Preemptive Decision Making in Backcountry Skiing: Diversifying Risk Management Strategies in Complex Environments

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Abstract

The backcountry skiing population has increased significantly over the past ten years. Current sales of backcountry ski and rescue gear outpace more traditional alpine, telemark, and snowboarding equipment. As higher numbers of people head into avalanche terrain more fatal accidents are occurring, human triggered avalanches being the primary cause of death. In the late 1980s there were an average of 11 avalanche related deaths per year in the United States. That number has risen to an average of 30 over the past five years. Over that time avalanche specific rescue gear has been quick to adapt to the changing needs of backcountry skiers. However, over that same period of time theoretical approaches to risk management have been slow to adjust to the community's changing needs. Consequently, this study examined the preemptive decisions and the risk perceptions skiers held as they prepared to enter Tuckerman Ravine. Results show that 69% of the survey population did not have formal avalanche training. Despite significant technological advances 56% of the survey population did not have everyone in their group carry a beacon, shovel and probe. Fifty-one percent of the survey population strongly disagreed with frequent beacon practice. However, a skier was more likely to practice with their beacon if they had taken a formal avalanche course. Women were less likely to feel as though the trip were a failure if goals were not met. Additionally, the underrepresentation of women in this study (n=4) required an assessment of broader gender disparities within the backcountry skiing community. Quantitative and qualitative results show a lack of female leadership among recreational backcountry skiers. This leadership gap limits mentoring opportunities and decreases accessibility to the community for novice female backcountry skiers. The lack of gender diversification has significant affects on the decision-making process. This study concludes that dual-process cognitive methods and multilayered risk management protocols can increase margins of safety and encourage diverse perspectives within the larger backcountry skiing community. This paper suggests that because backcountry skiing involves the interconnection between complex adaptive systems and complex physical systems skiers should adopt a systems thinking approach to their decision-making processes.

Keywords: Systems thinking, avalanches, dual-process cognition, complexity, preemptive decision making, risk management, female backcountry leadership, risk perception, human triggered avalanches.

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I have often heard speakers use the phrase “standing on the shoulders of giants” to express their appreciation for the work others have completed before them. While I always fundamentally understood what this meant I never had an actual emotional connection to the statement. The research conducted for this thesis has changed my perspective and enriched my understanding of the depth of work that has been accomplished in the fields of avalanche safety and backcountry risk management.

In many ways this work is a recalibration of the thoughts and ideas of researchers and professionals who accumulated vast amounts of knowledge before me. I have filtered their efforts through my own personal and academic lens and sought ways to celebrate, challenge and expand upon their ideas, theories, and results.

I would like to acknowledge the people and organizations that have had a direct and tangible affect on my work. My wife, Kennesaw, has been an intellectual and emotional pillar throughout the entire process of this investigation. She has offered valid insights and suggestions to ideas that would have otherwise sat dormant in my notes. Additionally, she was incredibly forgiving and compassionate in allowing this work to infuse itself in all aspects of our life together.

I would like to thank the Mt. Washington Snow Rangers, Hermit Lake caretaker Beth and the Harvard Cabin caretakers Rich and Marcia for supporting me in my work and providing warm places to organize my field notes and administer surveys. Without their generosity much of this research would have been impossible to complete. To that end I would also like to thank Tiffany Wynn, Denise Mitten, Blase Reardon, and Chris Richards for sharing their depth of wisdom and support throughout this project.

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Lastly, throughout the course of this research numerous professionals in the field made themselves available when they could have easily chosen to dismiss my e-mails and questions. Their support for this work provided unique insights that would have otherwise been absent in my investigation. This positive reinforcement was invaluable in the later, more challenging, parts of this project. Having people embedded in the process of making the backcountry community as healthy as possible take time to listen to my thoughts were small gifts that ultimately helped push this research to its conclusion.

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CHAPTER 1: PURPOSE AND SIGNIFICANCE OF WORK

Introduction

This study examines the preemptive decisions backcountry skiers make when preparing to travel in complex avalanche terrain. Proactive safety measures such as intragroup communication, planning, and group management are viewed as the next frontier in avalanche education (Edgerly & Baugher, 2012, pg. 1). It is reasoned that developing metacognitive abilities, goal abandonment strategies, systems thinking approaches, and diversifying decision-making agents, will create more robust avalanche risk management practices. These decision-making tools and methods expand margins of safety within complex alpine ecosystems by reducing exposure to cognitive traps and fallacies such as attachment to sunk-costs, confirmation biases, and the familiarity heuristic. Because these errors can be preemptively accounted for the processes of mitigating risk can and should extend far beyond the mountains.

Research Questions

1) Do individual and group perceptions of avalanche terrain translate into tangible risk reduction measures?
2) Which cognitive strategies can be incorporated to make preemptive risk-management more robust?
3) Who is guiding the current risk management discussion and who is absent?

Importance of Research

Backcountry skiing has seen a significant increase in participation rates over the previous decade. High resort ticket prices, advances in gear technology, and the idealized portrayal of the backcountry skiing experience, have all played their part in drawing skiers further into unmanaged terrain. Over the past four years backcountry skiing gear sales have increased by

85% and during the 2012-2013 season five million winter recreationists took to the backcountry (Solomon, 2014). Over that same time span avalanche related fatalities have edged back upward to 30 deaths per winter (Atkins, 2013, p. 1). According to Tremper (2008),"in most western states, avalanches account for the majority of deaths among all natural hazards" (as cited in Shay-Bright, 2010, p. 1) and globally an average of 150 winter backcountry recreationists are killed each year by avalanches (Tase, 2004, p. 1).

Mt. Washington is one of the few East Coast alpine environments that possess terrain and weather that is emblematic of larger mountain ranges. This makes it a unique and dangerous place to backcountry ski. According to an AMC caretaker 130 people lost their lives on Mt. Washington between 1849 and 2008, and from 1953 to 2013 thirteen people have died as a direct result of avalanches (personal communication, September 26, 2014). Each year many people make the pilgrimage to Mt. Washington's Tuckerman Ravine in order to achieve skiing rites of passage on its steep and challenging slopes (some estimates are over 3,000 on busy spring days). Often the social weight placed on skiing in this particular location overrides common sense and skiers behave in ways they probably would not under more remote conditions.

In response to the aforementioned fatality statistics significant resources have been invested in avalanche forecasting, research, and safety programs. As a result risk management practices have evolved from trailing long pieces of cord from ski boots, to the recent development of compactable probes that provide a full digital profile of the snowpack and allow for instantaneous crowdsourcing of regional data. Standard safety and rescue gear now includes a digital rescue beacon, probe, shovel, avalung, and increasingly popular avalanche airbags. Yet, over the course of the many beneficial technological evolutions one important trend has remained static; fatal avalanches are likely to be triggered by the victim or someone in the

victims party. In Gerlad Segman's (1936) book *Snow Structure and Fields*, a Swiss guide is quoted as saying, "I never fear that any avalanche will catch me unless I myself have brought it down" (Daffern, 1983, p. 3). Statistics show that 93% of avalanche fatalities in the United States result from the victim or someone in the victim's party triggering the slide (Tremper, 2013, p. 6).

Why seemingly rational people continue to bring down avalanches upon themselves and others by willfully traveling in avalanche terrain is one of the principal questions currently facing the backcountry skiing community. However, there are no easy answers to this question because the complexity of the systems needed to trigger a fatal avalanche means that a sole cause does not exist. Therefore, assessing avalanche fatalities requires an analysis of all the interconnected systems that comprise the backcountry skiing experience. According to Karwowski (2012)

> To improve the ability to prevent disasters from occurring again and to mitigate their unintended consequences in the future, one needs to gain a fundamental understanding of the emergent properties that result from the intricate interconnections of the complex system's components, including the humans in those systems. (p. 985)

In light of this statement, a more accurate understanding of whether or not skiers perceive the alpine ecosystem as static or dynamic should be achieved. Additionally, investigating the assumptions and beliefs that individuals have about the backcountry, and whether or not their actions align with their perceptions, is integral to the development of diverse risk management practices. Because goals are connected to individual perception, preemptive assessments of desires should be conducted before heading into avalanche terrain.

The phases of a trip in which goals are established and shared are often overlooked in backcountry skiing risk management analysis. Historically, skiers have based decisions off of quantitative data gained from avalanche forecasts and snow stability tests. The guiding thought

has been that if a skier understands the structure of the snowpack then he or she can extrapolate that information, combine it with other environmental data, and use the results to determine which terrain is safe to ski. Yet, good data doesn't necessarily equate with good decision-making (Tremper as cited in Page, 2014). Consequently, there are limits to the projective accuracy of reductionist risk-management methods.

The predictive limitations of system data reduce the ability to accurately forecast the short and long term evolution of avalanche terrain. This means that backcountry skiers will always operate with a certain level of *epistemic uncertainty*. Epistemic uncertainty "is an uncertainty that is caused by a lack of knowledge of quantities or processes of the system or the environment, also referred to as subjective uncertainty" (Ciloglu, Zhou, Moon, & Aktan, 2012, p. 1060). In avalanche terrain uncertainty stems from unsuccessful attempts at gathering accurate information from an emergent system. In these systems mental models "fall far short of representing the world fully" (Meadows, 2008, p. 86) because "we can keep track of only a few variables at a time" (Meadows, 2008, p. 87). Additionally, creating mental models of avalanche terrain is difficult because in complex systems there is often a delay in the information gathering process. Backcountry skiers are faced with the challenge of obtaining information about a system that is continuously yet often imperceptibly shifting. As a result once system models have been generated they are often outdated. Thus, as skiers move through avalanche terrain it is important that they account for the ubiquitous system delays that influence any decision making process (Meadows, 2008, p. 103).

The dangers associated with information delays are exacerbated when they occur in feedback poor systems. Daniel Kahneman calls these *wicked* environments because they unknowingly provide false positive responses to a person's behavior. For example, a skier with

no risk reduction measures could center punch (jump in the middle) a moderate slope 10 times and still only incur the same amount of risk as someone who chooses to go whitewater kayaking or skydiving under normal conditions (Temper, 2013, p. 2). In fact, 95% of the time avalanche terrain is actually safe, and when people are caught in avalanches 81% will survive (Tremper, 2013, p. 4). Results such as these develop flawed domain specific heuristics and inaccurate perceptions of the environment. Nassim Taleb (2010) accurately explains this predictive fallacy in a graph depicting 1,001 days in the life of a Thanksgiving Turkey.

For the turkey all experiences leading up to day 1,001 seem to confirm the fact that they live with kind owners who simply want to give them a good home and feed them well (Taleb, 2010, p. 40). There was no reason for the turkey to challenge previous experiences as somehow leading to disaster then on day 1,001 their perception of reality is drastically changed. Similarly, in backcountry skiing, "the avalanche game is like playing a slot machine in which 19 out of 20 times we pull the handle and quarters jingle into our cup. Then on the 20th pull, it suddenly takes back all the money we won" (Tremper, 2008, p. 285).

Results such as these are deceptive because they allow a decision maker to feel as though the system is safer than it actually is. People "begin to believe that the orderly behavior they see is the only possible state of the system" (Gonzales, 2003, p. 107) and forget that somewhere along the way the system will violate our understanding. Due to the complexity of avalanche terrain, and the people traveling in it, it is challenging to discern whether or not the system will respond negatively on the first time we ski a slope or the hundredth. This chaotic characteristic is what makes forecasting an imperfect process.

Complexity of Avalanches

It has been shown that the complexity of real world systems limits the ability of empirical observations to determine the outcomes of actions upon them

- Nassim Taleb

Avalanches are considered "high risk/low probability events dominated by incomplete information about risk and likelihood of a dangerous release" (Hendrikx, Johnson, & Southworth, 2013, p. 1). They are an emergent property of the larger alpine ecosystem; an avalanche transcends its "components so that the whole is greater than the sum of its parts" (Stewart, 2002, p. 367). A single snowflake isn't capable of creating an avalanche, however once a certain volume of snowflakes accumulates, in appropriate terrain, the potential for an avalanche exists. Avalanches develop as a result of the interconnection between changing variables within or across a system, specifically the steepness of a slope, strength or weakness of the snowpack, and the presence of a trigger. Furthermore, the avalanche system is considered chaotic because it is sensitive to microscopic uncertainties that can ultimately result in significant errors (Mitchell, 2009, p. 20).

Based on Holland's (2014) explanation of complexity, unintentionally human triggered avalanches exhibit some of the fundamental behaviors of complex systems. 1) Avalanches are sensitive to initial conditions and possess chaotic behavior that can create unintended results. 2) Avalanche terrain possesses *fat-tailed behavior* in which rare events occur much more frequently than a normal bell-curve distribution would predict. 3) Backcountry skiers travelling in avalanche terrain create *adaptive interactions* by modifying travel strategies over time (p. 5-6). The third component is the primary focus of this investigation because skiers have the ability to regulate how adaptive they are as individuals and as a group.

When backcountry ski groups prepare to travel in avalanche terrain they are developing the eventual interconnection between a complex adaptive systems (CAS) (e.g., a group of skiers) and a complex physical system (CPS) (e.g., alpine terrain). The two types of systems behave in different ways and are bound by different rules. "The elements of a CPS follow fixed physical laws" and "neither the laws nor the elements change over time; only the position of the elements change" (Holland, 2014, p. 13). Meanwhile CAS are "composed of elements, called agents, that learn to adapt in response to interactions with other agents" (Holland, 2014, p. 24) and with the surrounding environment. The Venn diagram (Figure 1), similar to Rick Curtis' (2010) dynamics of an accident model, shows the CAS and CPS interconnections created by backcountry skiers.

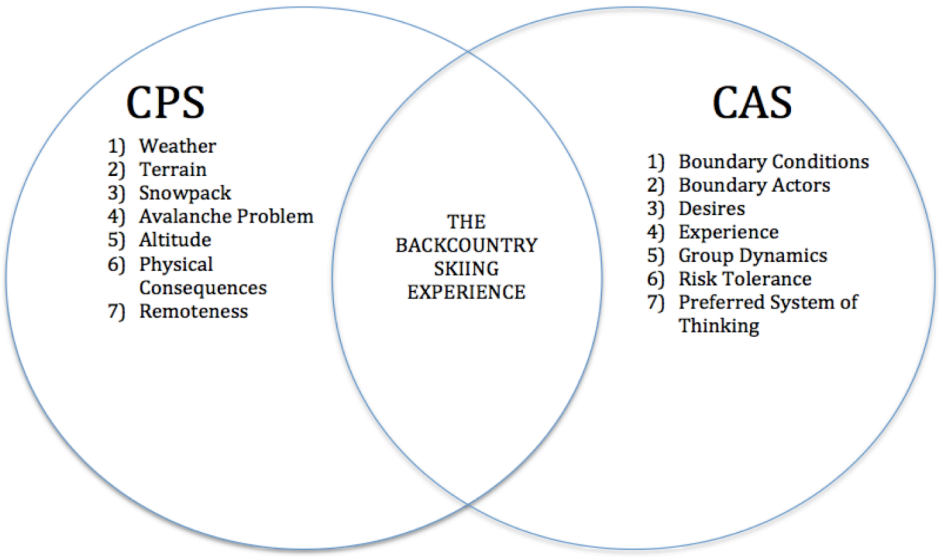

Figure 1. Venn diagram showing the interconnection between a complex adaptive system and a complex physical system.

A complete analysis of the intricate complexities of both systems moves beyond the intention and scope of this study. However, it is important to recognize that the interconnection of a CAS and a CPS can produce unforeseen and seemingly random events such as human triggered avalanches.

Figure 2 shows the complex terrain skiers have to manage when entering Tuckerman Ravine. This picture was taken after a significant winter storm and subsequent avalanche cycle revealed some of the interconnected avalanche terrain people have to negotiate when skiing in the ravines (note: these are some of the primary paths however there are many other paths and micro pockets adjacent to the center bowl that are capable of sliding as well).

Figure 2. Picture of interconnected natural avalanches in Tuckerman Ravine. Personal photo.

Complex terrain such as this exposes skiers to "multiple overlapping avalanche paths or large expanses of steep, open terrain; multiple avalanche starting zones and terrain traps below; minimal options to reduce exposure" (Tremper, 2013, p. 71). People attempting to navigate this type of system should possess the ability to accurately assess the complex environment laid out before them as well as the intricacies of the group dynamics. Attending to human factors requires

accurate individual and group situational awareness (SA). Vincenzi and Mouloua (2004) defined a situation as the "set of circumstances in which a number of objects may have relationships with one another and the environment, and situation awareness (SA) is knowing and understanding what is going on around you and predicting how things will change" (as cited in Naderpur, Lu & Zhang, 2014, p. 209). Imagining numerous ways that a system could potentially evolve is integral to safe travel in avalanche terrain.

While administering surveys on Mt. Washington I frequently overheard skiers, climbers and hikers, say that they were "just going to the bottom of the ravine to have a look." People assumed that because they weren't actually climbing anything steep and exposed that they would be out of harms way. However, unbeknownst to them (as one avalanche instructor articulately explained) "once someone enters the bottom of the ravine they become the pins in the avalanche bowling alley" (personal communication, 2013). In this situation people fail to imagine how the environment could change in a manner that would make their current location dangerous. Their thought process is presumably linear, the danger exists up there and I am down here, therefore I am safe.

A review of three separate avalanches recorded on point of view (POV) cameras in 2009 and 2011 all have secondary victims being struck in the bottom of the ravine (two of these slides had an initial human trigger further up the mountain). The avalanche in 2011 was a natural release during a moderate avalanche rating. The weather that day included consistent 100mph winds; consequently snow was being transported at a rapid rate, leading to the formation of a windslab on the terrain above the skiers. One of the people caught in the slide later stated that two of the skiers had AIARE Level 1 training but felt that they didn't need to carry a beacon,

shovel, and probe on that particular day. In this example skiers saw an independent variable (high winds) and were unable to connect that variable to a dependent hazard, avalanches.

The inability to create accurate cause and effect models is a signature element of black swan events and dynamic systems. These complex environments often exhibit stochastic behavior that is difficult to predict yet retrospectively easy to explain (Taleb, 2010, xxii). These characteristics mean that avalanche survivors and investigators are susceptible to *hindsight bias* in the aftermath of an accident. The following statement is an example of a typical avalanche incident reflection. "Looking back, there were enough red flags in the days and moments leading up to the accident, that it can't simply be explained away as a group of ill-fated skiers" (Page, chapter 1, para. 20, 2014). Research has shown that these types of statements result from overestimating what one might have known in foresight, and what others (victims) knew or should have known in foresight (Cook & Woods, 1999). "Knowledge of the outcome makes it seem that events leading to the outcome should have appeared more salient to practitioners at the time than was actually the case" (Cook, 2000, p. 2). In reality, an unintentionally triggered avalanche is a "discontinuous transition" or "critical point" (Connelly, 1996, p. 1) similar to a financial collapse in a complex monetary system (Stewart, 2002, p. 367), both of which are difficult to forecast and plan for. One of the reasons these events develop is because the coupling of apparently benign system failures go unnoticed by decision makers who are often attached to old information and fail to revise their plans (Cook & Woods, 1999, p. 17).

An example of this occurred on March 29th, 2014 on the Southeast snowfields of Mt. Washington's summit cone. On this day a R4 (Large avalanche relative to size of the path)/D3 (could destroy a wood frame house) avalanche was remotely triggered by one or more of the twenty people on the slope at the time. Mt. Washington snow ranger Frank Carus (2014)

reported that the slide was 650 feet across, left a three-foot crown, traveled 390 vertical feet, and the debris pile was 20ft deep in most places (consisting primarily of blocky hard slabs). The slide occurred as a result of a deep persistent slab. This type of avalanche is rare on Mt. Washington because the consistent high winds and variable temperatures typically never allow enough time for the aforementioned weak layer to develop. By all accounts this was an atypical avalanche. However, it occurred in terrain that clearly possesses the variables needed to produce a large slide. So why were so many good skiers and backcountry veterans taken by surprise when this avalanche occurred?

Due to infrequent avalanching and difficulty to forecast from the base of the ravine, this particular slide path is not included in the daily avalanche bulletin. As a result the zone is easy to dismiss as not being as dangerous as other aspects of the mountain. Additionally, on this particular day there were numerous large groups engaging in the herding instinct to find fresh tracks, on a familiar slope, all under warm temperatures and blue skies. In hindsight there are as many common warning signs as one could hope to find, but no one saw them, or chose not to discuss them. Yet, the ease with which these variables retrospectively come to mind is primarily a result of hindsight bias.

After the avalanche, Mt. Washington snow rangers reported that this was one of the largest slides recorded on that particular slope. “Snow Ranger Brad Ray, whose work in the ravines dates back to the early 60’s, confirmed that this avalanche is larger by far than any other avalanche he is aware of in this location” (Carus, 2014). Taleb (2010) calls these types of events *Black Swans* because they exist “outside of the realm of regular expectations” and have the potential to “carry an extreme impact”(Taleb, 2010, p. xxii). Furthermore, people manifest “explanations *after* the fact, making it explainable and predictable” (Taleb, 2010, p. xxii). These

black swans (otherwise referred to as dragons in the backcountry skiing community) "nobody talks about, since they escape models – those that you would feel ashamed discussing in public because they do not seem plausible" (Taleb, 2013, p. 77). The denial of plausibility most likely manifests within backcountry ski groups in order to maintain social homeostasis. The unwillingness to share individual concerns about seemingly implausible events, such as the potential for a slope to avalanche, has become a reoccurring variable in many avalanche fatality reports. Often there is someone in the group who wanted to voice her or his concerns about the avalanche hazard but instead chose to remain silent.

There are many variables that contribute to a person's unwillingness to speak up; however, one that requires specific attention is the role gender plays in the group decision-making process. Avalanche educator Nancy Pfeiffer consciously waits to ski with some male skiers on stable days because she does not want the stress of being the lone dissenting opinion (as cited in Wolfe, 2004, p. 13). Similarly, when asked if she feels that women speak up less in mixed gender ski groups, a prominent professional female skier answered "it's all relative but in mixed gender groups I would argue that women tend to say less than they might in an all female group regarding how they feel about safety" (personal communication, November, 2014).

An example of the reluctance to speak up occurred in an interview with one of the witnesses to the March 29, 2014 avalanche on Mt. Washington. The interviewee (a female skier) expressed the unsettling effect the event had on them due to the complexity of avalanche terrain, the stochastic nature of human triggered avalanches, and an overreliance on other group members. "I realized that regardless of how much education I get I will never be able to control all of the variables" (personal communication, October, 2014). The skier went on to explain that the experience made them skeptical of other people's knowledge. This likely developed out of a

sense of regret for not having spoken up before entering avalanche prone terrain; the skier stated, "I knew in the back of my head" (personal communication, October, 2014).

By quelling individual perceptions about the terrain this group was able to maintain a homogenous perception of the environment and thus were collectively blind to the black swan that existed. One of the take home messages from this incident (as with many avalanches) is that avoiding black swans and avalanche dragons requires more diverse individual and group perspective. Rather than just breaking one system (e.g., the snow pack) down into its component parts, skiers should assess how various systems interconnect and influence each other. This includes accounting for the unique life experiences that each member of the group brings to the table when entering avalanche terrain.

Systems Thinking Approaches

Incorporating systems thinking approaches to individual and group decision making processes can provide a more comprehensive model of an environment. Unlike reductionist approaches that break problems into component parts, thinking in systems encourages skiers to recognize interconnections, create predictions about future system behavior, and it promotes the diversification of system goals (Meadows, 2008, p. 7). Backcountry skiers should have the skills to acquire data about specific components of external and internal environments (e.g., the structure of a snowpack and personal risk tolerance) and the ability to use that information to "explore what would happen if a number of driving factors unfold in a range of different ways" (Meadows, 2008, p.7).

Laura Adams (2005) was among the first researchers in modern avalanche education to explicitly suggest that backcountry skiers should incorporate systems thinking approaches into their risk management strategies. Her master's thesis proposes a holistic approach to decision

making in avalanche terrain by considering "the inter-relationships between the human, physical, and environmental systems that inhere in avalanche phenomena" (Adams, 2005, p. 6). In a subsequent article stemming from her thesis work Adams (2005) advised that individual risk management should include the recognition of boundary conditions (p. 2). This includes "the knowledge, values, and attitudes of the decision maker" (Adams, 2005, p. 2). Accounting for adjacent systems and distant variables in the decision making process is important because "values garnered from one's family or community can and do influence an individual's view of risk" (Dzugan as cited in Ajango, 2005, p. 297). Therefore, even though backcountry skiers may feel isolated while on a trip they nonetheless remain connected to their communities via the risks they accept or avoid.

Given this fundamental and unavoidable interconnection, the beliefs, expectations, and concerns of boundary actors (people not present but who would be affected by positive or negative trip outcomes) should be recognized as essential variables during goal setting and system assessments. However, carrying additional cognitive and emotional luggage can be challenging given that many head to the wilderness in order to escape, clear their minds, and get away from the mundane. Backcountry skiers often report that they leave resorts and head to the backcountry in order to get away from crowds and enjoy time in nature. Tase (2004) found that significant portions of her survey population (N=1463) listed fresh tracks (80%), time outdoors (74%), and solitude (56%) as primary reasons for backcountry skiing (p. 56). While skiers are focused on the aforementioned motivations people can potentially become inattentive to how an accident might affect interconnected systems such as family and friends.

This common roadblock to systems thinking is known as goal fixation or the *focusing illusion*. This delusion manifests because people value possessions and experiences whose value

will eventually diminish over experiences that possesses greater longitudinal value (Kahneman, 2011, p. 406). *Miswanting* is often the source of rigid goals because people exaggerate the positive effects of goal attainment or acquiring specific goods on their future happiness (Kahneman, 2011, p. 406). This means people are less likely to abandon their investments because they don't weigh the potential cost of desires against hypothetical short and long-term losses. In the financial sector this is known as the *sunk-cost fallacy*. This cognitive error occurs when individuals "invest additional resources in a losing account when better investments are known" (Kahneman, 2011, p. 345). A backcountry skier's mindset has significant influence over their susceptibility to the sunk-cost fallacy and their ability or inability to create diverse backcountry goals. "Our mind-set consists of a collection of attitudes encompassing our perception of the avalanche hazard and the desires we hope to satisfy" (Atkins, 2014, p. 2). Mindsets can become overly rigid in complex environments because information is difficult to gather and analyze due to fluctuating variables.

In an effort to manage overwhelming amounts of information our brains create decision-making shortcuts called heuristics. Goal fixation and commitment to sunk costs often manifest because of the commitment heuristic. This mental shortcut works "because it provides us a shortcut through complexity. Rather than sift through all the relevant information we make a decision that is consistent with an earlier one" (McCammon, 2002, p. 4). Consequently, unless a skier maintains a flexible mindset and has established a diverse set of desires, it becomes increasingly difficult to abandon objectives once they are invested in a specific goal.

The ability to change desires is influenced by a skier's capacity to disengage from a primary objective. The inability or unwillingness to match desires with system conditions is the hallmark of brittle and poor goals (objectives that can only be successful in confined

circumstances) (Cook & Woods, 1999, p. 23). Additionally, "fixating on one desire, or just a few, is more likely to impede the ability to choose well" (R. Atkins, 2014, p. 2). Alpinist Ed Viesturs maintains the ability to disengage from sunk costs and goals by allowing boundary actors such as family and friends to influence his decision-making. Viesturs actually carries tangible reminders of his family in order to constantly "fight the charge of selfishness" (Coffey, 2003, p. 158) during his climbing pursuits. As a result he views choices through the lens of a seasoned athlete as well as from the perspective of a father, friend, and husband. Viesturs recognizes the duality of his backcountry and frontcountry goals and allows the two to coexist and influence decisions made in either realm of his life.

This systems thinking approach is more in keeping with feminist adventure theory than traditional western, masculine, and linear attitudes towards the mountains. The achievement of a singular goal, almost regardless of the costs, is understandable given the historical context in which much of modern alpinism originated. The paradigm of conquering mountains emerged from post WWI British explorations in the Himalaya. Given the atrocities that many of the early alpinists endured on the field of battle, and growing British imperialism, it is of little surprise that a hawkish approach to mountaineering manifested. On May 31st, 1920 the head of the Royal Geographical Society (RGS), Francis Younghusband, addressed critics who wondered whether the summit of Mt. Everest was worth risking human lives (Davis, 2011, p. 109-110). Younghusband argued that attaining the summit of Everest would "give men a feeling that we really are getting an upper hand on the Earth…[i]f man stands on Earth's highest summit he will have an increased pride and confidence in himself in his struggle for ascendancy over matter" (as cited in Davis, 2011, p. 110).[1]

[1] Interestingly, Younghusband would also argue "the characteristic of the world most worth

Conversely, feminist adventure theory proposes "a respect for life and a deep relationship with nature" (Mitten, 2009, p. 1) when exploring the outdoors. Through a feminist lens individuals tend to view their wilderness experience as a continuously evolving interaction *with* rather than a conquest *over* the environment (Mitten, 2004). This is an important perspective to maintain when operating in complex systems because it counteracts goal fixation and allows for a broader range of trip objectives to influence the decision making process.

Additionally, because feminist adventure theory values positive human-environment relationships it inherently reinforces the social science definition of complexity. It recognizes the coexistence of multiple systems within the same environment and that these "systems are complex in the sense that very large numbers of constituent elements of agents are connected to and interacting with each other in many different ways" (Mason, 2008, p. 2). Similarly, Adams (2005) advises backcountry skiers to consider "the relationships between human, physical, and environmental systems that inhere in avalanche phenomena" (p. 4). Adams' suggestion brings to light the coupling that occurs between systems when traveling in complex terrain. A system that is tightly coupled "must be capable of producing unintended complex interactions among components and forces" (Perrow as cited in Gonzales, 2003, p. 108). Attending to system coupling is another way of asking how far the ripples of an accident might extend.

Understanding how tightly a system is coupled also helps illuminate sources of information within complex environments. "Many interconnections are flows of information – signals that go to decision points within a system" (Meadows, 2008, p. 14). The ability to recognize flows increases the awareness of interconnections between system variables such as weather, snowpack, goals, group dynamics, and pre-trip plans. Attending to interconnections and

information flows creates a broader perspective on how decisions might affect boundary actors. Additionally, incorporating systems thinking approaches to pre-trip planning has the potential to reinforce the development of multiple route options for the trip.

Creating a list of diverse goals and routes is an essential preemptive action to take before entering avalanche terrain. When Lynne Wolf (ski guide and current editor of *The Avalanche Review*) was asked about what pre trip steps backcountry skiers should take to reduce risk her first suggestion was that skiers have multiple plans for the day in order to account for changes in the group (the complex adaptive system) and the environment (the complex physical system). This small act helps develop robust goals that "work well across a wide range of circumstances" (Cook & Woods, p. 23). Conversely, when skiers enter the backcountry with a single goal their risk management plan becomes brittle or poor because it only works "well under a limited set of conditions" or is "very vulnerable to breakdown" (Cook & Woods, p. 23). Furthermore, possessing diverse plans enables skiers to more readily disengage from a goal. "Disengagement is especially adaptive when situations are uncontrollable or goals are unattainable" (Lench & Levine, 2008, p. 128). Abandoning primary objectives helps skiers account for the innate complexity of the environment and the people engaged in it. Coming to terms with latent complexity is one of Meadows' (2008) guidelines for living in a world of systems (p. 194-195). Table 1 highlights the eight guidelines that are most relevant to avalanche risk management strategies.

Table 1
Eight rules for operating in complex systems

Rule	Guidelines
1	"Get the beat of the system."
2	Reveal mental models - use thinking out loud techniques.
3	"Pay attention to what is important, not just what is quantifiable."
4	Operate in the best interest of the group not the individual.
5	"Stay humble - stay a learner."
6	"Celebrate complexity."
7	"Expand time horizons."
8	Remain conscious of language and enhance it with systems thinking concepts.

Note: This table is an adaptation of Donella H. Meadows' (2008, p. 194-195) guidelines for living in a complex world.

Some of these guidelines are less obvious to accomplish than others however all of them can be achieved before ever entering avalanche terrain. For example, getting the beat of the system would require reading the daily avalanche report, the weather forecast, digging hasty pits, and doing at least one snow stability test (preferably an extended column test) before entering avalanche terrain. These actions will provide insight into the construct of the CPS. Paying attention to what is important and expanding time horizons can be achieved by including boundary conditions and actors into the pre-trip decision-making process. This helps incorporate goals and responsibilities outside of the current moment, helping to place consequences of decisions within a larger context. Celebrating complexity and remaining humble can be achieved by recognizing the dangers of heuristic traps, particularly the expert halo and the familiarity heuristic. These can be attended to by writing out the cognitive mistakes and fallacies that an individual is most susceptible to before a trip begins.

Risk Perception

A skier's perception of risk derives from their assessment of the environment and an assessment of the skills required to interact with the environment (Dzugan as cited in Ajango, 2005, p.291) Therefore, accurate external and internal system modeling is an important part of managing risk in avalanche terrain. During these system analyses individuals are tasked with determining the likelihood of an avalanche occurring and the potential impacts on short and long-term goals (for both the skier and associated boundary actors). According to Glynis Breakwell (2007) "risk estimation entails the identification of possible outcomes of an adverse event, the estimation of their likely size and severity, and the estimation of the probability that these will occur if the adverse event does occur" (p.13). However, because people have the propensity to miscalculate the impacts of future gains and losses risk estimates are often flawed.

An individual's risk perception also stems from intrinsic cognitive abilities as well as life experiences. As specific experiences are repeated a person's risk tolerance fluctuates as feedback from decisions is collected and stored as a guide for future behavior. A skier's risk tolerance is what he or she is willing to sacrifice in the pursuit of a particular desire (Dzugan, as cited in Ajango, 2005, p. 291). Risk tolerance in avalanche terrain can be misguided because the environment is a poor feedback system. There are system delays that make an environment seem more benevolent than it might actually be. In order to create accurate predictions of the costs associated with a particular goal an individual must accurately forecast the evolution of the system they are in.

However, because environmental data is often biased towards a particular objective, a skier's goal(s) influences her or his forecasting abilities. The attachment to desires (e.g., skiing a steep couloir) can cloud a skier's perception of risks associated with that goal and cause system

modeling to go awry. Adding to the decision-making confusion is the fact that often goals aren't pure byproducts of authentic wants and needs. Rather, a skier's "automatic response to things like social norms within peer groups, video images of extreme sports" contributes to how goals are created and the level of attachment to them (Atkins, 2014, p. 3). Fixating on one of the aforementioned goals can create system models that reduce predictive abilities and possibly lead to flawed perceptions of appropriate risk.

Sensitivity to risk is also regulated by whether or not the decision maker is the only one incurring potential costs or if losses are distributed throughout a group or community. Research has shown that people are often more willing to expose themselves to hazards than they are others. This is where the often heard saying "do as I say not as I do" stems from. However, the motivation behind placing oneself at greater risk than someone else isn't wholly altruistic. People often accept greater levels of risk because they feel they are less susceptible to negative outcomes than others. "People have been found to believe that they are personally less likely to experience negative events, and more likely to experience positive events, than other people" (Breakwell, 2007, p. 82). This is known as the optimistic or unrealistic bias. According to Kahneman (2011) "an optimistic bias plays a role – sometimes the dominant role – whenever individuals or institutions voluntarily take on significant risks. More often than not, risk takers underestimate the odds they face" (p. 256). These people feel they are being cautious when in fact they typically don't invest enough time into assessing the odds of incurring a particular loss (Kahneman, 2011, p. 256). A skier's inability to accurately predict future risks is exacerbated when the forecasting occurs in a complex environment.

The optimistic bias originates from our inability to collect the right data from dynamic environments with multiple interconnections. "Humans are incorrigibly inconsistent in making

summary judgments of complex information. When asked to evaluate the same information twice, they frequently give different answers" (Kahneman, 2011, p. 224). Some researches attribute inconsistencies in system evaluation to an overreliance on intuition and System 1 thinking. Evans (2010) argued that while intuition can at times produce correct answers, it is also responsible for generating cognitive biases and overconfidence in the wrong answers (p. 319). Consequently, when trying to manage risk in complex systems it is important to include intuition as part of a systematic decision-making process balanced with objective and subjective facts.

System 1, System 2, Naturalistic Decision Making, and Metacognition

In recent years a dual-systems approach to reasoning and decision-making has emerged within the field of cognitive psychology. At the forefront of the conversation are psychologists Daniel Kahneman and Gary Klein. Klein is responsible for much of the research supporting naturalistic decision-making (NDM), while Kahneman is more famously known for his delineation of System 1 and System 2 types of thinking. Kahneman (2011) argues that both systems possess inherent flaws that can be corrected via organizations because groups "naturally think more slowly and have the power to impose orderly procedures" such as the use of checklists (p. 418). The foundational differentiation between the two approaches is the context in which either researcher exams decision-making. Broadly speaking, Kahneman (and Taleb) is concerned with humans' predictive and forecasting abilities while Klein focuses on expert intuition employed in narrow timeframes and under conditions of high stress.

Naturalistic decision-making relies on the recognition-primed decision-making (RPD) that individual's with significant experience in a particular field develop over time and repeated positive system feedback. When people use RPD they unconsciously "highlight the most relevant cues, provide expectancies, identify plausible goals, and suggest typical types of

reactions in that type of situation" (Klein, 2008, p. 457). Having the ability to quickly recognize and interpret cues within a system is important, particularly in emergency situations where time is a limited resource. As a research subject NDM is concerned with understanding how people make "tough decisions under difficult conditions such as limited time, uncertainty high stakes, vague goals and unstable conditions" (Klein, 2008, p. 456). In backcountry skiing the ability to make decisions reflexively is particularly important when faced with the task of rescuing someone from an avalanche.

An example of the effectiveness of NDM in backcountry skiing occurred on the morning of February 19, 2012. On this date 16 skiers headed beyond the avalanche controlled areas of Stevens Pass with the intention of skiing an out of bounds zone known as Tunnel Creek. Regrettably, three skiers would die during this trip. However, one skier made the choice to turn around and leave the group based on a bad feeling she had at the top of the run. In an interview with the *New York Times* Erin Dessert provided insight into her difficult decision-making process on that day.

> I've been riding Stevens Pass since I was 3 years old, I can tell circumstances, and I just felt like something besides myself was in charge. They're all so professional and intelligent and driven and powerful and riding with athletic prowess, yet everything in my mind was going off, wanting to tell them to stop. (as cited in Branch, 2012)

Relying on a lifetime of experience in the Stevens Pass area (she had witnessed a nonfatal avalanche in that exact terrain before) as well as a willingness to disengage from the group, Erin was able to turn around and ski back to the resort, leaving behind one of the most prominent and tragic avalanches to hit the skiing community in recent years. Erin's reflexive System 1 thinking, and intuition, might have saved her life on that day.

Kahneman (2011) suggested that NDM is a function of System 1 thinking. System 1 "operates automatically and quickly, with little or no effort, and no sense of voluntary control" and can execute "skilled responses and generates skilled intuitions after adequate training" (p. 105). System 1 is responsible for the heuristic shortcuts that make walking to the mailbox a relatively simple endeavor. However, it is also the system that is guilty of creating an overreliance on previous experiences as illustrative of the current environment. As the complexity of a system increases System 1 struggles to adjust because it "focuses on existing evidence and ignores absent evidence" (Kahneman, 2011, p. 105). Honoring the presence of unknown variables is an important decision-making tool that requires critical self-reflection and situational awareness. These are adaptive cognitive tools in zones that are routinely skied throughout a season because they interrupt the development of cognitive traps such as the familiarity heuristic.

Additionally, backcountry skiers who consistently ski in a particular area can challenge both systems of thinking with metacognitive knowledge. Metacognition is defined as the "knowledge, awareness and deeper understanding of one's own cognitive processes and products" (Arslan & Akim, 2014, p. 33). This requires the conscious employment of System 2.

> System 2 is under intentional control and is also widely thought to be imbued with metacognitive awareness (given that it operates consciously) one would expect the presence of a meta-reasoning system to be manifested in a reliable natural facility in noticing and correcting errors in one's System 2 reasoning procedures as well. (Fletcher & Carruthers, 2012, p. 4)

In short, System 2 should be capable of correcting for System 1 mistakes as well as mitigating internal (System 2) mistakes. However, because System 2 is lazy and unwilling to invest

additional resources (Kahneman, 2011, p. 31) skiers must consciously employ mental checks and balances to correct for miscalculations stemming from both decision-making systems.

Listing personal disaster factors before a backcountry trip, or at the beginning of the ski season, is an effective preemptive risk management tool. According to Tremper (2013), all backcountry skiers possess unique disaster factors that can be accounted for and consciously guarded against throughout a ski tour (p. 38). Examples of disaster factors include haste, being overly competitive, maintaining narrow goals, relying on rigid thinking, and not speaking up or questioning norms. Understanding which cognitive biases and heuristic traps a skier is most susceptible to should be equally as important as knowing the avalanche hazard and weather forecast for the day. "Know before you go" includes outward as well as inward system analysis stemming from personal reflection and metacognitive knowledge. These preemptive approaches help skiers attend to a wider range of variables such as the conscious and unconscious objectives that influence decisions.

Being aware of personal and group goals is important because "desires sway our opinions and color our judgment"(Clelland & O'Bannon, 2012, p. 68). Clelland and O'Bannon (2012) suggest that while skiers can never completely eliminate the influence desires and objectives have on decisions, simply being aware of the potential negative effects may decrease the likelihood that they are ignored (p. 68). This awareness must stem from more reflective dual-process decision-making that has a *default interventionist* structure. According to Evans (2010) neural imaging evidence now supports the idea that the rapid responses provided by Type 1 thinking and intuition can either be accepted or rejected with overt Type 2 reasoning (pg. 314). Based on these findings skiers should be able to accept or reject reactionary plans (e.g., the snow looks deepest over there so we should ski it) via intervention from reflective reasoning.

This is an example of using diverse decision-making methods to help challenge individual and group beliefs. A 2011 study published in the *Journal of Small Business Management* "suggests that entrepreneurs utilize both linear and nonlinear dimensions in their overall cognitive process and employ either a linear or nonlinear thinking style depending on situational circumstances" (Groves, Vance, & Choi, 2011, p. 444). The authors of this article acknowledge the importance of matching internal desires with external realities via multisystem decision-making strategies. The take home point for backcountry skiers is to recognize when and where specific cognitive approaches should be relied on, questioned, or altered. In order to develop an awareness of appropriate decision-making strategies, skiers need to incorporate and strengthen their own unique intuitive processes.

Intuition

Throughout this investigation evidence has been presented cautioning against an overreliance on heuristics and intuition. However, when properly employed, heuristics remain "sensible estimation procedures' based on sophisticated underlying processes (e.g., retrieval and matching) in response to fairly simple questions posed under conditions of uncertainty" (Gore & Sadler-Smith, 2011, p. 306). McCutcheon and Pincombe (2001) found that in certain clinical settings, intuition enhances effective decision-making and crisis aversion (as cited in Robert, Tilley, & Peterson, 2014, p. 348). In the immediate aftermath of an avalanche, fall, or injury, expert intuition can quickly provide the skills needed to effectively manage the situation. Conversely, during the approach and terrain analysis phases of a ski tour novice intuition can provide fresh insights into what might be a familiar environment for skiers with more experience. With proper training and strong group dynamics neophyte perspectives can mitigate the negative effects of the familiarity heuristic. Risk management protocols will be enhanced if

group members acknowledge that intuition can develop in a variety of ways and is not limited to one type of person, feeling, or degree of experience.

Gore and Sadler-Smith (2011) argued, "intuition should be conceptualized as multidimensional rather than a unitary construct comprised of a variety of general and specific mechanisms and processes, and primary types" (p. 26). Intuition can be dissected into domain-general mechanisms (e.g., heuristics), domain-specific processes (e.g., expert pattern recognition), primary types (e.g., social and creative intuitions), and secondary types that are "composites of primary types of intuition" (Gore & Sadler-Smith, 2011, p. 29). In avalanche terrain skiers can rely on intuition that is adaptive, non-skill based, and helps maintain self-preservation within multiple environments, or intuition that is developed over the course of repeated exposure to a certain environment creating expert pattern recognition. Tremper (2013) discusses his conscious transition from pre-trip decision-making guided by System 2 thinking over to domain-specific intuition once he is actually in the mountains.

> Once we start traveling on the snow everything gets easier, at least for me. Suddenly, I'm not thinking academically about the avalanche problem, but instead I can use my senses to feel it, smell it, hear it, see it, and breathe it in. This is where my lifetime spent in the snowy places pays off because 10,000 unnamed sensations and millions of long-forgotten memories marinate in my unconscious mind. Intuition. (Tremper, 2013, p. 174)

Tremper goes on to articulate that his intuition doesn't remain unregulated; rather it is checked and balanced by mindfully employing concrete systems and linear analytical skills. This is an example of the multisystem cognitive approach being effectively employed in a complex environment.

Some studies suggest that reliance on intuition should be reserved for people like Tremper who are experts in a particular field. However, Ruth-Sahd and Hendy's (2005) investigation into ways of knowing among novice nurses, found that neophyte caretakers "do indeed value intuitive knowing and covertly rely on intuition in their practice" (as cited in, Ruth-Sahd & Tisdell, 2007, p. 116). Within backcountry ski groups it is important that novice skiers feel that their domain-general intuitions are validated when deciding to ski or not ski a line during moderate or considerable conditions. Diverse opinions should always be present during the decision making process, and non-evidenced based dissenting opinions need to be accepted in the group discussion.

A mental models approach to risk management is an effective way to address diverse perceptions of hazards. According to Breakwell (2007), this method assumes that "people have an intuitive understanding of risks" and that if information is presented in accordance with their "initial belief systems" the accuracy of their intuitions will be enhanced (p. 96). Backcountry skiers can incorporate the mental models approach by employing think out loud techniques, encouraging each other to recall pertinent information from weather and avalanche forecasts, and presenting hypothetical problems during the climb up the mountain (Breakwell, 2007, p. 96). Most importantly, no one, regardless of their level of experience, "should ignore the signs of the mountains, or the small intuitions that tell us maybe today isn't our day" (Krichko, 2014).

CHAPTER 2: LITERATURE REVIEW

Avalanche Literature

Individuals who plan to go backcountry skiing have numerous information outlets to turn to for advice and knowledge. As the popularity of the sport has increased so has the attention it has received in ski magazines such as *POWDER Magazine*, *The Ski Journal*, *Freeskier*, and

Backcountry Magazine. More widely read publications such as *Outside Magazine*, *The New York Times*, *The Washington Post* and *National Geographic Adventure* have also recently run stories about backcountry skiing (often in response to high profile avalanches). At the time of this writing there has been a noticeable shift in ski specific publications from reporting on trends and rescue gear to a deeper exploration of the cognitive factors involved in avalanche accidents.

For this study avalanche safety literature and multimedia was sourced from textbooks, journal articles, and a small number of educational videos. The intention was to diversify information outlets in order to see how different decision-making and risk management techniques are being communicated across a variety of mediums.

The absence of high quality avalanche safety videos is surprising in an era when technological advances provide access to superior filming. The lack of cinematic attention given to avalanche education is noteworthy given the significant progression in the adventure sports videography community and increased participation in backcountry skiing. Dozens of new ski films are distributed each year but none (with the exception of *The Fine Line* (2009) by Sherpas Cinema) are fully dedicated to avalanche safety and education. Moreover, many film companies make substantial profits from displaying professional athletes outrunning avalanches or magically rising to the surface as a slide comes to rest. Yet, what they often don't depict is how terrain is chosen and the fear many professional skiers experience when dropping into avalanche terrain (Berard, as cited in Whyte, 2012). Moving forward, films should be proactive and serve as a legitimate and effective means of communicating the actual risks involved with skiing in avalanche terrain.

With exception to PSA type videos, most of what is found online is reactionary (produced in response to a particular accident), skill specific (e.g., how to perform a compression

test), or a reminder to go take avalanche classes. Few films investigate the complex reality of planning a ski tour, going through the experience, and then reflecting on it. Consequently, most skiers are left with books and safety courses as their primary means of gaining avalanche safety information and instruction.

The books reviewed for this study were chosen in order to examine specific chapters that address cognitive and social processes affecting decision-making in avalanche terrain. Additionally, literature was chosen based on perceived frequency of use among recreational skiers, and professional AIARE educator recommendations. With these two variables in mind, the following books were reviewed for this study; *Avalanche Essentials, The ABCs of Avalanche Safety*, *Snow Sense, Avalanche Safety for Skiers and Climbers*, *Allen & Mike's Avalanche Book,* and *Staying Alive in Avalanche Terrain.*

Combined, the six avalanche safety books (not including appendices, bibliographies, and indexes) are 675 pages in length, of which 40 pages are dedicated to the discussion of human factors. This represents only six percent of the total pages published in all of the reviewed books. Furthermore, it is only the most recent publication (Tremper, 2013) *Avalanche Essentials* that begins to discuss the actual cognitive processes backcountry skiers go through when making decisions.

The polarized perspective of the books is not inherently bad. The skills and technical knowledge that avalanche professionals and guides have developed and shared are useful, applicable, and relevant to novices and veterans alike. Yet regardless of the effectiveness the vast majority of information contained in avalanche safety literature remains myopically focused on snow science and rescue skills. The predominance of Newtonian approaches to avalanche safety is frequently expressed in avalanche fatality reports that are "long on details about snowpack,

terrain and procedure, but short on the actual factors – human factors, social and psychological factors – that lead the victims out onto the slope in the first place" (Page, 2014). Consequently, skiers are often taught to look at a complex dynamic system through homogeneous and linear means of analysis.

The study of individual cognition in decision-making, and avalanche accidents has been a part of the backcountry risk management for some time. In 1980 legendary avalanche guru Doug Fesler wrote *Decision-Making as a Function of Avalanche Accident Prevention* in which he examines backcountry skiers decision-making processes. Early in the writing Fesler (1980) asserted, "the best piece of equipment that a man [sic] can carry in the backcountry is his brain" (p. 129). A decade later Fesler's shoes were filled by current avalanche sage Bruce Tremper. One of Tremper's earliest writings, *Life as a Human Being*, addresses what are now known in the avalanche education community as human factors and heuristics. In this article Tremper (1991) compares backcountry skiers to a herd of buffalo, aimlessly following each other around with little thought or intention behind their behavior (p. 1). Instead of discussing snowpack quality, route finding, or rescue skills Tremper analyzes the interpersonal behaviors between backcountry skiers and how those actions and beliefs affect risk tolerance. Around this same time, Jill Fredston and Doug Fesler published the 2nd edition of *Snow Sense* in which they list fifteen specific "human factors that were major contributors to avalanche accidents" (Atkins, 2000, p. 49).

In the early and mid 2000s, Ian McCammon and Laura Adams utilized quantitative social science methodologies to dig deeper into human factors associated with avalanche accidents. McCammon's 2002 International Snow Science Workshop article and presentation, *Heuristic Traps in Recreational Avalanche Accidents,* has since become a foundational piece for

avalanche education and literature. McCammon's research attempted to shift the human factor conversation away from judgment-based analyses (i.e., people who trigger avalanches do so because they are ignorant, have big egos, are adrenaline junkies, selfish, or just have a bad attitude) to an understanding of the actual cognitive traps and fallacies most people are prone to in both back and frontcountry settings. McCammon's article provided a researched based response to the often asked question of "how intelligent people with avalanche training could have seen the hazard, looked straight at it, and behaved as if nothing was there" (McCammon, 2002, p. 1).

McCammon's 2002 paper presents six specific heuristic traps that impact backcountry skier's decision-making abilities. Heuristics "are thought by some to benefit decision makers by providing convenient 'rules of thumb' that limit the number of potential factors that contribute to decision making" (Furman et. al., 2010, p. 455). A heuristic trap creates inaccurate perceptions and mental models of a system (McCammon, 2004, p. 1). McCammon reviewed 715 avalanche accidents that occurred in the United States between 1972 and 2003 in order to determine which cognitive rules of thumb influence avalanche accidents (McCammon, 2004, p. 1). The six heuristics he examined are outlined in the Table 2.

Table 2
McCammon's Heuristic Traps

Heuristic Trap	Definition
Familiarity Heuristic	An individual's past actions in a specific setting guide current behavior in the same or similar environment.
Acceptance Heuristic	Manifests when individuals engage in activities that they feel will bring them attention and recognition.
Scarcity	The tendency to view new snow as a finite and limited resource to acquire before others.
Social Proof	The presence of other people either enhances or diminishes a person's risk taking. This is dependent on an individual's self-perception of his or her own skills and abilities.
Expert Halo	Group members default to individuals who appear to possess more information than they do.
Commitment Heuristic	This trap occurs when our brains diminish information load by finding easy evidence that supports initial decisions

Note: This table is an outline of the six heuristic traps McCammon (2004) presented in *Heuristic Traps in Recreational Avalanche Accidents: Lessons and Implications.*

Adams (2005) masters thesis, *A Systems Approach to Human Factors and Expert Decision Making Within Canadian Avalanche Phenomena* closely followed McCammon's investigation into heuristic traps. Adams (2005) hypothesized that "defining avalanche decision skills, identifying the human factors that influence the decisions processes, and identifying strategies to speed up the development of expertise, can improve avalanche related judgment and decision-making" (Adams, 2005, p. 1). Throughout her research Adams advocates for naturalistic decision making (NDM) as an effect method of managing risk in avalanche terrain. NDM attempts to describe "how people actually make decisions in real-world settings….under difficult conditions such as limited time, uncertainty, high stakes, vague goals, and unstable conditions" (Klein, 2008, p. 1). NDM is a product of System 1 thinking which is automated and reflexive rather than contemplative and intentional.

Later in 2005 Adams reformatted her thesis results into articles for *The Avalanche Review* (TAR) and the Canadian Avalanche Center. Her three most prominent articles focused on

risk perception, systems thinking, and decision making as primary themes. These articles and Adams' thesis helped solidify the psychology of judgment and behavioral economics studies into the avalanche safety discussion. However, the degree to which these topics are addressed still lags behind the amount of attention given to traditional means of risk reduction.

One of the problems avalanche safety educators and authors face is that people aren't innately motivated to challenge their own assumptions and beliefs. This task is significantly more difficult to teach and perform than something more tangible such as reading the daily avalanche forecast. Additionally, incorporating systems thinking into avalanche literature and training challenges people's baseline perception of their environments. Individual's often "see a world that is vastly more coherent than it actually is" (Kahneman, 2013, p. 398) because it is difficult to imagine how seemingly unattached or distant systems can influence current objectives.

Literature from Adjacent Fields

Viewing a familiar system through a novel lens is imperative to positive change. The adventure education industry as a whole has done an effective job of mining other communities engaged in similarly complex environments for effective risk management strategies and protocols. Fields such as aviation, medicine, finance, and to a degree the military, are the typical focus points of outward analysis. However, it was Laurence Gonzales' (2003) book *Deep Survival* that addressed specific topics such as chaos, complexity, emotion, and the important role cognitive science plays in assessing risk. Similar to the avalanche industry, Gonzales investigates said topics in order to gain a better understanding of how seemingly smart people end up in life threatening situations. "Most people find it hard to believe that reason doesn't control our actions. We believe in free will and rational behavior. The difficulty with those

assumptions comes when we see rational people doing irrational things" (Gonzales, 2003, p. 14). This is the same question that has been posed by many within and outside of the avalanche education community. While Gonzales' book lacks the specificity and depth that many of the other books in this literature review possess, it would be wrong not to acknowledge the impact of his writing and it's place within backcountry risk management.

In response to progressively interconnected and complex global communities there has been a rise in research conducted in the psychology of judgment, complexity, behavioral economics, diversity, and risk management. Given the events of 9/11, the great recession of 2008, climate change, and changes in the healthcare system, numerous industries are now researching ways to strengthen predictive and adaptive abilities. A beneficial consequence of this is that there is now an abundance of research coming from a variety of sources that can help guide the avalanche risk management conversation.

The specific books chosen for review were *The Black Swan, Thinking, The Difference, Complexity, Does God Play Dice, Thinking in Systems, Thinking Fast & Slow, The Art of Changing the Brain, Chaos, The Psychology of Risk, How we Think* and *The Checklist Manifesto.* The common theme binding all of these works is that they all examine ways to assess, interpret, and make decisions about how best to interact with our environment. Moreover, regardless of the foundational systems being studied (e.g., finance, environmental science, medicine, aviation, education, etc.), all of the authors propose ways in which individuals can create accurate mental models of the system they are engaged in. Additionally, many highlight the challenges people face when attempting to turn observations into projections of how a system will evolve. Systems thinking, System 1 and System 2 thinking, intuition, and metacognition are some of the cognitive methods and tools frequently addressed throughout the literature review.

WEIRD Literature

Forecasting within any system, simple or complex, requires an accurate understanding of how the environment is currently behaving and how it is expected to unfold. Ideally, mental models will be constructed with quantifiable, simple data that helps construct robust goals. Backcountry skiers should be able to alter or reconstruct data with the evolution of a system. According to McClung (2002) reliance on redundant or static information "will most likely reduce the accuracy of predictions" (p. 114-115). During the literature review it became apparent that much of the avalanche safety information that is published into books is slow to adjust to the evolving decision-making needs of backcountry skiers. Based on McClung's assertion this means the accuracy of predictions resulting from these resources will be diminished.

Another limiting factor of the books reviewed for this study are the social and gender homogeneity of the authors. The majority of the books reviewed were written by male authors living in western, educated, industrialized, rich, and democratic societies (WEIRD) (Haidt, Greene, Harris, Baumeister, Bloom, Pizarro, & Knobe, 2013, p. 300). This is important because the "WEIRDer you are, the more you perceive a world full of separate objects rather than relationships, and the more you use an analytical thinking style, focusing on categories and laws, rather than a holistic style, focusing on patterns and contexts" (Haidt et. al., 2013, p. 300). WEIRD perspectives typically dissect objects and systems into component parts and dismiss interconnections that disrupt neat models and formulas. This approach is similar to how many recreational and professional skiers dissect the environment in order to achieve greater understanding.

A review of complexity literature and systems thinking was intentionally done to counteract the WEIRD approach to avalanche risk management. Yet, despite efforts to diversify

philosophical approaches to problem solving, the voices presenting the information remained relatively uniform. The perspectives of the 22 authors reviewed for this study typically derive from men residing within WEIRD communities. Of all the books reviewed for this study, 27% were written by a single female author, 13.6% by female/male coauthors, and 59% of the books had male authors.

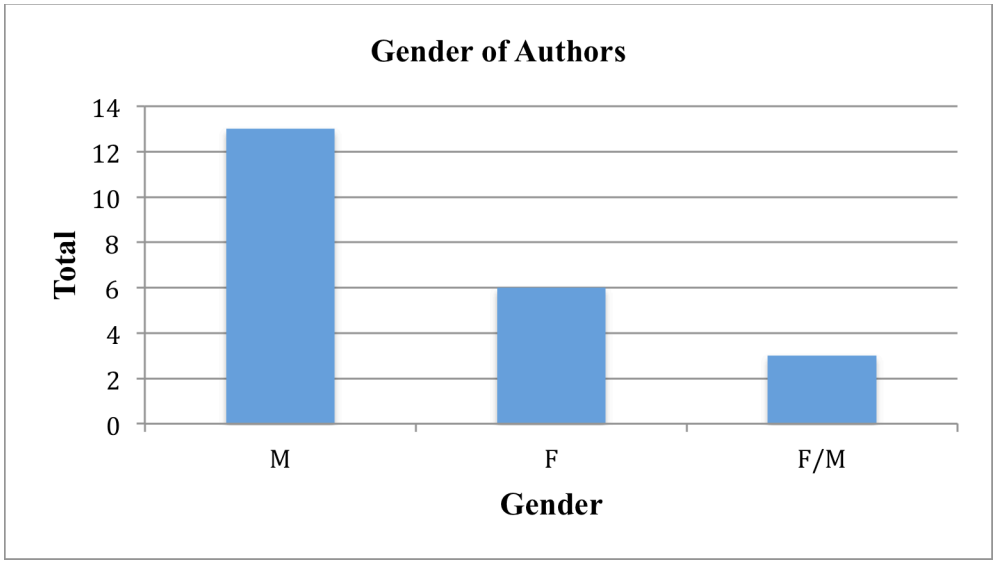

Figure 3. Column chart showing the gender distribution of the authors reviewed for this study.

Of the eight avalanche safety books that were reviewed, 50% have male authors, 25% have female authors, and 25% have male/female coauthors. While a complete diversity assessment of avalanche safety literature, and literature culled from similar industries, is beyond the scope of this study, it is nonetheless important to acknowledge the guiding view of a system and the influence this outlook has on future behavior. Considering the source of information and allowing that variable to influence decision-making is an adaptation that can positively influence future decisions by diversifying the information a skier is attached to.

Being unaware of myopic literary perspective is a result of bounded rationality or what Kahneman (2011) calls WYSIATI. According to Meadows (2008) bounded rationality means that decision makers are limited to making choices according to the information they currently have (p. 106). However, their information is often flawed because it does not account for "distant parts of the system" (Meadows, 2008, p. 106). Similarly, WYSIATI, the acronym for "what you see is all there is," can lead to overconfidence in system models because people "often fail to allow for the possibility that evidence that should be critical to our judgment is missing" (Kahneman, 2011, p. 87). In the past some of the evidence and information that is critical to backcountry skiers was missing from the risk management conversation because there were fewer professionals in the field. As the backcountry skiing community grows, diverse perspectives are slowly being integrated into the risk management discussion, expanding the information skiers have access to.

However, with an influx of new sources of knowledge comes the stress of trying to filter through the different types of information. For instance the ambiguity of heuristic traps and the psychology of decision-making can create unanswerable questions that contribute to analysis paralysis. Decision-making stagnation is understandable given that the simple act of paying close attention to a conversation with another person consumes one-third of our psychic energy (Csikszentmihalyi, 1995, p.18). Tremper (2013) addresses these cognitive limitations in the first chapter of his book *Avalanche Essentials.* He outlines the "stages in avalanche knowledge" with the final phase occurring when backcountry skiers "know the limitations of knowledge," (p. 33) and can account for the negative affects of bounded rationality and WYSIATI.

Based upon this literature review it is apparent that for many years backcountry skiers were guided by linear data based approaches to decision making. Historically avalanche

education has had "a strong foundation in physical and environmental research" yet it lagged behind in its understanding of "the human component of avalanche phenomena" (Adams, 2005, p. 6). A consequence of this approach is that skiers are restricted to making decisions based on narrow slices of environmental data that don't reveal the true interconnection between the CPS and CAS. Fortunately, authors such as Tremper, Atkins, McCammon, and Adams (as well as others) have made focused efforts to incorporate cognitive psychology into avalanche education literature in order to expand the backcountry skiing community's collective rationality.

CHAPTER 3: METHODOLOGIES

This chapter describes the methods used to design this study. The conceptual framework for this research is presented as well as the resulting research design, survey design and implementation, and an assessment of the methods used to collect and analyze data. Additionally, the participant population will be described, including participant selection methods. Finally, an evaluation of ethical issues and research bias associated with the investigation and survey implementation is provided.

This investigation took an inductive approach to the research and data gathering processes. Rather than entering the field with a predetermined hypothesis, the goal was to observe patterns and gather broad data that could then later be refined. The purpose of this approach "is not to test theory but to generate theory and explanations of phenomena" (Newman, 2000, p. 4). Data gathering methods used within this study, such as open-ended interviews, are in keeping with an inductive research process.

The survey distributed to skiers climbing into Tuckerman Ravine was designed to gain insight into the plans and insights skiers held as they ascended the mountain and prepared to ski in avalanche terrain. The survey contained questions pertaining to the long-term preparations

skiers made in advance of their trip such as the frequency of beacon practice, existence of a detailed emergency plan, and continued review of the avalanche forecast when not skiing.

The survey also inquired about group construct and dynamics such as size, gender, and level of avalanche training. In addition, more subtle aspects of individual and group perceptions were investigated such as an individual's willingness to abandon goals, their awareness of their own motivations for skiing, and level of comfort sharing concerns with the rest of the group.

The objective of the investigation was to gain an understanding of how people prepared for their backcountry skiing experiences, how their perceptions translated into actions, and to gain insight into specific human factors.

Research Approach

The investigation into human factors associated with avalanche accidents is grounded in a post-positivist research paradigm. A post-positivist perspective "recognizes that all observation is fallible and has error and that all theory is revisable" (Trochim, 2006). In response to innate observational error, post-positivist research methodologies typically employ mixed methods in order to triangulate a more accurate understanding of reality (Trochim, 2006).

Consequently, this study utilized a mixed methods approach to collect data from backcountry skiers preparing to ski in avalanche terrain. An explanatory sequential design was utilized in order to reinforce quantitative data with qualitative results (Caruth, 2013, p. 113). Combining survey responses with skier interviews (both structured and unstructured) intends to produce a more inclusive and accurate representation of the population being investigated. Moreover, a mixed methods approach aligns with the grounding argument of this study; diverse means of system analysis are required for an accurate understanding of a complex environment.

Additionally, through a mixed methods approach, research participants have increased agency because they are able to convey insights and opinions in their voice.

Mixed methods, triangulation, and post-positivist approaches are seen as being in accordance with feminist theory because they attempt to diversify how information is acquired and from whom knowledge is attained. Employing various means of acquiring data increase the likelihood of "uncovering subjugated knowledge" (Hesse-Biber, 2012, p. 138) and potentially bringing to light perspectives and information that are typically overlooked within the backcountry skiing community.

Administering Survey

The survey was distributed to forty participants throughout the months of March and April at the base of Tuckerman Ravine. Although forty participants took the survey only thirty-nine responses were included in data analysis due to incomplete and blank responses on one survey. While this total population does not represent the massive crowds that typically gather each spring in Tuckerman Ravine, they are an accurate depiction of the population of skiers who are increasingly traveling earlier in the spring and encountering avalanche hazards. The two primary threats these skiers faced were a human triggered avalanche, and or long sustained fall. Later in the spring the primary hazard is typically a long sustained fall or falling rock and ice due to rapid warming.

Participants were unsystematically asked to participate in the survey once they entered the hermit lake shelter area. During the survey design it was assumed that the survey would be administered at various locations along the Tuckerman Ravine trail in order to diversify responses. However, environmental risks such as exposure to high winds, low temperatures, and heavy precipitation required relocating the survey administration to the Hermit Lake caretaker

cabin. The cabin is marked in Figure 4 as “highest interview site.”

Figure 4. Google Earth image of survey locations in Tuckerman Ravine.

Participants were asked to complete the survey after they reached the Hermit Lake shelter and had time to review the daily avalanche bulletin. Participants were always given time to rest, recuperate, and an opportunity to confer with other group members about their plans for moving further up the mountain. The delayed request for survey participation increased participant safety and data validity by providing the researcher time to observe travelers and filter out people that had no intention of moving into avalanche terrain.

Participants were also filtered by their perceived intended activity. While climbers and hikers are certainly exposed to avalanches when traveling in Tuckerman Ravine this research focused solely on backcountry skiers and snowboarders. Thus, individuals who were carrying skis or a snowboard and who took the time to read the avalanche bulletin were asked if they would like to participate in a graduate thesis research project. If the participants agreed to take the survey then further details and instructions were provided. Forty participants agreed to

participate in the survey. An estimated 15 people declined to take the survey.

While this study fixated primarily on recreational backcountry skiers it did not intentionally exclude professional guides or educators as long as their professional status was unknown. The goal of the survey was to analyze a representative sample of the backcountry skiing population that chose to travel in avalanche terrain when a genuine avalanche hazard existed.

Once survey collection concluded it was determined that the avalanche forecast was rated Considerable/Moderate 43% of the time surveys were administered and Moderate/Low 57% of the time. The complex terrain on Mt. Washington means that there is rarely (except during extreme high or low events) a general avalanche hazard for the entire mountain. Mt. Washington is unique within the avalanche forecasting industry because of the micro scale analysis the snow rangers perform on a day-to-day basis. It is important to note though that there was at least a portion of the ravine rated as moderate throughout the entire data gathering process. Knowing how people interpret and act according to avalanche danger ratings is an important component in understanding their overall situational awareness.

Reading the daily avalanche bulletin has slowly become standard procedure for many backcountry skiers and snowboarders. Even, without attempting to fully interpret the snow science contained in daily reports skiers can still gain decision-making power with just the danger rating and some basic statistics about avalanche fatalities. For example, in the United States 37% of avalanche fatalities occur during a considerable rating and 26% occur during a moderate rating (Greene et al., 2003, p. 8). Thus moderate and considerable forecasts are responsible for 63% of total avalanche fatalities in the United States. An excerpt from the North American Avalanche Danger Scale (Figure 5) is provided to highlight the subjectivity involved

in interpreting the daily forecast when rated at moderate or considerable.

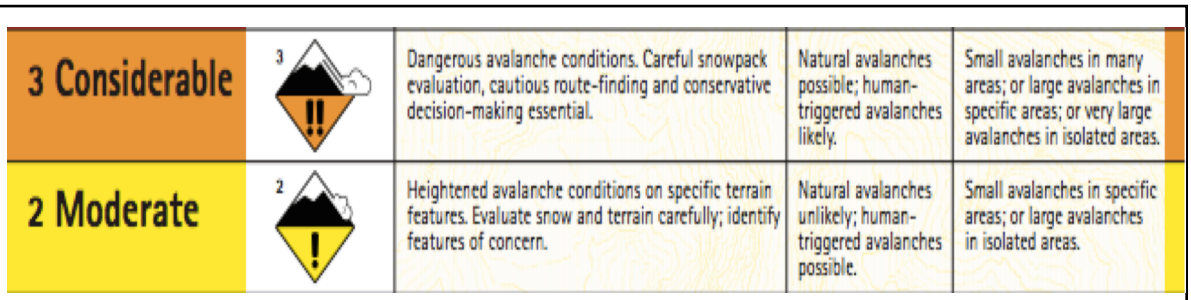

Figure 5. Screenshot of considerable and moderate avalanche ratings. Obtained from http://www.avalanche.org/danger_card.php.

Participant Description

Over the past decade an average of 350 people are caught in avalanches each season, 90 partially buried, 40 buried, 40 injured, and 40 known killed (Atkins, 2013, p. 2). The victim profile has remained consistent over that same period of time. Nine out of ten (92%) avalanche fatalities are men with an average age of thirty-five (Atkins, 2013, p.3). "Almost all are very skilled in their sport, fit, educated, middle class, and between the ages of 18 and 40" (Tremper, 2008, p. 15).

This profile of a typical avalanche victim influenced the development of research questions as well as the resulting research methodologies. Having an umbrella image of individuals most at risk afforded the ability to step back and ask what was missing from the social construct of the population and what are the risk management methods being employed by the population most at risk.

These questions required that all facets of this research maintain a sensitivity to voice, "paying close attention to who is being heard and who is being excluded" (Kralik & van Loon, 2008, p. 37). Given personal and professional ties to the community being studied, this investigation intends to address broader social issues "such as empowerment, inequality,

oppression, domination, suppression and alienation" (Creswell, 2009, p. 9) in order to create a change and not just the creation of knowledge (Kralik & van Loon, 2008, p. 42). Feminist worldviews have important implications for macro scale social concerns and micro level cognitive diversity that can potentially influence backcountry skiers' decision-making.

Feminist epistemology helped design a multilayered research methodology that attempts to provide as much participant agency in the data gathering process as possible. A mixed methods approach afforded the opportunity to conduct survey-based data gathering, take ethnographic field notes, and perform post survey interviews with key constituents. Abiding by purist quantitative or qualitative methods was seen as antithetical to the goals of this study, which are to help create a more diverse backcountry risk management process by integrating multiple cognitive methods of assessing risk.

Survey Instrument

The survey instrument used to collect data for this project consisted of thirty-six Likert type questions in addition to ten personal and demographic questions. Every effort was made to avoid using industry jargon in order to allow a variety of participants to feel comfortable with the survey. The instrument used a ten-point scale in order to increase reliability. A study examining the reliability of rating scales concluded that the least reliable scores derived from scales with the fewest response categories while "the most reliable scores were derived from scales with 7, 8, 9, or 10 response categories" (Preston & Colman, 2000, p. 13). However due to space limitations on the questionnaire, and attempting to reduce participant confusion, only two response anchors were used (1 = Strongly Disagree & 10 = Strongly Agree).

The survey was designed with ease of use in the field being a primary requirement. Thus questions and instructions were printed in standard Arial font with only black and white lettering.

Questions were printed on double sided pages in order to save weight and paper however this actually proved to be confusing for some participants thus any future surveys will only have single-sided printing. Additionally, the overall length of the survey appeared to be burdensome for some participants, especially those in a hurry to get up the mountain. However, the inductive nature of the research required building questions around multiple themes rather than a singular hypothesis. Consequently the survey was longer than typical field surveys might otherwise be in a harsh environment.

The information gathering process was initially intended to be a purely qualitative investigation relying on interviews with skiers and ethnographic field notes. However, it became clear that these methods could potentially increase skier exposure to inclement weather or significantly delay their trip, therefore it was decided that a Likert based survey would be a more appropriate means of gathering data. Fortunately, survey administration provided the ability to multitask and continue taking field notes while the survey was being completed.

Once surveys, field notes, and journal entries were collected and reviewed, interviews with four accomplished female backcountry skiers were conducted. These interviews were semi-structured so that participants were free to address what was important to them about gender and backcountry skiing. However, in the case of the one of the professional skiers that was interviewed, more direct questions were constructed due to time limitations. While the interviewee population size is limited the leadership role these women play, or have previously fulfilled, within the skiing and climbing communities gives them a uniquely powerful perspective.

Data Analysis

Once all of the surveys were collected and checked for validity they were individually

entered into Google forms. Since I was able to use my own e-mail account to fill out multiple forms this method allowed participants to remain anonymous. Once all responses were entered into Google forms a comma separated values file of the responses downloaded and transferred into Microsoft Excel. Within Excel the responses were coded and then uploaded to SPSS statistical software. Once data was fully uploaded into SPSS specific variables were chosen to test for association using a chi-square test of independence. The chi-square test assesses "how likely it is that an observed distribution is due to chance" (Ling, 2008). For 2x2 contingency tables a Fisher's exact test was used as well. However, the associations between tested variables proved to be inconsequential therefore the test was used sparingly and with no reportable results.

The data analysis for this study was difficult to perform due to a small sample size (n=39). Employing a chi-square test of independence to determine strength of association between variables was challenged due to having empty cells or cells with values less than five during the test. In an attempt to correct for the small population survey responses were binned from 1-10 to 1-5. However, even post consolidation and recoding assumptions of the test were violated due empty cells or counts below 5. This would end up being the most significant statistical limitations in this investigation.

Researcher Bias

Over the first few weeks of administering the survey it became apparent that my own experiences as a backcountry skier would have an impact on my research, most notably on participant selection. In order for data to have relevance to my research, questions needed to a) be drawn from a representative sample and b) gathered while people were in the process of making decisions. Being truly arbitrary in my participant selection was challenged by my awareness of which populations are most at risk of being caught in an avalanche. On numerous

occasions I found myself looking at specific groups of skiers and thinking, “those are the people I need to be interviewing” or “that is my ideal group.” This unconscious judgment had the potential to weaken the relevance of my sample selection. However, being aware and honest with my assumptions and bias helped maintain objectivity when selecting survey participants.

Similarly, knowing how underrepresented women are in the backcountry skiing community, and being innately sensitive to more global gender inequalities, I found myself looking harder for all female groups, or groups with women in them. Again, the conscious search for a particular type of skier threatened to violate indiscriminate population sampling. When speaking with AMC caretakers or avalanche forecasters I frequently expressed my frustration in wanting both a representative sample of the population as well as specific and robust data on nested populations within the backcountry skiing community.

I was also aware of my personal risk management needs as a backcountry skier and my desire to enhance my own decision-making strategies via this study. Having invested large sums of personal time, energy, and financial resources into backcountry skiing, I needed to guard against searching for answers to my own needs rather than what the backcountry skiing community actually requires. In order to challenge my own goals and assumption I regularly asked myself if what I was doing was for personal gain or to extend the community knowledge base? While the latter question is certainly influenced by the first it nonetheless provided a moment of pause for me to examine my research intentions.

CHAPTER 4: RESULTS

Demographic Results

Forty participants completed the survey distributed at the Hermit Lake shelters on Mt. Washington. Thirty-nine (*N*=39) surveys were considered valid because one survey was

incomplete.

Demographic statistics show men account for 89% (*n*=35) of the participant population and women comprise 10% (*n*=4). A 2004 study conducted by Jessica Tase reveals similar gender participation levels despite having a much larger sample size (*N*=1463). In Tase's study men accounted for 90% of the population while women accounted for 9% (2004, p. 38). Avalanche fatality gender statistics appear to mirror general backcountry skiing participation rates. Of all the avalanche victims between 2004-2013 92% were men and 8% were women (Tremper, 2013, p. 21).

In this study 82% of participants stated that their primary motivation for skiing (Figure 8) that day was to have fun. Other motivating factors included physical exercise (3%), to push personal comfort zone (5%), to enjoy nature (8%) and nondescript reasons (3%). About half of the population (49%) had less than five years of backcountry skiing experience, 28% had 5-10 years experience, and 23% had 10+ years of experience (Figure 6).

Thirteen percent (*n*=5) of the survey population traveled alone, 43% (*n*=14) traveled in groups of two, 10% (*n*=4) traveled in groups of 3, 15% (*n*=6) traveled in groups of four, 15% (*n*=6) traveled in groups of 5, 5% (*n*=2) traveled in groups of 6, one participant traveled in a group of seven skiers and one participant was unsure of how many skiers were in their group. Survey participants were most likely to travel in groups of two while skiing on Mt. Washington.

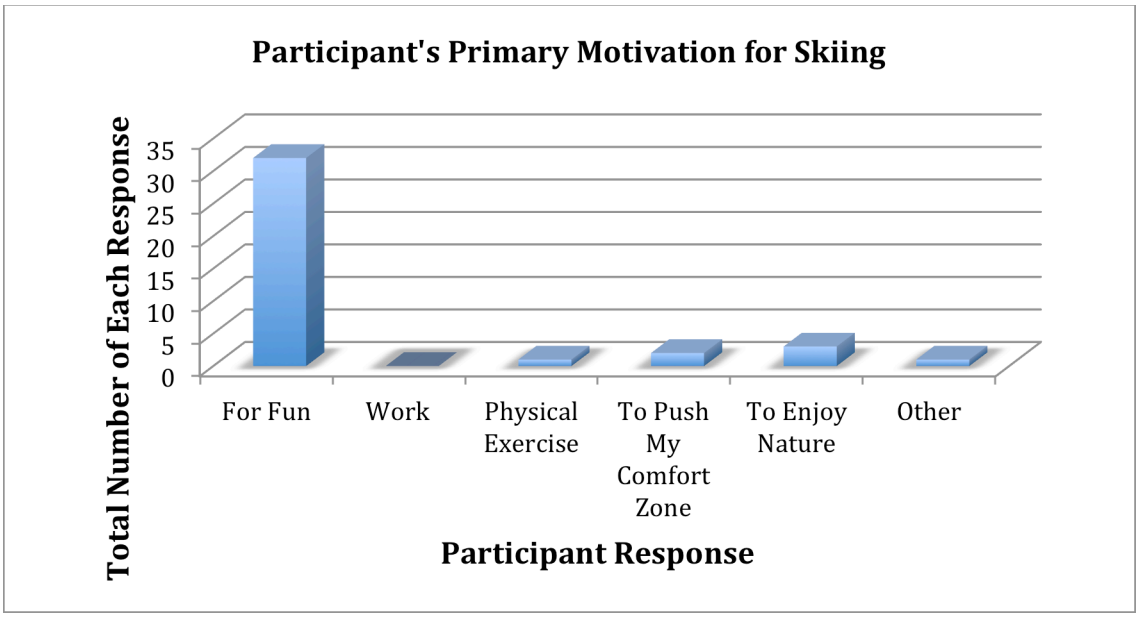

Figure 6. Column chart of participants' primary motivation for backcountry skiing.

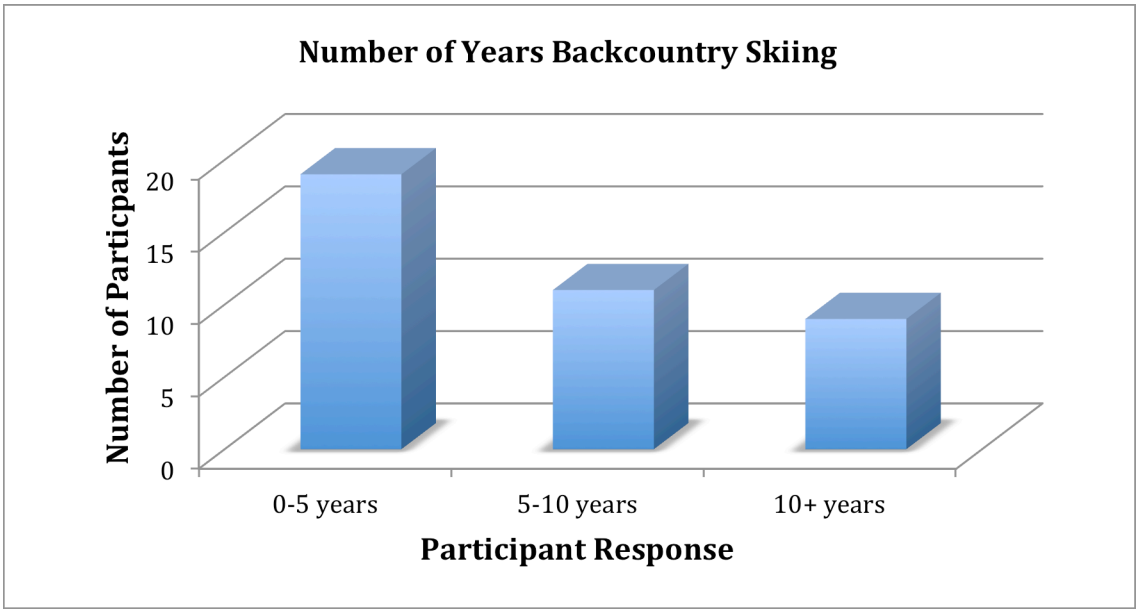

Figure 7. Column chart showing number of years participants have been backcountry skiing.

The mean age for the population was 35 with the youngest participant being 22 and the

oldest 74. The mean age for men (*n*=31) was 30 years old; the mean age for women (*n*=3) was 33 years old.

Table 3
Median ages of participants according to gender

Age Statistics

		Male Participant Age	Female Participant Age
N	Valid	31	3
	Missing	8	36
Median		30.00	33.00
Minimum		22	30
Maximum		59	74

Note: Median age of survey participants according to gender.

The mean and median ages of survey participants for this study are younger than reported national figures. A study of avalanche fatalities from 2003-2013 conducted by Dale Atkins found that the "mean age for all victims is 35.8 (median, 33.5); which is up significantly from a decade ago" (Atkins, 2013, p. 3). When gender is accounted for "the average age for men is 36, while the average age for women is 40" (Atkins, 2013, p. 3). Results from this study show that three participants (7% of survey population) reported having been involved in an avalanche. The three participants had a mean age of 31, all were male, and each skier had greater than five years of backcountry skiing experience.

Micro and Macro Gender Statistics

In total, 35 participants self-identified as male, the remaining four participants self-identified as female. Therefore 89% of the survey population consisted of primarily Caucasian men (one Asian American in the population sample) while 10% consisted of Caucasian women. The lack of gender and racial diversity mirrors macro scale backcountry skiing demographic

statistics.

Data from SnowSports Industries America's (SIA) *Snow Sports Participant Study* revealed that in the United States 3,297,200 women went alpine skiing in the 2012-2013 ski season; representing 40% of the total alpine skiing population. Within the same season there were 1,928,520 female freeskiers (36% of total freeskiing population), and women comprised 27% of the backcountry skiing population. In 2013 women only accounted for 11% (as cited by AMGA) of the alpine and backcountry skiing guide population. These numbers show a significant decline in female rates of participation as they progress from resort alpine skiing to professional backcountry guiding (note: the 11% includes rock, ice, and alpine climbing therefore how many women are specifically ski guides is unknown).

While an accurate total backcountry skiing population can not be precisely calculated, it is safe to say that both national statistics and results from this research show that women are underrepresented in the backcountry skiing community. The reason for this gender imbalance is beyond the scope of this study however it is important to note that the lack of gender diversification has significant affects on the group decision-making processes. Sole and Emery (2008) found that males who travel with females less than 75% of the time may be more likely to experience an avalanche (p. 501).

One of the immediate consequences of a lack of female participation is that female backcountry skiers have fewer mentors to learn from. In interviews with a professional and former professional female backcountry skiers, both women independently reported that not being able to find female mentors is a genuine obstruction to gaining backcountry experience. "Girls are guiding but we need more so there can be female mentors to bring in new skiers and make it easier for girls to get ahead." Another interviewee reported that her "introduction to

backcountry skiing was with all men" and that her "avy course was all men." The data in Tables 4 and 5 support the previously mentioned interview results. Additionally, these tables show a lack of female leadership among survey participants despite 30% of skiers agreeing and 23% strongly agreeing that that they often ski in mix gender groups.

Table 4
Distribution of participants' responses when asked if they frequently ski in mixed gender groups

Ski in Mixed Gender Groups

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	9	23.1	23.1	23.1
	Disagree	7	17.9	17.9	41.0
	Neutral	2	5.1	5.1	46.2
	Agree	12	30.8	30.8	76.9
	Strongly Agree	9	23.1	23.1	100.0
	Total	39	100.0	100.0	

These results show that while 54% (combined percentages of "agree" and "strongly agree" responses) of participants reported that they "often ski in mixed gender groups" 72% reported that they rarely backcountry ski with a woman as the primary leader. Similarly, qualitative results from a post-survey interview with an Appalachian Mountain Club (AMC) hut caretaker, revealed that while they do see women heading into Tuckerman Ravine to ski, these women are typically in mixed gender groups and that they frequently observe women deferring to men during the decision making process (personal communication, October 16th, 2014). The interviewee went on to say that they rarely see all female groups traveling in Tuckerman Ravine.

A chi-square test for independence was conducted to examine the relationship between gender and skiers that reported frequently skiing in groups where women are the primary leaders.

The association between these variables was found to be significant, $X^2(3, N = 39) = 21.25$, $p < 0.000$. This result shows that women are typically leaders of all female groups rather than mixed gender backcountry ski groups. Table 5 shows that 31 of the 35 male skiers surveyed strongly disagreed or disagreed when asked if they frequently backcountry ski with a female leader

Table 5
Crosstabulation of gender and skiing with a female leader

*Male/Female * Often Ski With Female Leader Crosstabulation*
Count

		Often Ski With Female Leader				
		Strongly Disagree	Disagree	Neutral	Agree	Total
Male/Female	Male	26	5	4	0	35
	Female	0	1	1	2	4
Total		26	6	5	2	39

Table 6
Chi-square test of independence for gender and frequently skiing with a female leader.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.255[a]	3	.000
Likelihood Ratio	15.382	3	.002
Linear-by-Linear Association	15.239	1	.000
N of Valid Cases	39		

Preemptive Risk Reduction Data

Only 44% of the survey population traveled in groups which all skiers carried a beacon, shovel, and probe (BSP) into Tuckerman Ravine. Carrying, and knowing how to use a beacon, shovel, and probe is fundamental to any backcountry ski tour. The data from this study is similar to national statistics showing that fifty percent of avalanche victims do not carry basic rescue gear (Tremper, 2013, p. 16).

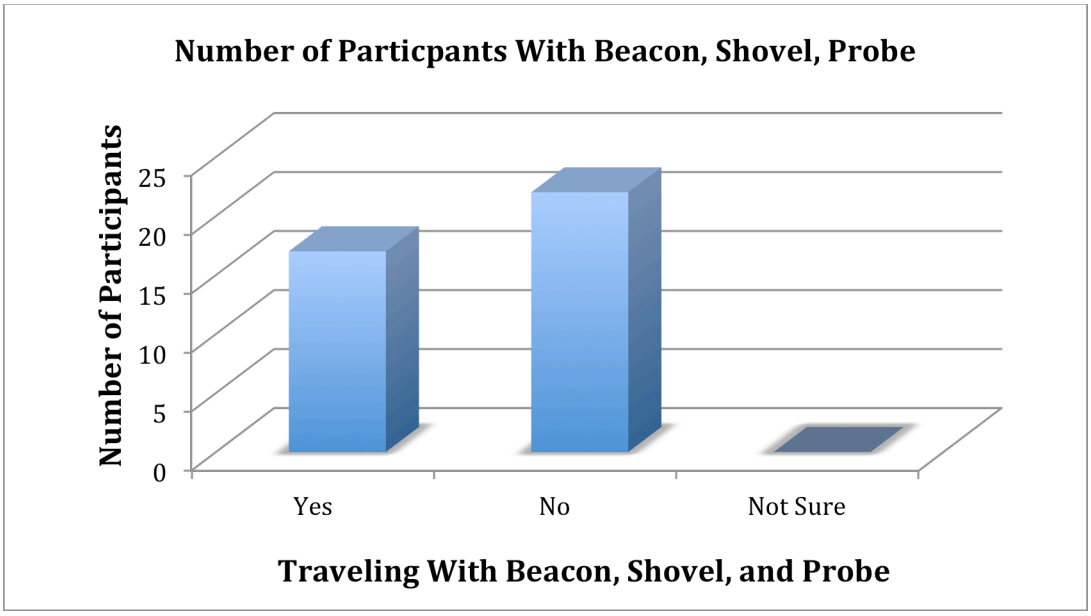

Figure 8. Column chart of participants that traveled in a group in which all skiers had a beacon shovel and probe.

Similarly, Figure 9 and Table 8 show that a significant portion of the survey population never participated in a formal avalanche education course. A commonly overheard mantra in backcountry skiing is know before you go (KBYG), yet 69% of participants had not taken an AIARE (industry standard) approved course before heading into Tuckerman Ravine.

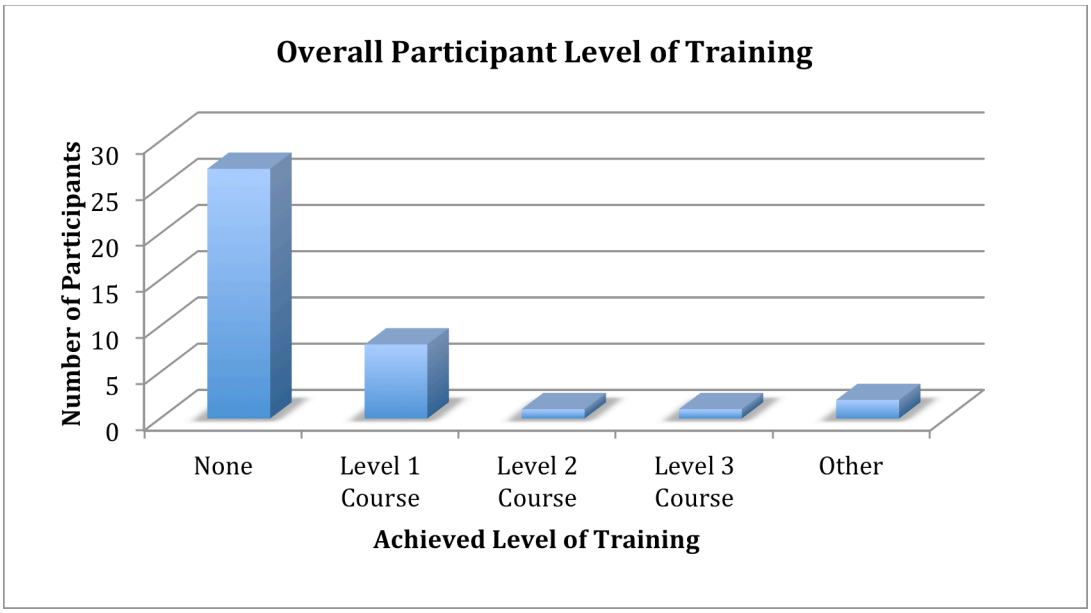

Figure 9. Column chart of participants' achieved level of formal avalanche training.

Table 7
Total Level of Training

Level of Training

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	27	69.2	69.2	69.2
	Level 1	8	20.5	20.5	89.7
	Level 2	1	2.6	2.6	92.3
	Level 3	1	2.6	2.6	94.9
	Other	2	5.1	5.1	100.0
	Total	39	100.0	100.0	

Table 7 shows that 20% of participants had taken a level one course, 2% a level two course, 2% a level three course and 5% qualified their years in the backcountry as formal training. Table 8 shows that men and women were likely to have achieved the same level of avalanche education.

Table 8
Gender and Level of Avalanche Training

*Male/Female * Level of Training Crosstabulation*

			Level of Training					
			None	Level 1	Level 2	Level 3	Other	Total
Male/Female	Male	Count	24	7	1	1	2	35
		% within Male/Female	68.6%	20.0%	2.9%	2.9%	5.7%	100.0%
	Female	Count	3	1	0	0	0	4
		% within Male/Female	75.0%	25.0%	0.0%	0.0%	0.0%	100.0%
Total		Count	27	8	1	1	2	39
		% within Male/Female	69.2%	20.5%	2.6%	2.6%	5.1%	100.0%

Over half of the male and female populations did not have formal avalanche training; 68% of men and 75% of women hadn't taken an avalanche course at the time they took the survey. Similarly, 20% of male participants had level 1 training and 25% of female participants had level 1 training. Tase (2004) found similar results, "males and females were similar in the proportions of respondents with rudimentary or no awareness, basic training, and advanced training" (p. 43).

Potentially negative consequences of not having formal avalanche education appeared in responses to survey questions about how people gather data from the environment (Table 9), how frequently they practicing rescue skills, and whether or not they have a detailed emergency plan.

Table 9
Frequency of snow stability tests

Snow Stability Tests

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	13	33.3	33.3	33.3
	Disagree	8	20.5	20.5	53.8
	Neutral	10	25.6	25.6	79.5
	Agree	4	10.3	10.3	89.7
	Strongly Agree	4	10.3	10.3	100.0
	Total	39	100.0	100.0	

Table 9 shows that 33% of survey participants strongly disagree when asked if they perform multiple snow stability tests over the course of their trip. Similar data is found in Tase's 2004 study; 20% of her respondents did not perform snow stability tests and 46% only performing them sometimes (p. 47). While full snowpack profiles aren't necessary on every slope, frequent hasty pits on diverse aspects and terrain can provide valuable information.

Table 11 shows that 51% of the participants in this study strongly disagree with regularly practicing with their beacon, 5% disagree and 20% are neutral. Tase (2004) found comparable results in her survey responses; 32% of her population practiced once a year, 25% practiced a few times a month, and 14% practiced less than once a year (p. 45). According to Tremper (2009) consistent beacon practice ensures that a) each person's beacon is transmitting and receiving properly, b) each beacon has sufficient battery power, and c) each skier knows how to use their beacon with minimal struggle (p. 271-272).

However, a chi-square test of independence did reveal an association (Table 10) between level of training and frequency of beacon practice, X^2 (16, N = 39) = 31.69, p = .011.

Table 10
Chi-square test for level of training and frequent beacon practice

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	31.697[a]	16	.011
Likelihood Ratio	27.558	16	.036
Linear-by-Linear Association	4.757	1	.029
N of Valid Cases	39		

Table 11
Frequency of beacon practice

Frequently practice with beacon

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	20	51.3	51.3	51.3
	Disagree	2	5.1	5.1	56.4
	Neutral	8	20.5	20.5	76.9
	Agree	5	12.8	12.8	89.7
	Strongly Agree	4	10.3	10.3	100.0
	Total	39	100.0	100.0	

Survey participants were unlikely to have a detailed emergency plan and to have shared those plans with everyone in their group. Figure 10 and Table 12 show that 35% of respondents strongly disagreed with this statement, 23% disagreed, 10% were neutral, and 15% agreed or strongly agreed to creating and sharing an emergency plan for their ski tour.

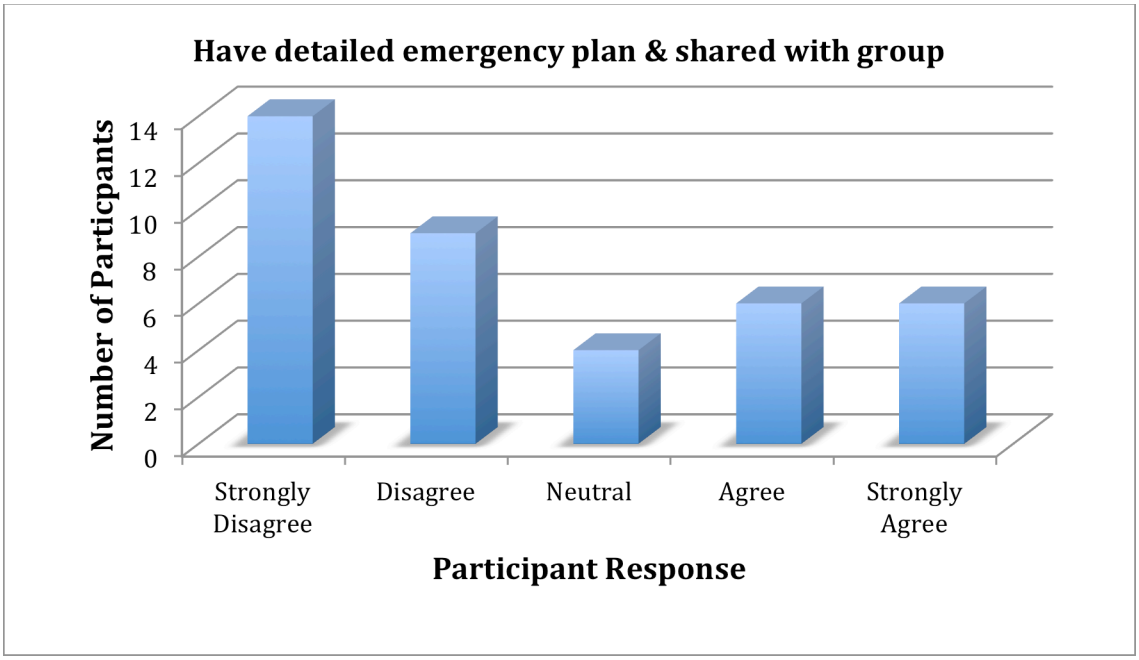

Figure 10. Column chart showing the degree to which participants agreed to having an emergency plan and communicating it with the rest of the group.

Table 12
Emergency plan distribution of responses

Group has emergency plan

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	14	35.9	35.9	35.9
	Disagree	9	23.1	23.1	59.0
	Neutral	4	10.3	10.3	69.2
	Agree	6	15.4	15.4	84.6
	Strongly Agree	6	15.4	15.4	100.0
	Total	39	100.0	100.0	

Results from the survey show that skiers were aware of their lack of formal avalanche training and recognize that their skiing abilities outpace their backcountry specific skills. When participants were asked to what degree they agree or disagree with the following statement *my*

backcountry skills (i.e., ability to interpret snow, read terrain, observe weather patterns, or perform a rescue) are just as strong as my skiing abilities, 12% strongly disagreed with the statement and 35% disagreed. A complete distribution of the responses is provided in Table 13

Table 13
Backcountry skills vs. skiing skills distribution of responses

Backcountry Skills & Skiing Skills

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	12.8	12.8	12.8
	Disagree	14	35.9	35.9	48.7
	Neutral	10	25.6	25.6	74.4
	Agree	6	15.4	15.4	89.7
	Strongly Agree	4	10.3	10.3	100.0
	Total	39	100.0	100.0	

Backcountry specific skills help skiers gather data and cues required for the development of mental models used to predict how avalanche terrain might evolve over the course of a trip. The self-awareness exhibited in these results is a good indicator that skiers are beginning to recognize the bifurcation of skillsets.

Without formal avalanche education it is difficult to acquire and interpret system information. Fortunately, snow rangers and forecasters throughout the United States synthesize large amounts of data into daily avalanche bulletins. Reading the daily avalanche report provides a baseline of information about historical, current, and hypothesized states of avalanche terrain. This study found (Table 14) that 64% of participants agree or strongly agree that they read the daily avalanche bulletin even if they don't have a trip planned. Additionally, 56% of participants read and discussed the daily avalanche bulletin before departing on their trip on the day they took

the survey.

Table 14
Reading daily avalanche forecast with no immediate trip planned

Reading Forecast Daily

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	9	23.1	23.1	23.1
	Disagree	2	5.1	5.1	28.2
	Neutral	3	7.7	7.7	35.9
	Agree	9	23.1	23.1	59.0
	Strongly Agree	16	41.0	41.0	100.0
	Total	39	100.0	100.0	

A chi-square test of independence was performed to determine the association between gender and whether or not everyone in the group read and discussed the daily avalanche bulletin before departing on their trip. The results from this test show (Table 15) a significant association, X^2 (4, N = 39) = 14.14, p = .007. The null hypothesis is rejected, therefore a participant's gender does correlate with whether or not they had read and discussed the avalanche report prior to leaving on their trip.

Table 15
Chi-square test of independence for gender and reading and discussing the daily avalanche bulletin

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	14.144[a]	4	.007
Likelihood Ratio	10.019	4	.040
Linear-by-Linear Association	4.384	1	.036
N of Valid Cases	39		

In addition to regularly reading the daily avalanche forecast, many skiers also planned multiple routes for their trip. When asked if they strongly agreed or strongly disagreed with the statement, "we have planned a variety of descent options for today's trip," 30% of survey participants said they agreed and 33% said they strongly agree. Therefore, 63% of the populations agreed to having planned a variety of egress options before entering Tuckerman Ravine. Additionally, 69% of the population strongly agreed with the statement "I am confident in my ability to abandon today's primary skiing objective." Similarly, 64% of the population strongly disagreed with the statement that the trip would be a failure if primary skiing objectives were not met. However, an association (Table 16) was found between gender and feelings of failure surrounding goal disengagement, X^2 (3, N = 39) = 10.31, p = .016. Women were less likely to feel that the trip was a failure if goals were not met.

Table 16
Gender and failure to reach goals

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.318[a]	3	.016
Likelihood Ratio	7.447	3	.059
Linear-by-Linear Association	.038	1	.844
N of Valid Cases	39		

An association (Table 17) was also found between individuals with multiple routes planned and individuals who had selected ski terrain based on the abilities of the weakest skier in the group, X^2 (16, N = 39) = 30.03, p = .018. Additionally, a second chi-square test of independence (Table 18) shows an association between skiers with multiple routes planned and skiers who frequently practice with their beacon, X^2 (16, N = 39) = 29.60, p = .020. Only 12% of skiers agreed to frequently practicing with their beacon, 10% strongly agreed.

Table 17
Chi-square test of independence for multiple routes and terrain selection based on weakest skier

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	30.030[a]	16	.018
Likelihood Ratio	29.093	16	.023
Linear-by-Linear Association	1.928	1	.165
N of Valid Cases	39		

Table 18
Chi-square test of independence for multiple routes planned and regularly practicing with beacon

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	29.601[a]	16	.020
Likelihood Ratio	29.053	16	.024
Linear-by-Linear Association	3.355	1	.067
N of Valid Cases	39		

Perception of Environment

A skier's perception of Mt. Washington as either a safe or dangerous place to ski is an important variable in this investigation. In this study 69% percent of participants feel strongly that Mt. Washington is a hazardous place to ski. Table 19 shows that no one disagreed or strongly disagreed with the statement "Mount Washington is a dangerous place to ski;" the most passive responses were from three participants who were neutral towards the hazards and risk associated with skiing on Mt. Washington

Table 19
Perception of Mt. Washington frequency table

Is Mt. Washington a Dangerous Place to Ski

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	3	7.7	7.7	7.7
	Agree	9	23.1	23.1	30.8
	Strongly Agree	27	69.2	69.2	100.0
	Total	39	100.0	100.0	

Although participants generally viewed Mt. Washington as a dangerous place to ski, very few skiers (2%) reported being nervous or anxious about the terrain they intended to ski the day the completed the survey.

Table 20
Anxious about terrain frequency table

Feel anxious about terrain

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	15	38.5	38.5	38.5
	Disagree	13	33.3	33.3	71.8
	Neutral	10	25.6	25.6	97.4
	Agree	1	2.6	2.6	100.0
	Total	39	100.0	100.0	

The perception of the mountain as a dangerous place to ski is important because it could logically be assumed that this cautious view of the terrain would manifest into specific risk management protocols. However, false positive feedback from unsafe habits such as regularly traveling in avalanche terrain without formal training and proper rescue gear can override common sense and provide a false sense of security in the mountains.

Employing specific systems of preparation such as checklists can help guard against the aforementioned cognitive errors. According to Tremper (2013), studies have shown that using checklists engages the logical brain and can result in better decision-making (p. 34). Utilizing checklists are preemptive risk management measures that have the ability to positively or negatively influence the outcome of a ski tour. Survey results in Figure 11 show that 20% of participants strongly agree with using a checklist, 20% agree, 25% are neutral, 10% disagree and 23% strongly disagree.

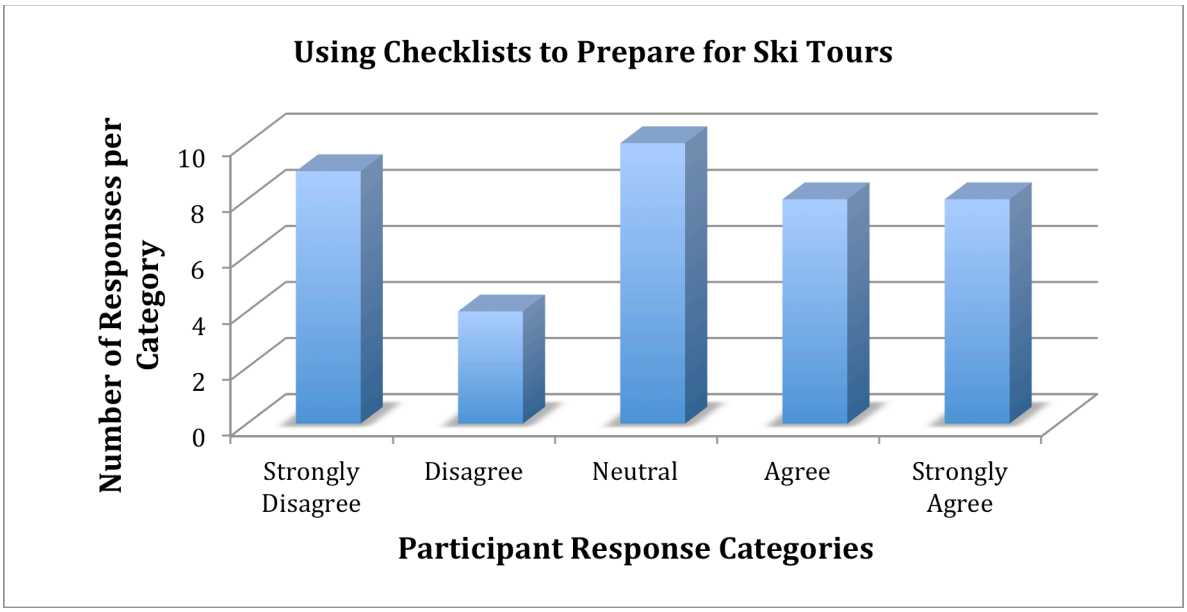

Figure 11. Distribution of responses for skier use of checklists to prepare for ski tours.

Field notes taken during survey administration tend to corroborate quantitative results indicating a lack of formal risk-management procedures among backcountry skiers in Tuckerman Ravine. The notes provided below were taken over the course of four days of heavy skier traffic at the Hermit Lake shelters.

Field Notes:

March 7th, 2014

Avalanche Danger: Moderate

1) Skiers, 1 male, 1 female. Male read avalanche report, no discussion with other group member.
2) Group of 5. No avalanche gear, 1 woman.
3) Skiers, 1 male, 1 female. Couple, skiing the ravine for the first time together. Female skier is PSIA trained and works at a ski resort in the region.
    a. Quote from female skier "I know how to get down the mountains but I leave the decisions to him."
4) Two skiers go right past avalanche bulletin. No discussion
5) Group of 2 skiers 1 male, 1 female. Short discussion about route. Didn't read avalanche report.

March 8th, 2014

Avalanche Danger: Moderate/Low

1) Two groups went by and never stopped to talk with snow rangers or ski patrol.
    a. Good/newish gear.
    b. Didn't look at avalanche board
2) Group of 3 skiers, 2 female, 1 male. All young. Seemed rushed.
    a. Didn't want to take survey
    b. Never looked @ avalanche board

March 15th, 2014

Avalanche Danger: Considerable/Moderate

1) Slow in the ravine. Most people are skiing the Sherb (no avalanche hazard). One group of 2 women didn't want to take survey.
    a. Overall people seem very conservative with decision-making.
    b. Only 1 party, maybe 2, entered the ravine.
    c. One solo skier up Hillman's Highway.

March 16th, 2014

Avalanche Danger: Considerable/Moderate

1) One climber (male) in Harvard Cabin. Brought new beacon but has never turned it on.
    a. Taking diligent notes about weather.
    b. Climbing partner forgot his beacon – generally a very casual approach to beacons.
    c. Decided not to bring beacon on hike into Huntington.
    d. Note: They turned around in Huntington and didn't climb intended route.

A more extensive list of field notes and journal entries can be found in appendix B. The notes provided in the previous section are emblematic of typical skier and climber behavior in Tuckerman Ravine in early to mid spring. The field notes I was able to collect support the earlier mentioned quantitative results showing that while 70% of the survey population strongly agrees that Mt. Washington is a dangerous place to ski, many participants (56%) still travel in groups in which all skiers aren't equipped BSP, and haven't taken a formal avalanche education course (69%). This study also found that there was no significant association between gender and perceived danger, X^2 (2, N = 39) = 4.39, p = .111, meaning that men and women were equally as likely to view Mt. Washington as a dangerous place to ski. Table 21 shows the results of a chi-square test of independence examining the association between gender and perception of Mt.

Washington as a dangerous place to ski.

Table 21
Chi-square test for gender and perception of Mt. Washington

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.395[a]	2	.111
Likelihood Ratio	3.885	2	.143
Linear-by-Linear Association	4.211	1	.040
N of Valid Cases	39		

Similarly, no association exists between gender and practicing with a rescue beacon on a regular basis. Both men (50%) and women (51%) reported that they strongly disagree with the statement *I frequently practice with my beacon throughout the season.*

A chi-square test of independence (Table 22) was performed to examine the association between participants' gender and whether or not a participant considered how an accident would affect boundary actors (people not present in the decision making process but who would be affected by a positive or negative outcome). During their decision-making men were more likely to consider boundary actors than women, X^2 (4, N = 39) = 10.13, p = .038.

Table 22
Chi-square test for gender and how others would be affected

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.132[a]	4	.038
Likelihood Ratio	9.502	4	.050
Linear-by-Linear Association	4.427	1	.035
N of Valid Cases	39		

A chi-square test of independence (Table 23) was also performed to examine the

association between participants that had thought about potential mistakes on their trip and skiers that reported imagining how mistakes would affect people back at home. The results from this test show a significant association, X^2 (16, N = 39) = 29.34, p = .022. Skiers who thought about potential mistakes were likely to contemplate how boundary actors might be affected.

Table 23
Chi-square test for skiers who thought about potential mistakes and those who considered how boundary actors might be affected

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	29.343[a]	16	.022
Likelihood Ratio	27.724	16	.034
Linear-by-Linear Association	4.587	1	.032
N of Valid Cases	39		

Key Survey Results

- Over half (56%) of the people surveyed travel in groups in which at least 1 skier is not equipped with a beacon, shovel, and probe.
- A significant number of participants (69%) did not have formal avalanche training.
- Analysis showed that higher levels of training correlated with increased frequency of beacon practice (Table 10).
- Skiers with multiple routes planned were more likely to practice with their beacons and select terrain based on the weakest skier (see chi-square test results in Tables 17 and 18).
- The skiing population in Tuckerman Ravine remains homogenous, composed primarily of Caucasian men (87%) between the ages of 25-45.
- Sixty-nine percent of participants feel strongly in their ability to abandon their primary goal.

- A chi-square test of independence revealed that women were less likely to feel as though the trip was a failure if primary objectives weren't reached (Table 16).
- Men (60%) were more likely than women (25%) to read and discuss the daily avalanche forecast (Table 15).
- Women were more likely than men to regularly backcountry ski with a female leader (Table 6) and none of the male participants agreed or strongly agreed to frequently skiing with a female leader.
- Male skiers were imagining how potential mistakes might affect people at home (Table 23).
- The Perception of Mt. Washington as a dangerous place to ski did not positively correlate with a specific gender.
- Fifty-nine percent of participants did not formulate and share a detailed emergency plan with the rest of their group.
- Eighty-two percent of participants said their primary reason for backcountry skiing was to have fun.
- Almost half of the participants (48%) acknowledge that their skiing abilities outpace their backcountry specific abilities.
- Only 20% of participants report performing multiple snow stability tests over the course of their trip.

Limitations

A limitation to this study was the small participant population. The low numbers of participation combined with my survey design made it difficult to perform chi-square tests of independence for many variables. The test was frequently, if not always, violated due to multiple

cells having expected counts less than 5. In an effort to correct for this error, survey responses were binned, reducing the Likert scale from 10 points to 5. Violations of the test continued post binning.

The survey design posed limitations as well. The survey was cumbersome for participants and in a few instances this appeared to lead to boredom and fatigue and as a result some responses were rushed. Additionally, the length of the survey meant that on busy days I spent too much time explaining the survey and assisting with questions with a small group of people while potential participants continued up the mountain. Future investigations using a similar survey instrument and site should employ two researches during this phase. This is a course of action I considered but since I had not addressed multiple researches in my IRB proposal I erred on the side of caution and continued to work alone.

The language used in some survey questions was overly vague and caused confusion and unintentionally nested inquiries. These variables also made it challenging to test the strength of responses across multiple questions during the data analysis phase. Questions needed to be more direct and concise.

The weaknesses in the survey design partially stem from a general unfamiliarity with quantitative analysis. While the design and implementation phases of the survey were enlightening, there were unknown nuances that more experienced researchers would have caught in order to strengthen results. Additionally, during the data analysis phase an overabundance of resources were redirected to learning how to properly upload and analyze data with SPSS. Large portions of this work could have been reassigned to individuals with appropriate skillsets who would have been able to produce more reliable results in a timelier manner.

Finally, a significant limitation to this investigation was the way in which survey

participants were chosen. Initially skier traffic was slow enough that the few potential participants were easy to identify. However, on two busy weekends the absence of specific means of selection resulted in an inability to know how many skiers entered the ravine vs. how many were surveyed. Given the limited access to Tuckerman Ravine this is an error that would be easy to correct in future studies. Furthermore, the eventual location of the survey distribution was so centralized that on high traffic days backcountry skiers would become lost in the mix of climbers, hikers, and other skiers that had no intention of heading further into avalanche terrain. Potential participants were lost in the crowd.

CHAPTER 5: DISCUSSION

This investigation examined whether or not a skier's perception of avalanche terrain translated into standard risk reduction measures such as carrying basic rescue gear, taking avalanche education classes, and reading the daily avalanche bulletin. The study also examined how cognitive variables affect the planning and approach phases of ski touring. Because human triggered avalanches are an emergent property of the alpine ecosystem their existence is dependent on small variables such as a skier's ability to disengage from a goal. The overarching goal of the project was to establish more effective means of preemptively managing risk for travel in complex avalanche terrain. The conscious inclusion of diverse perspectives is considered a fundamental step in creating robust pre-trip strategies and plans. Consequently this research also assessed the role gender plays in the decision-making process.

Perceptions and Preparations

Mt. Washington is similar to other high alpine environments near large cities (e.g., Mt. Rainier) in that it regularly draws large crowds into difficult terrain and unpredictable weather. As a result the mountain has a regrettably justified place on the list of the world's deadliest

mountains. In order to gain a complete understanding of the decades of misfortune on Mt. Washington readers are advised to read *Not Without Peril* by Nicholas Howe (2001). For the purposes of this study it is suffice to say that Mt. Washington and Tuckerman Ravine are dangerous places to climb and ski. In the early stages of data analysis it was promising to see that almost 70% of the skiers surveyed strongly agreed with the statement that Mt. Washington is a dangerous place to ski. However, this well shared perception did not result in the widespread use of basic backcountry skiing risk management measures.

Many skiers continue to enter Tuckerman Ravine and its complex avalanche terrain without employing standard risk reduction measures such as carrying BSP (56%) or taking a formal avalanche education course (69%). Jill Fredston and Doug Fesler (2011) advised that at a minimum all backcountry skiers carry and know how to use BSP and that those who do not are greatly reducing the likelihood of surviving an avalanche (p. 111). Avalanche accidents are unique because they leave a very short window of time in which to perform a successful rescue. For fully buried victims Falk, Brugger, and Kastner (2002) found that "at 15 min the survival probability (92%) is markedly higher than previously assumed, but the survival function then drops precipitously to only 30% at 35 min" (p.1). This narrow time frame means that beacons "are a necessity for anyone willfully entering avalanche terrain" (Ferguson & LaChapelle, 2003, p. 83-84). In the event that a rescue has to occur skiers should rely on specific training and skills guided by NDM to execute their plan. This is why consistent practice with beacon searches and mock rescues are vital to the skier and her or his partners.

However, this study found that only 12% of the survey population agreed with the statement "I frequently practice with my beacon" (another 10% strongly agreed). Additionally, of the three skiers in this study who reported having previously been involved in an avalanche

only one stated that they strongly agree to frequently practicing with their beacon. This is interesting given that these skiers presumably know better than most that in the event of an accident a fully buried skier's chances of survival hinge upon her or his partners having sufficient beacon skills to find them.

AIARE approved avalanche courses have a well developed rescue curriculum that provides skiers with the skills needed to perform a rescue and ways to continue practicing and learning. An example of the effectiveness of formal training was found in a chi-square test of independence (Table 10) that shows an association between participants with some level of formal avalanche training and participants who reported frequently practicing with beacons. The test result also highlights the positive impact formal avalanche training can have on preemptive decision-making. Practicing with a beacon means that a skier has accepted the idea that avalanches are a genuine objective hazard and that the skier is susceptible to being caught in one. This is an important realization because it negates the out of sight out of mind trap that can occur in feedback poor systems.

Skiers also reported doing a sufficient job of gathering longitudinal date about the CPS they intended to enter. Sixty-four percent of participants reported reading the daily avalanche bulletin even when they didn't have trips to Tuckerman Ravine in the immediate future. Additionally 56% strongly agreed to having preemptively read and discussed the avalanche report on the day they took the survey. This corroborates findings from the 2013 Eastern Snow and Avalanche Workshop showing a significant increase in website traffic over the previous three years. Checking the daily avalanche and weather forecasts is the first thing skiers should do before they head out on a trip (O'Bannon & Clelland, 2012, p. 30). Ideally each skier will have the opportunity to read the forecasts alone and then share their interpretations and questions with

the group. This will help prevent any one person's perspective from becoming the dominant interpretation of the information.

The big picture though still shows that many skiers went into complex avalanche terrain without everyone in their group carrying BSP, without formal avalanche training, and most people not practicing with their beacons on a routine basis. Additionally, 53% of the survey population disagreed with performing multiple snow stability tests on slopes they intended to ski.

These results correlate with national statistics showing that from 2000-2012 half the avalanche victims in the United States did not have basic rescue gear (Tremper, 2013, p.16). Additionally, general findings from this investigation reinforce results from a 2014 study that found that on average avalanche information doesn't translate into tangible risk reduction measures (as cited in Michelson, 2014). Randi Kruse, the research consultant leading the study, attributed this disconnect to a decrease in skills and abilities received from avalanche education (as cited in Michelson, 2014). Whether or not the decrease in skills results from lack of practice (e.g., this study found that 51% of skiers did not frequently practice with beacons) on the part of the skier, skiers never having actually taken a formal course, or a result of poor curriculum design, requires additional research.

Gender in Backcountry Skiing

Outside of a small hut in the cascades an instructor was driving home her point that skiing in mixed gender groups decreases the likelihood of being caught in an avalanche. Many avalanche educators and researchers acknowledge the fact that men are more likely than women to be involved in an avalanche however few studies examine why. Sole and Emery (2010) scratched the surface of the positive impact women have when skiing in mixed gender groups but their work has yet to be repeated with significant depth. Karl Geisler (2014) acknowledged

gender as an important variable in his ISSW article *Explaining Human Factor's With Behavioral Economics*, but only made reference to the work of Sole and Emery (2010) and McCammon (2004) and does not spend considerable time looking at gender as a unique variable. This is a familiar theme within avalanche literature, the topic of gender is addressed but the depth of understanding remains limited.

Results from this study show that women are generally underrepresented in the backcountry skiing community. The fact that the survey population for this investigation (n=39) includes only four female participants is in and of itself evidence of the disproportionate rates of participation between men and women. According to the 2012-2013 SIA *Snow Sports Participant Study* women accounted for 27% of the non-resort backcountry skiers. However Leslie Shay Bright's 2010 dissertation found that based on the 523 people "who responded to the gender item for him/herself and others in their group, 19.5% percent of the total group members were female" (p. 110), in Tase's (2004) investigation women accounted for 9.4% of the survey population (n=1463), and in this study women comprised 10% of the total survey population (n=39). Additionally, a 2013 report released by the American Mountain Guide Association (AMGA) showed that women made up 11% of the guiding population. While there is some disparity between these various studies the take home point is that there are significantly less women backcountry skiing than there are men and these women are filling fewer leadership type roles.

In an interview with Lynne Wolfe, avalanche specialist Carol Ciliberti reported that "[w]hen men are involved often times one or more of them wants to be in control" (2004, p.13) Statements such as these reinforce results from this study showing that women are rarely in leadership positions in backcountry skiing groups on Mt. Washington. Sixty-six percent of the

survey population strongly disagreed and 13% disagreed with the statement *I frequently ski in groups where women are the primary leaders*. Additionally, a chi-square test of independence revealed an association between gender and skiing with a female leader, $X^2(3) = 21.255$, $p \leq 0.05$. Based on this result it seems that when women are leading groups they are leading with or for other women but not in mixed gender groups. None of the men in this study reported frequently skiing with a female leader. According to ski guide and coach Nasheed Ahmed Henderson, the leadership gap manifests because when women are skiing in mixed gender groups "it is very easy for them to take a back seat and be a passive member of the decision making team" (as cited by Wolfe, 2004, p. 13). The lack of female leadership within backcountry ski groups manifests from outside societal influences as well as internal levels of confidence.

An article published on November 6th, 2014, to Outdoor Research's *Verticulture* blog brings light to the fact that some female guides feel as though they are imposters within the guiding community. Aspirant guide Sheldon Kerr hypothesized that women have developed a sense that they don't belong among IFMGA mountain guides and thus legitimize their own inferiority. Kerr continued, "its reinforced because we feel defeated before we even start. Fewer women do it, so we have fewer role models" (Kerr as quoted in Oliver, 2014). The distinct absence of female role models was brought up during at least once in all of my interviews with female backcountry skiers. The absence of female mentors means that it is more challenging to acquire the initial skills required to safely travel in the backcountry as well as continuing to progress within the sport. One interviewee discussed wanting to push herself and do bigger things but there are not any girls around to do it with (personal communication, 2014).

The role gender plays in the backcountry skiing experience, particularly as it pertains to avalanche safety, requires further investigation. This is especially true in light of results from a

2010 study that found that "women and those traveling with women were less likely to experience an avalanche incident" (Sole, Emery, Hagel, & Morrongiello, 2010, p. 1). A homogenous group of people attempting to navigate a complex environment will be exposed to greater risk than a more diverse one. This is because people with different identities are treated differently, thus they possess different experiences and ways to manage life events. "We can expect, however, that identity differences lead to experiential differences that in turn create tool differences" (Page, 2007, p. 307). Recognizing and honoring individual identities as part of the risk management process is important because it creates a more adaptive human system that possesses diverse means of engaging with the complex physical system. If Erin Dessert had been able to vocalize her intuitions about skiing Tunnel Creek the group might have more effectively adjusted to the current conditions.

Examples of a potentially adaptive group exists in the results of two separate chi-square tests examining three different variables, gender, perception of failure, and reading the daily avalanche bulletin. One test found an association between gender and reading the daily avalanche report before leaving on a trip (Table 15). This result shows that on the day the survey was administered men were more likely to read and discuss the daily avalanche bulletin than women. This is considered positive preemptive risk management behavior that should be a part of any group. The second chi-square test (Table 16) found that women were less likely to consider the trip a failure if primary objectives weren't achieved. The combination of these two results highlight unique skillsets and perspectives skiers bring into the backcountry based on their experiences within and outside of the backcountry skiing community. One method of managing risk is not better than the other, nor can it stand alone as a solitary decision making point. It is the effective melding of approaches that has the potential to provide greater margins

of safety when traveling in a complex environment.

When accounting for gender as a variable with potential positive affects on the risk management process it is important to keep in mind that each person is unique. Making assumptions based on gender or appearance can easily create a gender heuristic. Professional guide Margaret Wheeler (2008) advised that "when dealing with human factors related to or exacerbated by gender, don't let your perceptions or stereotypes be a 'gender heuristic trap.' (p. 28). Wheeler is suggesting that backcountry skiers take the time to assess the people they are skiing with just as earnestly as they would the avalanche bulletin or a snow stability test. Having a clear understanding of how individual ski partners think, what their tolerance for loss is, what their ski specific as well as non skiing related goals are, and what unique skills they bring to the group, helps avoid a gender heuristic trap while simultaneously honoring outlooks and abilities that might be unique to a particular group of people.

The Complex Adaptive System

Like most groups of people, backcountry skiers aren't entirely logical actors. A 2014 study investigating how backcountry skiers make decisions found that "most of the decisions backcountry users are making are emotional" (Kerr as quoted in Michelson, 2014). Additionally, because people are often limited to making decisions based only on the information in front of them they "fail to allow for the possibility that evidence that should be critical to our judgment is missing – what you see is all there is" (Kahneman, 2011, p. 87). Similarly, Holland (2014) suggested that from the complex adaptive system viewpoint the 'fully rational' agent assumption is overly strong and that in order for someone to be fully rational they must act "on full knowledge of the future consequences of its actions, including the responses of other agents to those actions" (p. 24). In light of our innately irrational decision-making processes skiers should

embrace their own *anitknowledge*. *Antiknowledge* is what people do not know, and in complex dynamic environments what we don't know is far more valuable than what we do (Taleb, 2010, p xxv).

Skier uncertainty can also derive from changing or misunderstood variables within the personal or interpersonal complex adaptive systems. Over the past decade a growing body of avalanche safety research has focused on the effects of individual behavior on the group decision-making processes. A more complete risk-management process now includes an assessment of the cognitive and emotional states of the individual(s) choosing to ski in avalanche terrain. Taking this a step further requires the inclusion of boundary conditions and actors within the decision making process as well. Incorporating variables that aren't physically present is an easy and efficient way to create more adaptive individual and groups systems. This study found an association between skiers who imagined potential mistakes and those who had thought about how people at home would be affected if they were involved in an accident (Figure 21). Thinking of hypothetical errors requires imagination and allowing boundary actors to influence the ongoing decision making process helps broaden and diversify individual risk perception. Both of these behaviors contain elements of systems thinking.

Avalanche educators and researchers have spent significant amounts of time unpacking cognitive biases, traps, and errors as critical variables in the decision making process. Recently, some avalanche professionals have gone a step further and proposed community wide paradigm shifts in order to reduce avalanche related fatalities. According to Tremper (lead forecaster for the Utah Avalanche Center) and Tom Murphy (Operations Director for the American Avalanche Institute) in order to create a new normal the entire backcountry skiing community (e.g., recreational users, guides, equipment manufacturers, film companies, and avalanche

professionals) needs to focus on ways to more effectively communicate a specific avalanche problem so that people avoid certain terrain rather than try and manage it (as cited in Michelson, 2014).

At the time of this writing numerous ski movies have been released publicizing the beauty that exists in the winter alpine environment and promoting the continued progression of freeride and backcountry skiing. However, none of the major film companies have created full length features dedicated to explaining the actual risks associated with the sport they are promoting. If the aforementioned paradigm shift is going to occur then changes in the way avalanche safety is presented to the masses must be a factor in ushering in change. The same story told over and over again leaves individuals with a false understanding of their place within and control over a system. The images people are presented with have an important effect on the manner in which they perceive an environment. A study by Kimberely Wade, Maryanne Garry, Don Read, and Stephen Lindsay (2002) exposed 20 adults to a fake childhood event (riding in a hot air balloon) and were asked to reflect on those images during interviews and guided-imagery exercises. When the study was completed 50% of the subjects had created partial or complete false memories of riding in the air balloon (p. 1). Images create our perception of reality and if the images we are constantly provided are of one type of person successfully engaging in one type of behavior in the same system then there is little reason to envision a different outcome for oneself. This is what leads skiers down a similar path as Taleb's (2007) Thanksgiving turkey.

Acquiring perspective stems from the process of mapping which "takes reality and encodes it in the internal language" by assigning specific and unique names to objects (Page, 2007, p. 30). Thus, people with two different perspectives "map reality differently into the same internal language…or they map reality into different internal languages" (Page, 2007, p. 30).

More simply, people are either using a shared perspective to create a different model of the environment or they are using the same model but viewed through the lens of different perspectives. What allows multiple perspectives to be of value is that they provide a realistic structure of the environment and possess "meaningful relatedness" (Page, 2007, p. 33) to the problem at hand. Given that each person possesses a unique string of life experiences he or she will have a novel way of looking at an environment compared to the people they are with. However, it is a person's ability to share their perspective in a relevant manner that allows for the development robust plans.

In order for dynamic plans to develop, everyone within a group needs to feel comfortable sharing their views. In backcountry skiing this means allowing dissenting or conservative voices just as much airtime as goal oriented ones. The presence of multiple perspectives is important because each individual skier resides on a spectrum of risk tolerance that consciously or unconsciously influences their decision-making. A skier's individual perception of risk is their awareness of the likelihood of loss or injury within a specific environment (Ajango, 2005, p. 291). Risk tolerance is "defined as the amount of risk an individual is willing to accept in the pursuit of a desired goal" and it will "make a significant difference in that person's decision-making process" (Ajango, 2005, p. 291). Thus, backcountry skiers are tasked with assessing the likelihood of an accident occurring in a certain environment and then determining how much they are willing to gamble on the likelihood of a particular outcome.

Another way to frame this process would be to ask an individual, or a group, what their desired goal is and how much are they willing to give up in pursuit of that objective. Having a clear understanding of goals is important because a skier's objectives for the day influence their "persistence during failure and their emotional reactions to failure" (Lench & Levine, 2008, p.

137). The ability to disengage from goals is a necessary counterbalance to goal persistence. Wrotmen et al. suggested that abandoning goals and desires is "especially adaptive when situations are uncontrollable or goals are unattainable" (as cited in Lench & Levine, 2008, p. 128). Results from this investigation show that skiers felt confident in their ability to abandon their goals for the day, 69% strongly agreed that they were willing to walk away from primary desires and none of the participants disagreed or strongly disagreed. An association was found between individuals who thought about how boundary actors would be affected by an accident and a skier's willingness to abandon the day's primary objective. Individual's who thought of boundary conditions and actors were also likely to disengage from goals. By creating a more complex decision making community these skiers have increased their ability to pursue alternative plans in the face of uncertainty or deteriorating system conditions.

During the course of this investigation numerous ski guides and avalanche professionals advised that skiers preemptively develop multiple plans for their trip as a means of facilitating goal disengagement. An important stipulation when diversifying ski lines is that all of the potential descents are considered enjoyable. Therefore, diverse goals and diverse understandings of what constitutes an enjoyable backcountry experience should be shared during pre-trip planning. This study found that 82% of participant's primary motivation for skiing was to have fun on their trip. While this may seem like a benign statistic ranking fun as a primary ski objective is actually positively associated with sensation seeking (Sole & Emery, 2008), "which has been linked to risk taking" (Breakwell, 2007, p. 50). Interestingly, Sole and Emery (2008) found that individuals who ranked "having fun" as their primary motivation for backcountry skiing were more likely to experience an avalanche accident (p. 4). As a community, backcountry skiers can begin to diversify fun by sharing and validating less popular but

beneficial reasons for being in the mountains such as for exercise, connection with nature, time for reflection, and spiritual connectedness.

Numerous field notes from this study showed significant numbers of skiers heading up to Tuckerman Ravine for reasons other than to ski its steep slopes. Many would hike to the Hermit Lake shelters simply to enjoy the view and being a part of the skiing and climbing community. These skiers would typically rest and then enjoy the long descent back to the parking lot via the Sherburne ski trail. This trail is a moderate run with no potential for avalanching on or above the run. The Sherburne is a great example of a fun plan B or C when conditions further up the mountain prove to be too uncertain or are obviously dangerous. If the decision making process is considered its own nested system, creating diverse egress options are the small nudges that can make the system more efficient and robust.

Using foresight to expand decision-making abilities requires the use of a skier's System 2 thinking. In order to encourage forethought McCammon (2009) suggested skiers and avalanche educators adopt the introspection model as a way to guard against individual heuristics traps (p. 646). This approach mitigates the risks associated with human error by having backcountry skiers "embark on an introspective journey to identify personal weaknesses that may derail decisions" (McCammon, 2009, p. 646). Tremper (2013) called these personal weaknesses *disaster factors*; these are the unique human variables that contribute to poor event outcomes for a particular individual (p. 38) (e.g., being overly competitive, fixating on goals, and being rushed during the planning and preparation stages of a trip). Personal disaster factors can be preemptively addressed through preflection activities such as writing premortems and outlining the heuristic traps an individual skier is most susceptible to. Attending to psychological variables before a trip even begins can create small nudges that positively impact the evolution of a

complex system. These seemingly small steps also help develop metacognitive skills, which are "our knowledge of, and ability to control, the state and process of our mind" (Adams, 2005, p. 132). Possessing greater insight into primary means of thinking allows skiers to take their own cognitive strengths and weaknesses into account throughout all phases of a ski tour (Adams, 2005, p. 132). The aforementioned steps are often more difficult to accomplish than simply checking batteries in a beacon or making sure a first aid kit is in someone's backpack.

In order to facilitate cognitive risk management and systems thinking approaches, results from this study were used to create a seven-item checklist for backcountry skiers and groups to use before they enter avalanche terrain. Note, robust means something "works well across a wide range of circumstances, brittle means it only "works well under a limited set of circumstances, and poor means it is "very vulnerable to breakdown" (Cook & Woods, 1999, p. 23)

1. What are *my* goals and what are *our* goals for the day?
    a. Are they robust, brittle, or poor?
2. Is the environment becoming more or less complex? How quickly?
    a. Are changes in weather, snowpack, terrain exposure, and etc. rapid or slow?
3. How are assumptions going to be challenged today?
4. How are today's goals going to affect boundary actors and conditions?
    a. If something goes wrong how will people at home be affected?
5. What are my personal disaster factors?
6. Has everyone taken standard AIARE recommended risk reduction measures?
    a. BSP, checked avalanche report & discussed, traveling in a small group, taken an avalanche education course, etc.
7. Is the group an adaptive interpersonal system?

a. Is the group dynamic robust, brittle, or poor

b. Do group members include and support diverse perspectives and decisions?

Future Research

While reviewing literature and data for this investigation it became apparent that much of the research in backcountry skiing is gathered outside of the actual experience of skiing. Participants typically fill out forms online, or via mail, well before or well after they have entered avalanche terrain. This is important because post hoc investigations rely on hindsight, which is often flawed. "A general limitation of the human mind is its imperfect ability to reconstruct past states of knowledge, or beliefs, that have changed" (Kahneman, 2011, p. 202). Retrospective exercises are influenced by hindsight bias wherein people "assess the quality of a decision not by whether the process was sound but by whether the outcome was good or bad" (Kahneman, 2011, p. 203). Consequently, in order to develop a clearer sense of how skiers are interacting and making decisions future research must focus on acquiring field data.

Similarly, backcountry skiing statistics are blurry because many of the reported figures and statistics derive from gear sales and reported avalanche accidents. These methods provide insight into who is buying gear and who is involved in accidents, but they don't offer a clear picture of the vast majority of skiers that avoid being caught in slides and therefore might be employing effective risk management procedures.

During the literature review it became clear that avalanche research remains widely dispersed and somewhat difficult to access. There is no central platform of curated avalanche safety literature to which professionals and novices alike can refer. Research remains nested in pockets such as the American Avalanche Association, International Snow Science Workshops, American Institute for Avalanche Research and Education, Colorado Avalanche Information

Center, Utah Avalanche Center and avalanche.org (as well as numerous other national and international sources). The centralization of avalanche research would help organize what has been studied, how individual investigations were performed, the effectiveness of various methods, and most importantly what topics should future research be exploring in greater depth.

This study found that one of the subjects requiring further investigation is multi-process approaches to decision making. While significant work has been done in the area of human factors, heuristics traps, and naturalistic decision-making, an equally vigorous investigation should be undertaken to understand how aware skiers are of their own thought processes. Metacognitive knowledge is a necessary tool for safe backcountry travel. Some ski guides and avalanche professionals feel that having an awareness of personal knowledge and antiknowledge is the defining trait of an expert. "The mark of a true avalanche master is realizing the limitations of our knowledge…and acknowledging that the world is a much more random place than we would like to believe" (Temper, 2013, p.33). Future research should investigate how skiers are attending to uncertainty and acknowledging personal limits to knowing.

Conclusion

In complex systems there are few easy answers, and because change is constant predictions often miss their mark. Every time a skier enters the mountains they are witness to something new, novel, and distinctly separate from the average post-industrial western existence. The modern world is composed of feedback rich systems that have seemingly predictable networks providing rapid understanding of decision-making abilities. Minimal cognitive strain with maximum efficiency is often the goal of decision makers within these environments. Yet, the requirements for safe backcountry travel stand in stark contrast to those of the aforementioned community. The mountains require methodical reflection supported by diverse

decision-making systems and a willingness to abandon or significantly alter goals. Moreover, well-rounded risk management derives from outward analysis of the complex physical system as well as an inward analysis of the complex adaptive system. In the wake of a fall that claimed the lives of four of his climbing partners Edward Whymper (1871) succinctly summarized alpine risk management philosophy; "[d]o nothing in haste, look well to each step, and from the beginning think what may be the end" (as cited in Howe, 2000, p. V).

In an era of rapid athletic and technological progress the backcountry skiing community should pause and take an honest look at how future growth can be achieved in a manner that insures the safety of people and the preservation of the environment. An assessment of human and ecological costs needs to be conducted in order to pinpoint ways to reduce harm caused in either system. Encouraging this systemic change requires a conscious realignment of the philosophies and social norms broadly shared by the community. The definition of what it means to be *good* backcountry skier should become more robust and include how individual actions might affect boundary conditions and actors. "As competition increases for finite resources, like fresh powder, conflicts are bound to surface. It's not enough to just take a class and have the right gear; you need to show some responsibility to your fellow skiers" (Loomis, 2014). Broadening and diversifying backcountry skiing risk-management philosophies can help deconstruct the historically myopic perception of alpine success.

Acceptable long-term progress will derive from a common understanding that diversifying and disengaging from goals is acceptable behavior, especially in the face of uncertainty. A culture that supports walking away just as much as sending it will be able to facilitate healthy and mindful growth. To date there has been little quantitative research gathered investigating how frequently and for what reasons people choose to abandon their alpine goals.

The results of a chi-square test of independence revealed that women are less likely to feel as though the trip is a failure if primary objectives aren't met, however this result requires further testing and analysis. It is important to note that gender and unique perceptions of failure should be incorporated into nontraditional decision-making tools. As new safety paradigms are created, a conscious effort to diversify the backcountry skiing community should be made in order to see recurring problems, such as goal fixation, through novel perspectives. Fresh viewpoints can enhance the awareness of both the depth and limitations of individual and group knowledge.

Avalanche terrain is sensitive to small decisions. When the backcountry skiing community reflects on avalanche accidents red flags appear with greater ease than foresight would have allowed. People propose hypothetical small shifts that could have helped avoid disaster. The unfortunate reality is that there will always be data and clues that skiers miss and the environment will always remain sensitive to small perturbations deriving from inaccurate mental models. Fortunately, if small changes can have a large negative effect then they can also have a large positive effect. Thus, skiers have the ability to preemptively influence the unfolding of their trip by making slight adjustments to their methods of preparation and philosophical approaches to the alpine environment.

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Appendix A

Sample Field Notes and Journal Entries

This section contains samples of field notes and journal entries written during my time in the field. Some of the entries are very rough, egregious spelling and grammatical errors have been fixed otherwise these are as they appear in my notes and journal. The notes are discontinuous in their content, length, and detail, because I was administering surveys at the same time as I was taking notes and the surveys were my priority. The journal entries were put together at night and at home based off of my field notes. These were submitted to my mentor and second reader most weeks.

2/27/14 - 3/2/14
Journal Entry:

The 27th was my first day in the field on Mt. Washington. I realized quickly that the cold weather would change my location if I wanted to get a significant amount of surveys completed. The winds on the first two days were driving temperatures well below zero thus I was forced to use the hermit lake shelter as my interview location. I had initially anticipated being further up the ravine trail however this location was too exposed to the elements and ultimately unsafe for potential participants and myself.

People were generally enthusiastic and curious about the study. No one had very specific questions for me, however I did see it spawn a productive conversation within one particular group. It was interesting to see which questions people really latched onto. I realized that I would have to include solo skiers and snowboarders who I hadn't really created the survey for. The wording of some questions isn't appropriate for this user group and some questions are barely relevant (i.e. does everyone in your group known and understand the emergency plan). I am

concerned with how I will account for these individuals within the final analysis. However I think having more surveys than too few is a better problem to have.

3/7/14
Field Note:

Surveys are tough this AM – some great groups who I would love to interview but no dice. Guess this will be observational data…..maybe I need to work on the sales pitch. Ironic how the ideal groups are the least likely to participate.

- One group just arrived, party of 2, male and female skier, new gear, only male read avy report, no discussion afterwards.

- Group of 5 French Canadians arrived, never looked at avy board. No discussion about route. One female in the group, all seem very young and eager to get up the mountain. Asking lots of questions but not listening to advice. Seemingly little in the way of trip planning.

- When speaking with one woman about her trip she said "I know how to get down the mountain but I leave the decision making up to him." This is her first time in Tuckerman, she is a PSIA certified ski instructor, she knows exactly what the problems are a) communication b) asking questions c) sharing info.

- Two skiers cruised right past avy board, no discussion.

3/8/14
Field Note:

Busy day in the ravine. Mixed user groups. Two groups went by and never stopped to speak with ski patrol or snow rangers – good gear – didn't look @ board, these are the people I would love to talk to. How do I access them? Could I do a post survey?

- Party of 3, 2 women, 1 guy, in a hurry, didn't want to take the survey. Again ideal group. Young and hard charging. Never looked at big board avy advisory (maybe looked at trailhead or home??)

3/9/14
Field Note:

- Group of three snowboarders, no experience but very willing to listen to advice and our conversation (between me and Beth).
- JP will be here in the coming weeks. We will have to coordinate plans to figure out who is handing out surveys where.
- Very slow day on the hill!!

3/12/14 - 3/16/14
Journal Entry:

This last time spent in the field was by far the least productive in terms of surveys completed. We received 14+ inches of snow on Wednesday night and Thursday morning, thus it is understandable that people would shy away from entering the ravine during a high avalanche warning. I was able to join the snow rangers on their fieldwork the day after the storm and sure enough there was widespread avalanche activity. However by the time Saturday arrived numerous routes had been moved to a moderate rating while others remained at considerable. During this time I witnessed maybe 5 parties attempt routes with true avalanche hazard. Selfishly it would have been nice to obtain more data however more important than my academic interests is the safety of backcountry users, and to that end I was very impressed with the conservative measures most people were taking during and immediately after the storm (really good resort/lift access skiing could have influenced the lack of BC travelers as well).

I did however obtain seven more completed surveys, thus I am only 3 away from my intended goal. I am hoping to have 50 completed by the end of this upcoming weekend, which will most likely be my final weekend in the field collecting data.

As has been the case all along I took detailed notes and observations in addition to the surveys. I continue to find at least one or two parties that cruise right past me and the avalanche

information board, additionally I continue to have individuals who decide not to participate (interestingly these individuals do not seem to be in a great rush and they often stay and ask questions about the conditions).

Additionally, I had an interaction with an individual (climber) that was very interesting. This individual woke up early with me and the hut caretaker and joined us for coffee and the early weather report. While we were sitting at the table waiting for the days forecast we started discussing beacons. He said he had just purchased his and that he was still learning how to use it. Now in his defense I am very impressed because most climbers don't wear beacons in Huntington ravine (this is another thesis in and of itself). However on the other hand I found it amazing that he would take such care to record the day's weather in order to make safe and accurate decisions throughout the day but would be willing to climb with a partner who had forgotten his at home. This seems odd and almost contradictory to me. This individual is a) intelligent b) aware of objective hazards c) in the habit of minimizing his exposure to high consequence risk by choosing not to travel during high winds and low temperatures. Yet this same individual feels it is safe to travel with a partner who isn't wearing a beacon? How and why does the perception change when it comes to avalanches? Conversely I have seen people wear airbags, avalungs, beacon, shovel and probe to ski lines with no avalanche hazard whatsoever. To me there is a missing link when it comes to perception. We are able to mitigate cold weather and high winds because we have experienced what it is like to be too cold. However, since most people don't have the neural networks capable of producing clear images of what a snowpack is telling us and what an avalanche looks, feels, and sounds like, errors arise in our perceptions of an environment and the resulting safety preparations taken in order to travel in those areas. At the end of the day I give credit to this individual for looking at the world around him, listening

and watching as closely as possible and then ultimately making the decision to stay in the cabin and wait to climb another day. Ultimately his low level of risk tolerance and patient relationship with the natural environment enabled him to make a decision that didn't require the use of beacons, shovels, or probes, just a good book.

It was nice meeting JP the other researcher on the mountain. He is in the process of earning his PhD and is including a chapter on the "human element" in his final thesis. His work is different enough that we often aren't looking for the same participants but similar enough in scope that we will be able to share and collaborate once our data analyses have been completed. I am looking forward to more conversations with JP. His knowledge and experience will be a huge help.

I am beginning to think about whether or not social interactions can create flow states. If it is true that flow states elicit the release of neurochemicals such as norepinephrine, dopamine, and serotonin, and social dynamics in outdoor recreation generally create optimal experiences, then it can be hypothesized that our prefrontal cortex shuts down earlier than anticipated when preparing to enter avalanche terrain (trailside fMRIs are a long ways away so for now researching the effects of social interactions on the PFC will be important). This could be an interesting perspective/insight into pre-trip decision-making and the effect it has on group and individual safety.

Looking forward to the upcoming week in the field. More snow on the way and hopefully more survey participants. As always I have attached a picture from the previous field session. This is taken the day after the big storm. Clearly lots of avalanche activity. Many thanks to the snow rangers who allowed me to tag along and get some first hand experience with snow analysis and fieldwork.

Appendix B

PARTICIPANT CONSENT FORM

Title of Project: Backcountry Skiing Preemptive Decision Making

Name of Researcher: Blake Keogh

1) I have read and understood the attached information sheet giving details of the project.
2) I have had the opportunity to ask the researcher any questions I had about the project and my participation in it, and understand my role in the project.
3) My decision to consent is entirely voluntary and I understand that I am free to withdraw at any time without providing a reason.
4) I understand that data gathered during this project may form the basis of a report or other form of publication or presentation.
5) I understand that participation in this survey may delay my travel time and thus alter the course of my/our trip. I am solely responsible for any actions or results of those actions that occur after having participated in the aforementioned study.
6) I understand that my name will never be used in any report, publication or presentation and that every effort will be made to protect my confidentiality.
7) I am aware of the inherent dangers in backcountry skiing and snowboarding and I am choosing to partake in this/these activities of my own free will.
8) I understand that backcountry skiing/snowboarding can be a physically, cognitively, and sometimes emotionally strenuous activity that may take place in cold and inclement weather conditions on steep and slippery mountain terrain and that uncontrolled falls and injuries do occur and that medical assistance may not be immediately available and that if I am injured as a result of engaging in such snow-related activities that I and I alone am responsible for my actions.
9) I am fully and personally responsible for where and how I choose to ski. This includes the selection of ascent and descent routes, the speed at which I ski/snowboard, and the manner in which I approach natural and manmade obstacles or hazards. I acknowledge that I and I alone made decisions on which backcountry safety equipment to carry and that I am solely responsible for understanding how to utilize this gear for its intended and appropriate use.
10) I am of legal age (18 or older) and competent to sign this release form.
11) I have signed and initialed this document of my own free act.

Note: If you wish to find out more information please contact the researcher or head faculty research supervisor.

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Participant's Signature:_____

Date:

Participant's Name (printed):_____

Date:

Researcher's Signature:_____