion and are shown on the following page.

This is a role-play simulation. You will have a 20-minute discussion with your peers, assuming the role as a member of the MERRELL Design Team. Listed below is what you know about this project:

- The shoe has a full-grain leather upper
- The in-sole is made with Memory Fit® foam which molds to unique shape of the foot
- Will leather be “in fashion” this year?
- Who would buy a shoe that isn’t comfortable?

Once you feel you understand the instructions, notify the moderator that you are ready. If you have any questions, please contact the moderator before the simulation begins.
## Appendix C – Shoe Design Item Validation and Distribution

Please rate each of the following as either a “fact” or a “question”:

**Fact** - An objective and verifiable observation, information about circumstances that exist

**Question** - A sentence worded or expressed so as to elicit information

<table>
<thead>
<tr>
<th>R#</th>
<th>C</th>
<th>Area</th>
<th>Question Statement</th>
<th>% Agree</th>
<th>R#</th>
<th>C</th>
<th>Fact Statement</th>
<th>% Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1</td>
<td>Upper</td>
<td>Will leather be “in fashion” this year?</td>
<td>97%</td>
<td>2</td>
<td>F1</td>
<td>The shoe has a full-grain leather upper</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>C2</td>
<td>Dual MF</td>
<td>Men like strength, women like grace. Can a shoe do both?</td>
<td>96%</td>
<td>3</td>
<td>F2</td>
<td>The colors are earth tones for Men’s (sizes 7-15) and pastels for Women (sizes 5-11)</td>
<td>90%</td>
</tr>
<tr>
<td>3</td>
<td>C3</td>
<td>Brand</td>
<td>What’s more important: a brand name that generates interest or a “look” that’s hot?</td>
<td>94%</td>
<td>4</td>
<td>F3</td>
<td>This shoe is made with brand name materials like Vibram®, Gore-Tex® and Aegis®</td>
<td>100%</td>
</tr>
<tr>
<td>4</td>
<td>C4</td>
<td>Odor</td>
<td>Do you think odor control could be an important benefit for hiking shoes?</td>
<td>97%</td>
<td>5</td>
<td>F4</td>
<td>The in-sole is made of Aegis® anti-microbial material for odor control</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>C5</td>
<td>Reflective</td>
<td>What if reflective materials improve safety and that’s important to urban walkers?</td>
<td>91%</td>
<td>6</td>
<td>F5</td>
<td>The heel tab is made of reflective webbed nylon</td>
<td>97%</td>
</tr>
<tr>
<td>6</td>
<td>C6</td>
<td>Heel</td>
<td>“Knobby” heels are so 2010 … what’s 2012?</td>
<td>89%</td>
<td>1</td>
<td>F6</td>
<td>The tread has a 5MM lug depth for extra traction</td>
<td>100%</td>
</tr>
<tr>
<td>1</td>
<td>C7</td>
<td>Comfort</td>
<td>Who would buy a shoe that isn’t comfortable?</td>
<td>97%</td>
<td>2</td>
<td>F7</td>
<td>The in-sole is made with Memory Fit® foam which molds to unique shape of the foot</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>C8</td>
<td>Breathability</td>
<td>Don’t experienced hikers expect shoes that are both breathable and water resistant?</td>
<td>93%</td>
<td>3</td>
<td>F8</td>
<td>Gore-Tex® meshing provides increased air flow to the foot</td>
<td>94%</td>
</tr>
<tr>
<td>3</td>
<td>CA</td>
<td>Confidence</td>
<td>Confidence is important, so do these shoes make the wearer feel confident?</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>CB</td>
<td>Identity</td>
<td>What if shoes are a statement about who you are as a person?</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>CC</td>
<td>Quality</td>
<td>People will pay for quality; so is this a quality shoe?</td>
<td></td>
<td></td>
<td></td>
<td>93%</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>CD</td>
<td>Look</td>
<td>This year it’s the “layered look;” does this shoe deliver on the “layered” look?</td>
<td></td>
<td></td>
<td></td>
<td>88%</td>
<td></td>
</tr>
</tbody>
</table>

| 4  | FA| Sole| The outer sole is made of Vibram® TC5 rubber | 100% |
| 5  | FB| Laces| The laces are made of high tensile strength Kevlar® | 100% |
| 6  | FC| Closure| The closure system is lace-up | 100% |
| 1  | FD| Weight| The weight of this shoe is 482 grams/pair | 100% |

### Demographics

| Gender (%F) | 63% |
| Age (Mean – Years) | 34 |

Mechanical Turk - March 9, 2009 – 10:38p “Question Fact Concept – Paired V2” (n=97)
Appendix D – Shoe Design Item Rating

Name: ________________________________

For each statement of information below, rate your opinion of the importance of this information to the discussion. Please rate each item. Circle your choice below:

Rating Scale:  
5 = Very Important  
4 = Important  
3 = Neither Important Nor Unimportant  
2 = Unimportant  
1 = Very Unimportant

<table>
<thead>
<tr>
<th>Statement</th>
<th>Rating Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>The shoe has a full-grain leather upper</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The in-sole is made with Memory Fit® foam which molds to unique shape of the foot</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>Will leather be “in fashion” this year?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>Who would buy a shoe that isn’t comfortable?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The colors are earth tones for Men’s (sizes 7-15) and pastels for Women (sizes 5-11)</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>Gore-Tex® meshing provides increased air flow to the foot</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>Men like strength, women like grace. Can a shoe do both?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>Don’t experienced hikers expect shoes that are both breathable and water resistant?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>This shoe is made with brand name materials like Vibram®, Gore-Tex® and Aegis®</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The outer sole is made of Vibram® TC5 rubber</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>What is more important a brand name that generates interest, or a certain &quot;look&quot; that is hot?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>Confidence is important, so do these shoes make the wearer feel confident?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The in-sole is made of Aegis® anti-microbial material for odor control</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The laces are made of high tensile strength Kevlar®</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>Do you think odor control could be an important benefit for hiking shoes?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>What if shoes are a statement about who you are as a person?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The heel tab is made of reflective webbed nylon</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The closure system is lace-up</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>What if reflective materials improve safety and that’s important to urban walkers?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>People will pay for quality; so is this a quality shoe?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The tread has a 5MM lug depth for extra traction</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>The weight of this shoe is 482 grams/pair</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>“Knobby” heels are so 2010 … what’s 2011?</td>
<td>5 4 3 2 1</td>
</tr>
<tr>
<td>This year it’s the “layered look;” does this shoe deliver on the “layered” look?</td>
<td>5 4 3 2 1</td>
</tr>
</tbody>
</table>

Finally, would you proceed with further development of the Kinetic shoe design? 

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>
Appendix E – Shampoo Prototype Subject Role Description

(Example: for Subject #1)

Neutrogena Styling Essence Shampoo

Neutrogena is a global leader in women’s personal care products. You are a member of the Product Development Team for Neutrogena Hair Care and must decide, as a team, to launch one of three new shampoo hair care prototypes. These prototypes were developed by your global R&D labs in Tianjin China, Toronto Canada and Trebbin Germany – and have the code names Tianjin, Toronto and Trebbin.

The discussion today is about a shampoo product called Neutrogena Styling Essence. This is the first time you have seen or discussed this product prototype as a group. Standard CAD 3-D prototypes of the bottle shape and product color have been mocked-up for this discussion and are shown on a separate page.

Consumer research shows that over 70% of women do some sort of “hair styling,” meaning they use a gel or spray to hold their hair in a particular styled shape. Within this broad group is a segment called “styling involved” that use two or more styling products and often color their hair. The benefit of Neutrogena Styling Essence shampoo is to enhance the use of styling products and should result in a noticeable better hair care look.

The purpose of this meeting is to share product information that may be helpful for the group in making a decision. The Product Development Team is a collection of the top managers at Neutrogena and you meet once a quarter to discuss potential products and make a go/no go decision for marketplace expansion. Some information may be helpful for this discussion, some information may not be helpful – decide what you think is important to share with the group. Please do not show your paper to others in the group.

This is a role-play simulation. You will have only a 20-minute discussion with your peers, assuming the role as a member of the Product Development Team for Neutrogena Hair Care. Following this discussion, you will Rank Order (from #1 - Highest to #3 - Lowest) your preference for the prototype products for possible expansion.
Listed below is what you know about these products:

<table>
<thead>
<tr>
<th></th>
<th>Toronto</th>
<th>Trebin</th>
<th>Tianjin</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Formula contains new, consumer preferred “pre-styling” conditioners that enhance and extend the effect of styling agents</td>
<td>Formula contains new, consumer preferred “pre-styling” conditioners that enhance and extend the effect of styling agents used on the hair</td>
<td>Formula contains new, consumer preferred “pre-styling” conditioners that enhance and extend the effect of styling agents used on the hair</td>
</tr>
<tr>
<td>*</td>
<td>Contains new, better performing “wheat protein” fortifiers to nourish and strengthen hair</td>
<td>Contains new, better performing “wheat protein” fortifiers to nourish and strengthen hair</td>
<td>Contains standard Neutrogena fortifiers to help strengthen hair</td>
</tr>
<tr>
<td>*</td>
<td>New and consumer-preferred “elegans” fragrance</td>
<td>Consumer acceptable and current “mist” fragrance</td>
<td>New and consumer-preferred “breeze” fragrance</td>
</tr>
<tr>
<td>*</td>
<td>Base formula is not compatible with conditioner, so no future shampoo-conditioner combination products are possible</td>
<td>Base formula is easily compatible with conditioner, so future products can include the consumer preferred shampoo-conditioner combination</td>
<td>Base formula may be compatible with conditioner; further testing is required</td>
</tr>
<tr>
<td>*</td>
<td>New and consumer-preferred “forest” color profile</td>
<td>Consumer acceptable and current “ice clean” color profile</td>
<td>Consumer acceptable and previous “ruby clear” color profile</td>
</tr>
<tr>
<td>*</td>
<td>Formula is rated “very good” by consumers for texture enhancement</td>
<td>Formula is rated “acceptable” by consumers for texture enhancement</td>
<td>Formula contains new, volume boosting amino acids that promote moisture absorption and enhances hair texture</td>
</tr>
<tr>
<td>*</td>
<td>Contains new, naturally derived proteins that seal hair cuticles for maximum shine</td>
<td>Contains proprietary Neutrogena hair shine enhancers</td>
<td>Contains new, naturally derived proteins that seal hair cuticles for maximum shine</td>
</tr>
</tbody>
</table>

Once you feel you understand the instructions, notify the moderator that you are ready. If you have any questions, please contact the research administrator before the conversation begins.

**Unique Information** – Not shaded for subject
### Appendix F – Shampoo Prototype Common and Unique Item Overview

<table>
<thead>
<tr>
<th>Code</th>
<th>Toronto</th>
<th>Trebbin</th>
<th>Tianjin</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Formula contains new, consumer preferred “pre-styling” conditioners that enhance and extend the effect of styling agents</td>
<td>Formula contains new, consumer preferred “pre-styling” conditioners that enhance and extend the effect of styling agents used on the hair</td>
<td>Formula contains new, consumer preferred “pre-styling” conditioners that enhance and extend the effect of styling agents used on the hair</td>
</tr>
<tr>
<td>C2</td>
<td>Contains new, better performing “wheat protein” fortifiers to nourish and strengthen hair</td>
<td>Contains new, better performing “wheat protein” fortifiers to nourish and strengthen hair</td>
<td>Contains standard Neutrogena fortifiers to help strengthen hair</td>
</tr>
<tr>
<td>C3</td>
<td>New and consumer-preferred “elegans” fragrance</td>
<td>Consumer acceptable and current “mist” fragrance</td>
<td>New and consumer-preferred “breeze” fragrance</td>
</tr>
<tr>
<td>C4</td>
<td>New and consumer-preferred “forest” color profile</td>
<td>Consumer acceptable and current “ice clean” color profile</td>
<td>Consumer acceptable and previous “ruby clear” color profile</td>
</tr>
<tr>
<td>C5</td>
<td>Formula is rated “very good” by consumers for texture enhancement</td>
<td>Formula is rated “acceptable” by consumers for texture enhancement</td>
<td>Formula contains new, volume boosting amino acids that promote moisture absorption and enhances hair texture</td>
</tr>
<tr>
<td>C6</td>
<td>Contains new, naturally derived proteins that seal hair cuticles for maximum shine</td>
<td>Contains proprietary Neutrogena hair shine enhancers</td>
<td>Contains new, naturally derived proteins that seal hair cuticles for maximum shine</td>
</tr>
<tr>
<td>U1</td>
<td>Base formula is not compatible with conditioner, so no future shampoo-conditioner combination products are possible</td>
<td>Base formula is easily compatible with conditioner, so future products can include the consumer preferred shampoo-conditioner combination</td>
<td>Base formula may be compatible with conditioner; further testing is required</td>
</tr>
<tr>
<td>U2</td>
<td>Contains pyrithione zinc that reduces itching and flaking but requires an FDA warning label</td>
<td>New “split-mend” ingredient that prevents split-ends from excessive styling</td>
<td>Formula provides good but average prevention of styling generated split ends</td>
</tr>
<tr>
<td>U3</td>
<td>Ingredients are expensive – requiring a projected 15% retail price increase</td>
<td>Ingredients are less expensive than current – allowing for a 10% price reduction or profit improvement</td>
<td>Ingredients are the same as current – no retail pricing changes are required</td>
</tr>
<tr>
<td>U4</td>
<td>Ingredients are available for production with acceptable lead time</td>
<td>Ingredients are easily sourced and readily available from several suppliers at low cost</td>
<td>Ingredients are difficult to source and require longer than average lead times</td>
</tr>
<tr>
<td>U5</td>
<td>Product testing shows that formula is acceptable to consumers with a broad range of hair types, straight to naturally curly</td>
<td>Product testing shows that formula is preferred by consumers with a broad range of hair types, straight to naturally curly</td>
<td>Product testing shows that formula is deficient among consumers with naturally curly or frizzy hair</td>
</tr>
<tr>
<td>U6</td>
<td>Consumer testing shows that formula strips away existing hair color enhancement after 10 washings</td>
<td>Consumer testing shows that formula lengthens the effect of existing hair color enhancement</td>
<td>Consumer testing shows that formula strips away existing hair color enhancement after 10 washings</td>
</tr>
</tbody>
</table>
List of References


Galinsky, A. D., & Kray, L. J. (2004). From thinking about what might have been to sharing what we know: The effects of counterfactual mind-sets on information sharing in groups. Journal of Experimental Social Psychology, 40(5), 606-618.


