Ergonomics in cold climate technical apparel:
An exploration of protective clothing in extreme winter sports and the psychological effect it has on an athlete's performance.

ABIGAIL BURGESS

Honours Design Research Thesis

Bachelor of Fashion (Design) (Honours)
Royal Melbourne Institute of Technology, Australia.

Fashion & Design Research B
Semester Two, 2019

Ergonomics in cold climate technical apparel: An exploration of protective clothing in extreme winter sports and the psychological effect it has on an athlete's performance.

"How does designing specialist, ergonomically driven protective apparel for winter sports increase how safe or secure an athlete feels when wearing the clothing?"

Abstract 1

Introduction 2

Background

An introduction to cold climate sports. 3

Part One

What defines technical apparel? 4

Part Two

Textile technology. 6

Part Three

Sensation seekers and their "second skin". 8

Discussion 11

Conclusion 13

Bibliography

References 14

Figure Listing 16

Abstract

Within the outdoor apparel industry there are various components required in creating weatherproof and climate specific clothing. Clothing taken into the wilderness by freeride skiers and snowboarders must fit seamlessly to an individual's muscle structure. Ergonomically driven clothing made for this type of sport must not only keep an athlete physically safe and comfortable but mentally secure. Freeride skiing and snowboarding is considered one of the most dangerous competitive and recreational snow-sports with riders navigating often uncharted natural terrain. To understand how clothing affects these athletes' psychological, and consequently physical performance, one must address ergonomics, body movements, and individual variations within designing specialist protective outdoor apparel. This thesis examines a wide range of examples from scientific journals to address different components required for technical apparel design. These include studies on human factors, ergonomics and materials, and case studies on extreme athletes and their psychological tendencies. Rossi's heat balance equation: M-W=E+R+C+K+S (2009), garment design, insulation and body mapping in Havenith et al. (2011), and the Sensation Seeking Scale (SSS) developed by Cohen (2016) are all primary examples used within this thesis to further prove the link between the comfort and protection of technical apparel, and how it can positively impact an athlete's performance within extreme winter sports. These three sections are paramount in the design of outdoor apparel, in order to enhance an athlete's experience and create garments that work with the body to process both bodily and environmental changes. In addition to this, advances in research into the field of cold climate technical apparel will be investigated, alongside its enormous potential to develop more innovative and sustainable ways to design customised and specialist clothing for athletes exposed to the harsh climates seen in the remote mountains around the world.

Introduction

Everything taken into extremely cold climates must keep a person alive. Each item has a specific role in the outdoors in order to keep its user safe and protected in often dangerous and potentially life-threatening conditions. In order to aid the performance of today's athletes in cold climate sports, clothing must address the ergonomic design and protective aspects of technical apparel and outdoor clothing, allowing them to feel comfortable and able to perform to the best of their ability. This thesis will investigate ergonomics in cold climate technical apparel and how designing specialist, ergonomically driven, protective apparel for winter sports has the potential to increase how psychologically safe or secure an athlete feels when wearing the clothing. In order to comprehensively understand the components required in technical apparel, various scientific journals involving studies on human factors, ergonomics and textiles have been primary sources in considering design for human movement in specific environments. To support these design claims, numerous studies considering athlete psychology in high risk sports will aid in analysing technical apparel design in winter sports and the effect it has on an individual's performance. Winter sports apparel design has increasingly been a topic of relevance in today's culture with sports becoming more accessible and dangerous as we continue to push human limits. Thus, the demand for highly functional outdoor apparel is changing how clothing is made and redefining how winter apparel can enhance all aspects of an athlete's performance.

Since the beginning of competitive snow sports, there has been preferred clothing styles, brands, fits and materials. An individual's outfit is a variable that requires the designers to consider scientific and statistical data to determine sizing, insulation and articulation. Blocks are then created based on anthropological data and desired company silhouettes. Within the realm of freeride skiing and snowboarding, there are a variety of other factors that are considered and are imperative in the design process. For the purpose of this research, an understanding of terms such as ergonomics, technical apparel, and freeriding is necessary in order to comprehensively understand the significance of ergonomics in cold climate technical apparel. These issues will be addressed in using the UTCI clothing model, developed around garment design, insulation and body mapping (Havenith et al. 2011). This model interrogates the theory of thermal equilibrium in air trapped between the body and clothing layers, in order to understand the microclimates created. Further investigation into ergonomic design through the example of articulation techniques in real outerwear is then addressed. The M-W=E+R+C+K+S thermal balance equation (Rossi 2009) is then applied to these articulation techniques, using modern textiles in order to perfect the microclimates within an athletes garment, or their "second skin" (Das Neves et al. 2015, pp. 6135). In addition to garment related terminology, there are several terms related to measure of performance and high-risk sports that will be outlined and defined to give the reader a greater understanding of risk perception and clothing worn in extreme environments. The Sensation Seeking Scale (SSS) developed by Cohen (2016) measures risk perception is extreme athletes. This scale, combined with Zabardast (2018), a freeride film that captures the raw emotions and problems athletes face when in the field, illustrates the varying factors that affect the mental state of an athlete. With an understanding of these theories, garments worn by freeride athletes and alpinists can be interrogated in order to further understand and develop apparel that optimises the performance of the users.

Background

An introduction to cold climate sports.

With the rise of snow sports, particularly snowboarding in the US and Canada, there has become a need for more refined clothing as people continue to push the limits of what the sport can be. Freeriding is a classification of skiing or snowboarding that involves navigating often steep, unforgiving and unstable natural terrain. Usually taken place in the backcountry regions of the world (Swiss, Italian and French Alpes, Alaska, Pakistan, Argentina, Chile, Scandinavia, and most recently Antarctica) freeriding as a recreational sport has no set rules, aside from avalanche risk and safety guidelines, and simply relies on an individual's ability to steer themselves over cliffs, through deep snow and other off-piste (ungroomed) terrain. With an increase in affordability of commercial backcountry skiing, mountaineering and freeriding, the market for highly technical snow apparel has increased considerably, with many well-travelled and seasoned ski-bums seeking more challenging terrain, now accessible by light plane and helicopters (heli-touring). Not only do these thrill seekers aim to score deep, untouched powder (colloquial: pow), but they also need clothing that will cater for a variety of snow conditions worldwide. And, as is often the case, the clothing owned must be versatile and able to be worn on the way up the mountain, as well as down, or while doing a variety of other intensive sports such as ice-climbing, skinning (attaching synthetic strips to the base of skis to go uphill), hiking with skis or snowboard in tow, or lugging a gear sled. This element of variability in activities done while wearing, donning, and doffing various garments calls into question the comfort factor of garments, and how athletes and other freeride snow enthusiasts psychologically connect themselves to their garments throughout the course of their adventures.

Part One

What defines technical apparel?

Naturally existing environmental factors that affect design in cold climate apparel are as diverse as the people who use the end products. However, unlike clothing designed for warmer climates, technical winter apparel must consider arguably more vital human factors. A decrease in temperature is directly associated with hazard, making clothing a necessity for humans to maintain core body temperature of vital organs and extremities, along with dexterity in limbs and digits. A drop in temperature and exposure to cold will gradually cause loss of blood flow to the extremities as the body attempts to maintain a core temperature around the vital organs. As a result, both designers and scientists are challenged with ways to design apparel for humans in order to give them as much movement and agility as possible whilst still maintaining maximum warmth and comfort in cold climate sports apparel. With cold climates requiring multiple layers of clothing, and warm climates demanding less clothing, the difference between the two climates clothing markets is highlighted, and thus asks the designer to step out of their comfort zone and design user-centred products that consider the microclimates created within the two extremes of temperature. Bougourd et al. in 'Factors affecting the design of cold weather performance clothing' (2009) addresses viable solutions to ergonomic design and sustainability in this industry such as using Computer Aided Design systems to map and measure movement on real bodies in order to design for simulated three dimensional movements. Using this method also allows for heat mapping on the body, challenging designers to plan an effective system to trap or release heat throughout the body to keep the wearer comfortable. Closure systems are also integral in either venting or strategically blocking air flow, in addition to easing donning and doffing for the wearer. Gathering data surrounding requirements for garments, for example: climate, environment, geography, types of users and their body structures, is essential in design for both summer and winter technical apparel (pp. 170, 171).

Within garment design, insulation and body mapping are used to create an equilibrium between body heat trapped between the garment and the skin, and heat expelled out to the surrounding air. The UTCI-Clothing Model (Havenith et al. 2011) interrogates this system, proposing that donning and doffing, or adjusting layers is a learnt pattern of behaviour that humans have close to perfected as a response to change in environmental conditions or climate (pp. 462). In addition to adding or subtracting layers, expanding surface area of material relative to skin increases insulation and traps larger amounts of body heat, thus keeping an individual warmer. A practical example of this would be entering cold conditions with and without gloves and a beanie: An individual without gloves or beanie will feel significantly cooler due to heat lost through the head and hands as the body tries to maintain its core temperature. It is imperative that designers consider garment design and insulation in order to create garments that are not under or over-insulated, in loft or length, for the climatic conditions their product is functioning in. If any of these factors are not carefully considered, athletes may find themselves hyperthermic in warmer temperatures, or hypothermic with impaired function in extremely cold conditions.

With different personal garment insulation and waterproofing preferences becoming global standards for different temperature ranges and weather conditions, addressing body mapping from a comfort or fit perspective and using the body's natural lines to drape and cut fabric in one piece is a more recent method of pattern cutting developed in Sweden (Lindqvist et al. 2014). This method of cutting directional patterns and eliminating seams allows garments to be equally graded up and down as needed when insulated layers allow it. The ergonomic possibilities for high end, performance skiwear using this method of construction lend themselves to producing more technical garments, precisely tailored to an athlete's body to shape their preferred level of insulation. Pictured in *Figure one* are Royal National Lifeboat Institution (RNLI) volunteers in the Helly Hansen *Ægir Ocean Dry Suit* (Helly Hansen 2019). Although it is not skiwear, sailing and the conditions professional sailors, or in this case volunteers, face are not dissimilar to those frequented by freeride skiers. This image encapsulates the purpose of outerwear, which is to protect and to accommodate any activity the user may undertake. As a suit produced to shield the entire body, from head to toe with the exemption of hands, against outside conditions, its oversize design allows for layers to be worn underneath and provides ample room between the skin and textile to trap and warm air. Physical activity done while wearing such an item will result in sweat and radiant body heat, thus requiring the outerwear textile to breathe in order to keep

Figure one:

Helly Hansen (2019), RNLI volunteers from Dunbar Rescue.

This image gives an example of extreme weather conditions catered for by Ski and Sailing clothing brand Helly Hansen. Clothing designed for these conditions must not only function as a comfortable garment, but also be a barrier between the skin and the elements, thus being a lifesource for the people donning the garments in these conditions.

sweat off the body in order to maintain the comfort of the user and balance between outer air temperature and trapped warmth (Havenith et al. 2011). Although not made through Lindqvist's techniques, the air balance is further aided by the articulated design of the suit, by which Helly Hansen pattern blocks have been refined through years of analysing their preferred sailing customer body type. This articulation throughout, including a welded diagonal front zipper, articulated sleeves, knees, hood and an adjustable waist and leg hems allows users to customise the suit to their preferred size depending on weather conditions. These features grant the wearer easy use of the garment as the articulation remains the same when adjusting size depending on current weather conditions (Lindqvist et al. 2014). Examined through both Lindqvist's directional pattern cutting techniques and the UTCI Clothing Model, the *Ægir Ocean Dry Suit* presents key elements of functional outerwear designed for extreme conditions sailors may face, providing them with peace of mind in knowing their garment will perform when presented with less than ideal environments and climatic conditions. Examining techniques used in outerwear and the construction of garments in relation to the body is imperative in designing outerwear that works with the user at an elite level. This enhances their performance and acts as a second skin to further reduce the risk of injury or a drop in execution of technique in freeride athletes or alpinists taking part in high altitude winter sports.

Part Two

Textile technology.

The mental stability of an athlete is vital in performing in a sport at an elite level. Within this chapter, the combination of physical and psychological components that go into making a winter garment function cohesively with the user in its intended environment will be addressed from the perspective of textile technology, relative to Havenith et al. (2011) garment design, insulation and body mapping. Rossi's equation for thermoregulation (2009) will further assist in clarifying the necessity of textile features in outerwear textiles and garment components for the technical apparel market. The equation is as follows:

> "M (metabolism) – W (mechanical work) = E (heat transfer by evaporation) + R (heat transfer by radiation) + C (heat transfer by convection) + K (heat transfer by conduction) + S (heat storage)" (Rossi 2009, pp. 4).

One of the more well-known names in the outdoor textile market is Gore-Tex Brand. Their outerwear products are observed throughout a series of simulated indoor tests which scrutinise the material and system of the textile, alongside human performance and field testing (Gore-Tex 2019). By donning apparel that has been tested in conditions replicating those where the products are intended to be used, the brand is able to deem textiles fit or unfit for use in technical apparel and outerwear in extreme conditions (ibid. 2019). The Arc'teryx *Alpha SV* jacket in *Figure two* and *Figure three* is an example of carefully considered outerwear for high altitude extreme sports such as freeride skiing or snowboarding, and alpinism (Arc'teryx 2019). Arc'teryx products are also developed alongside the latest windproof, waterproof and breathable textiles, that are designed for efficient movement in alpine environments (ibid. 2019).
To understand the properties, technology and design process of the *Alpha SV* jacket, the M-W=ERCKS formula has been applied. This will then be further analysed from a psychological perspective using perception of performance through garment design. The production of a technical jacket comparable to the *Alpha SV* jacket would require the 'M' of athletes – alpine rock climbers, ice-climbers, hikers, freeride skiers and other alpinists to be tracked and analysed. The number derived from 'M' is then subtracted from the 'W' or how strenuous the athlete's activity is. This heat production equation is then equal to 'E' which is regulated by the wicking of the textile and how well it draws sweat away and out from the inside of the garment, plus (+) 'R' which is determined by the thickness, materiality, colour and reflective properties of the inside and outside of the textile plus (+) 'C' which is regulated by the textile trapping air and sweat between the fabric and the skin to heat or cool the body, plus (+) 'K' by which the textile itself traps air or water particles inside it in order to heat or cool, plus (+) 'S' through the process of sweating, the fabric then releases the sweat in order to cool the body (Rossi 2009). Combined, these things produce the heat balance equation.

Moreover, when high end Gore-Tex products are introduced into the picture, the textile becomes much more responsive to the user, changing the microclimates produced within the layers between skin and textile, and textile and outer environment. In this particular example, due to the jacket's minimal seams, bonded materials, specialised Gore-Tex fabrication and carefully considered articulated design, this product provides breathability, a free range of movement and a fully featured hood, pit zips and abrasion resistant construction for use in the harshest environments imaginable in cold climate sports. While 'M' would remain low, provided the participants are fit, calm and familiar with the conditions, 'W' is variable and dependent on the sport or the amount of physical work. With the presence of a Gore-Tex membrane, 'E' allows evaporated sweat to be expelled into the outside environment through layers without retaining moisture through microscopic pores in the membrane. In the three-layer structure of the material, the brushed inner lining decreases material surface area touching the skin or other layers which in turn increases moisture wicking. These three layers also contribute to 'R', which is determined by the thermal retention properties of the Gore-Tex and its ability to trap or release air from the microclimate inside the jacket in order to retain just enough body heat to keep the user comfortable. Good thermal retention is essential in the comfort of a garment in cold climates, notably for a cold climate athlete's mental wellbeing. In addition to textile construction and technology, various vents on a garment, zippers and storm covers help to keep water out or cool the user down during wear, since frustrated and hot, or depressed and cold freeride skiers or alpinists are more likely to perform less confidently in comparison to a thermally

Figures two and three:

Arcteryx (2019), Mens Alpha SV Jacket.

Arcteryx products are some of the most highly regarded technical outdoor products on the modern market. This image captured the seamless Alpha SV jacket which has been specifically tested and manufactured for alpinism and extreme alpine sports. From minimal and articulated seaming, to the latest seam sealing and Gore-Tex textile technologies, this jacket is a force to be reckoned with.

balanced athlete. 'C' then allows the different layers to pass heat through the fibres of the textile to heat or cool the air between each layer between the individual's skin and outer environment, and 'K' measures the amount of trapped air inside each layer of clothing. Finally, 'S' which is determined by the textile used, in this example a Gore-Tex membrane and an outerwear material which is developed in layers predominantly using Polytetrafluoroethylene (PTFE) based products, which although excellent for waterproof and breathable textiles, is an environmental pollutant. Layers of the Gore-Tex membrane are typically sandwiched between an inner lining material, and a Durable Water Repellent (DWR) coated nylon shell, to produce a waterproof and breathable textile. All these work together to form an equilibrium between M-W and E+R+C+K+S, thus providing a sufficient system that performs under the conditions presented in freeride and high altitude alpine sports. This suggests that there is a direct link between mental performance and long-term exposure to cold, thus providing a basis for ergonomic design in outerwear that is developed and tested in the field for the exact needs of individual groups of freeride skiers and snowboarders or alpinists. By mapping the areas of the body prone to sweat, heat, chill, friction or abrasion and interviewing athletes to gather data around their mental performance while wearing various outerwear products, garments like the Arc'teryx *Alpha SV* jacket can be specifically manufactured to act as a second skin for athletes tackling extreme cold conditions.

Part Three

Sensation seekers and their "second skin".

With advances in technology and a better understanding of body mapping technology in recent years, technical apparel has become incredibly specific to certain sports, with scientists striving to create garments that are planned in relation to the body. However, no matter how technical a garment is, if the wearer does not feel comfortable in it, the garment will take a toll on the athlete's performance. Research into anthropometric biomechanics to create clothing that follows the 'topography' of an individual's body to form the perfect outfit with regards to their physical, mental, social and cultural needs has become an increasingly relevant conversation. Thus, outerwear developers should consider that

> "Clothing, due to its contact with the user, acts like an extension of the body such as a "second skin", which, in turn, is essential to optimise the interface between product and user in order to avoid any discomfort." (Das Neves et al. 2015, pp. 6135)

Those who take part in extreme alpine sports are sensation seekers (Cohen 2016). Hence, outerwear should work cohesively with the user to 'optimise' the performance of sensation seekers. There are many other varying factors that affect the mental state of an athlete. With mental health being an ever-increasing issue in competitive sports due to persistent pressure to push the limits of extreme sports and explore the few unknown high places of the world, more refined, lighter and warmer clothing is needed. It gives users peace of mind to know their garments will work with them subconsciously, and not put more unnecessary strain on their bodies.

Zabardast (2018), a freeride film that captures the raw emotions and problems athletes face when in the field, gives a picture of how freeriders overcome and conquer mental and physical challenges together. Combining this with the high levels of alpinism and mountaineering required to take on such a mission, this film features extensive, unedited narration of the group's experiences. The clothing worn by the team illustrates how garments, although sponsored, work cohesively with freeride athletes in a variety of weather conditions to protect them so that they do not have to consider the mechanics of the garment. It is only put on or taken off as they so wish, which is largely dictated by temperature and precipitation. This action of donning or doffing a garment also acts as a risk perception action, such as taking a calculated risk to take off a garment if it poses a risk to anything the athlete may be doing (Cohen 2016). These calculated risks are part of the Sensation Seeking Scale (SSS), which measures "thrill and adventure seeking, disinhibition and boredom susceptibility and experience seeking" to provide an individual with an overall SSS score (ibid. 2016). In *Zabardast* (2018), the high-risk nature of the expedition required the group to be proficient and safe, carefully planning their trip around time of year, weather conditions and clothing needed (See *figure four* and *figure five*). Not only would thermoregulatory requirements in clothing for their trip be substantial due to the remote and freezing environment, but their pre-existing knowledge of the mountains and each individual's preferred layering system would require different cuts, styles and materiality of garments as mentioned in part one and two of this thesis. Even so, in the heart of the Karakoram Range in Pakistan, during a vertical ascent on the final face the team climb, one of the team, Thomas Delfino, still finds only his hands are chilled to the bone, due to wearing only liner gloves to ensure full dexterity in his fingers:

> "Attracted like magnet to a vertical wall of snow, Helias, Zak and myself start the attack on the mountain. A real monster, for me the thrill goes up one notch. Finally, a face I really want to go. The hand gripped around the ice axe is completely frozen. Because of the ice, Helias insists to rope me in for the first turns. Great, I was not planning on sliding towards my death. It's steep, very steep, but the snow is good and I'm feeling it. I let the rope go" (Zabardast 2018, 42:53)

Although wearing full insulation and outerwear at the highest peaks in full sun, it is still windy and freezing. And with a fresh coating of snow avalanche risk is high. Delfino speaks after spending multiple days tent bound after choosing to descend an earlier face due to an even greater avalanche risk, however the climb up and freeride down this face immediately cheers him up. Not only did the descent of the earlier face take a toll on Delfino's mental state, but the

Figure four:

Picture Organic Clothing (2018), Passing time throughout a blizzard.

Figure five:

Picture Organic Clothing (2018), En route to the next ski face.

Documenting their trip to Pakistan to ride one of the most challenging faces in the world, these two snapshots of the film show the unedited highs and lows of life freeriding in some of the worlds most remote backcountry. Highlighting the mental strength required to face expeditions like this, and how the clothing used in the unforgiving environment must work in harmony to keep each and every explorer comfortable and warm.

act of staying in a tent for days would increase chances of becoming cold due to inaction, requiring a change from hardwearing body-mapped outerwear to a down suit. Although somewhat comforted by the down, it is obvious that Delfino, like the other freeriders, is happiest and most comfortable in his outerwear, regardless of how cold he is at the time. As complex and trained sensation seekers one might expect the team to wear fewer layers and relish in the subzero temperatures, however at a basic level, humans need coverings to survive as temperature drops. The M-W=E+R+C+K+S formula allows this to occur providing warmth through microclimates, thus keeping the freeride athletes both warm and able to focus on their sport. Subsequently, throughout the film there is no mention of clothing, giving the viewer the opinion that there were no issues with the clothing taken and it performed in the various weather conditions presented.

Further exploration of the film suggests that the team took only what they needed for the expedition, meaning no extra items of outerwear were taken in order to cur down on weight. This left no room for fashion statement items that may potentially have increased competitive thoughts to be the 'coolest'. Branded snow apparel has always been presented as a fashion statement to those who could afford it at resorts. Being away from this mentality took pressure off the group, thus allowing their clothing to function solely as a technical garment without impending pressure from friends. Yet, although away from the peer pressure of wearing the latest colour, brand, patterned apparel, it could be argued that freeride athletes face pressure to buy into brands that feature the latest backcountry safety and technology. This need for the latest and greatest may induce feelings of jealousy and could impact the performance of a freerider or alpinist if they feel their clothing is not technical enough, thus making their performance or skillset outdated or amateur. However, this mentality is often counteracted by well used and comfortable garments owned by such athletes, as their good experiences in well-worn and broken in garments outweigh their need for a new garment. In a film such as *Zabardast* (2018), which was sponsored by sustainable French snow apparel brand Picture Organic Clothing, the team was kitted out with the brands latest collection, calling into question how comfortable each team member felt wearing the clothing, and ensuring that they were all mentally secure that the brand would provide apparel to the standard needed for the expedition. The SSS could be applied to further understand the group's experience with technical apparel taken on the trip (Cohen 2016). Provided the team members had limited experience with the brand, the element of risk involved in taking an unknown brand's clothing into backcountry Pakistan would be high, testing its limits from a human perspective in regards to the M-W=E+R+C+K+S formula, in addition to the unpredictable environmental circumstances. This calculated risk was taken by every member of the team travelling through the Karakoram Range, basing their judgement on their individual mental capacity to take on a new adventure while essentially testing the limit of the garments. Responding quickly to a change in conditions, without additional strain worrying about underperforming garments, is a key element in reducing mental stress felt by freeride athletes and alpinists, particularly for this expedition as only a couple of groups had ever attempted an excursion like the one taken on in *Zabardast* (2018). The group's decision to wear clothing sponsored by Picture Organic Clothing is yet another psychological trait of sensation seekers, consequently causing camaraderie among the group through shared risk experiences (ibid. 2016). Although a calculated risk, the technical outerwear worn by the group in *Zabardast* (2018) was not only a positive addition to Delfino's experience, but to the whole group, despite Delfino having chilled fingers. Thus, proving that the garments taken into the Karakoram Range worked cohesively with the freeride athletes, in various weather conditions throughout their experience, to protect them and work in sync with their bodies to subconsciously act as a second skin in order to protect them from the elements. Subsequently, the group's mental health, regardless of highs and lows throughout the trip, ended on a high, with all of the members satisfied and happy with no injuries or faults noted as a result of apparel.

Discussion

Within the ever-expanding world of exploratory textiles, there is ample room to investigate new solutions for technical apparel. Michael Stinco's Polychromelab label in Switzerland provides a real-life example of new technology that enhances a wearer's experience on the mountain while being comfortable and ergonomic. From the elimination of sewing in garment production, articulated construction, welded seaming and reversible materials that cool or heat the body relative to body temperature, his work pursues a future for multi-purpose garments that can be used for any alpine sport, and in any weather (Polychromelab 2019). Stinco actively tests his work, documenting the durability of his designs, by both wearing them himself, and placing them on altered mannequins with build in technology, to measure data in a variety of conditions in the Alps (ibid. 2019). *Figure six* depicts four Polychromelab jackets, demonstrating the raw brutality of the conditions in which Stinco tests his designs. This method of testing durability leans away from simulated commercial approaches, such as those presented by Gore-Tex, mentioned in Part Two, and lets the power of natural elements test each garment design for various lengths of time. Data is then gathered from the mannequin and any necessary changes to each garment are made. His methods are considered bespoke within the technical apparel industry due to the length of time each garment spends in development, and the limited number of garments manufactured. Such methods of testing allow designs to be produced for longevity of garment life and with low emissions, keeping textile manufacturing and outerwear production local, with strict quality control. These approaches are just a small step in reducing the harm caused to the environment by large scale brands that continue to produce new looks each season and transport products across the world, regardless of the carbon emissions and waste that unused and unwanted clothing adds to landfill.

Figure six:

Polychromelab (2017), Snow conditions testing on mannequins.

As a pioneer in new alpine clothing technologies, Polychromelab presents real, tested and durable garments that consider human factors in design

Another theory to be considered for sustainable future possibilities involves producing 'low energy' materials by mimicking existing structures found in nature. 'Biomimetics and the design of outdoor clothing' (Kapsali 2009) addresses this theory, targeting the outdoors community as a result of the clothing and textile solutions imitating biological adaptions found in animals and nature around the world. Applications for biomimetics in the textile industry can be engineered specifically for outdoors apparel, with consideration of the end user, their environment (precipitation, UV exposure, wind), and their physiology (see M-W=E+R+C+K+S formula by Rossi (2009)). For use in cold climate sports, Kapsali (2009) gives the example of Penguin physiology, by which muscles are used to pull the feathers down, against the body for swimming, and raise them outside of the water to allow for the 'afterfeather' to loft and create an insulated layer against the cold and wind. The adaptive solution presented in the paper presents a textile with two layers that are joined by internal perpendicular layers, which can be raised or smoothed depending on the level of insulation needed (ibid. 2009). Outdoor apparel on the market today requires the wearer to operate garment functions in order to maintain the perfect microclimate inside their garment. With biomimetic technologies at prototype stage, outdoors apparel could see new, self-adaptive garments becoming mainstream, giving freeride athletes even more freedom to focus on their sport, and less on the garments they take into the backcountry. Together, these two examples lay the foundation for considering how new technology, garment testing techniques and sustainable practices in technical apparel will affect the design, comfort and performance of future garments.

Conclusion

Considering the human element in design for performance clothing, rather than designing clothing for specific climates, has led to various styles emerging as part of the freeride ski and snowboard culture. These styles have also filtered down to the fashion and comfort aspects of snow clothing in recent years with the amalgamation of ski and snowboard cultures, particularly at large resorts in North America. In addition to this, innovation in the areas of technology and sustainability in the technical apparel market has been developed in recent years, and companies are examining how these things can further be integrated and tested by athletes to adapt their experiences to the effects of global warming. New sensory technologies, biomimicry, renewable energy sources and interactive fibres are all becoming a larger part of clothing design, largely in technically focused industries, which includes high end snow apparel for specific riders. With these significant changes occurring within the snow apparel industry, it is evident that rider psychology plays a major role in the design of garments. To create the ideal outfits for extreme riders, each and every detail, from the fit to the colour of a pit-zip, must be considered, to give individuals the maximum amount of comfort, movement and peace of mind. Shining a light on the importance of apparel in the cold climate textile industry, and analysing how the body processes extremes of temperature, can offer an insight into future design for human movement in technical clothing, and enhance athletes' performance in freeride snow sports.

Understanding the mind and body of athletes, and their influence on ergonomics in cold climate apparel, has significantly impacted the design choices of professionals in the ski-wear industry. The apparel developed is becoming increasingly technical as more products become available on the market for soft goods manufacturers. This has led to an increase in the study of clothing that seamlessly adapts to an individual's body structure, chosen sport and insulation or heat mapping. Athletes are also pushing the boundaries of human capabilities, requiring more expensive and technical apparel, designed and tested for years before it is placed into the hands of an elite athlete. All of these things ultimately affect the athlete's psychological, and consequently, physical performance. With studies on human factors, ergonomics and materials, and case studies on extreme athletes and their psychological tendencies, research into the field of cold climate technical apparel has the potential to become more sustainable, and also to mimic nature which replicates and can react to the harsh and varying conditions found in mountainous areas. By working with formulas such as M-W=E+R+C+K+S formula, founded on the basis of explaining heat transfer between garments and an individual (Rossi 2009), designers can optimise their technology-driven performance wear to allow athletes to feel physically safe and psychologically secure in the knowledge that what they take to the peaks of freeride snow sports will be suitable for the conditions they may face.

Bibliography

Anatomy of a snowboarder: Discover the hidden strengths of a slopestyle star 2017, youtube video, Olympic Channel, viewed 5 April 2019, <https://www.youtube.com/watch?v=H5MqypS-wOM>.

Arc'teryx 2019, *Men's Alpha SV Jacket Specifications,* online webpage, viewed 7August 2019, <https://arcteryx.com/ca/en/shop/mens/alpha-sv-jacket>.

Bougourd, J & McCann, J 2009, 'Factors affecting the design of cold weather performance clothing', in JT Williams (ed.), *Textiles for cold weather apparel,* 1st edn, Woodhead Publishing Limited, Cambridge, pp. 152-191.

Black, S., Kapsali, V., Bougourd, J. & Geesin, F 2005, 'Fashion and function factors affecting the design and use of protective clothing', in R. Scott (ed.), *Textiles for protection,* Woodhead Publishing Limited, Cambridge, pp. 60-89.

Cohen, R S 2016, Chapter 15: *Extreme Sport in Sport psychology: the basics: optimising human performance*, Bloomsbury Sport, London, UK, pp. 137-145.

*Conroy Nachtigall – The mission to create the ultimate alpine jacke*t 2017, youtube video, The Dyneema Project, viewed 15 May 2019, <https://www.thedyneemaproject.com/en_GB/trailblazers/conroy-nachtigall.html>.

Das Neves, EP, Brigatto, AC & Paschoarelli, LC 2015, 'Fashion and Ergonomic Design: Aspects that influence the perception of clothing usability', in *6th International Conference on Applied Human Factors and Ergonomics,* Sao Paulo State University, Brazil, July 26-30, viewed 15 March, <https://www.sciencedirect.com/science/article/pii/S2351978915007702>.

Gore-tex 2019, *Testing Gore-Tex Outerwear,* online webpage, viewed 2 August 2019, <https://www.gore-tex.com.au/technology/testing>.

Havenith, G, Fiala, D, Blazejcyk, K, Richards, M, Brode, P, Holmer, I, Rintamaki, H, Benshabat, Y & Jendritzky, G 2011, 'The UTCI-Clothing Model', *International Journal Biometeorol*, vol. 56, pp. 461-470.

Heirene, RM, Shearer, D, Roderique-Davies, G & Mellalieu, SD 2016, Addiction in Extreme Sports: An Exploration of Withdrawal States in Rock Climbers, *Journal of Behavioural Addictions*, vol. 5, no. 2, pp. 332 – 341, DOI: 10.1556/2006.5.2016.039.

Helly Hansen 2019, *AEgir Ocean Dry Suit*, webpage, viewed 5 April 2019, <https://www.hellyhansen.com/en_no/gir-ocean-dry-suit-31706>.

Holmer, I 2011, 'Cold weather clothing and comfort', in *Improving Comfort in Clothing*, Woodhead Publishing Limited, Cambridge, pp. 412-426.

Jussila, K, Valkama, A, Remes, J & Anttonen, H 2010, 'The Effect of Cold Protective Clothing on Comfort and Perception of Performance', *International Journal of Occupational Safety and Ergonomics,* vol. 16, no. 2, pp. 185-197.

Kapsali, V 2009, 'Biomimetics and the design of outdoor clothing', in JT Williams (ed.), *Textiles for cold weather apparel,* 1st edn, Woodhead Publishing Limited, Cambridge, pp. 113-129.

Lindqvist, R & Thornquist, C 2014, 'Enhanced construction technology for ergonomic clothing: a new approximation of the body and system for garment construction', in *Ambience 14,* Tampere University of Technology, Finland, 7-9 September, viewed 16 March 2019, < http://www.diva-portal.org/smash/get/diva2:887984/FULLTEXT01.pdf>

Polychromelab 2019, Alpine-proof Methodology, webpage, viewed 5 August 2019, <https://www.polychromelab.com/en/alpine-proof/>.

Rossi, R 2009, 'Comfort and thermoregulatory requirements in cold weather clothing', in JT Williams (ed.), *Textiles for cold weather apparel*, 1st edn, Woodhead Publishing Limited, Cambridge, pp.3-15.

Schinke, R J, Stambulova, N B & Moore, Z 2017, International society of sport psychology position stand: Athletes' mental health, performance, and development, *The International Journal of Sport and Exercise Psychology,* Vol. 10, No. 6, pp. 622 – 639, DOI: 10.1080/1612197X.2017.1295557.

Twenty: An accidental history of freeriding by Guido Perrini 2019, youtube video, Timeline Missions, viewed 20 April 2019, < https://www.youtube.com/watch?v=0ME_hvlaf7I>.

Zabardast 2018, Streaming video, Picture Organic Clothing, France, first viewed 7 April 2019, <https://www.picture-organic-clothing.com/en/poster/zabardast/>.

Figure Listing

Figure 1:
Helly Hansen 2019, *RNLI volunteers from Dunbar Rescue*, digital Image, viewed 20 April 2019, <https://www.instagram.com/p/BxP0xOVI9OF/>.

Figure 2:
Arc'teryx 2019, *Alpha SV Jacket Men's Front*, digital image, viewed 2 August 2019, <https://arcteryx.com/ca/en/shop/mens/alpha-sv-jacket>.

Figure 3:

Arc'teryx 2019, *Alpha SV Jacket Men's Side*, digital image, viewed 2 August 2019, <https://arcteryx.com/ca/en/shop/mens/alpha-sv-jacket>.

Figure 4:
Picture Organic Clothing 2018, *Zabardast film snapshot 1*, digital image, viewed 7 April 2019, <https://www.youtube.com/watch?v=AkigzUFr3ys>.

Figure 5:
Picture Organic Clothing 2018, *Zabardast fim snapshot 2*, digital image, viewed 7 April 2019, <https://www.youtube.com/watch?v=AkigzUFr3ys>.

Figure 6:
Polychromelab 2017, *Snow conditions testing on mannequins,* Instagram, viewed 15 June 2019, <https://www.instagram.com/p/BV90VyCly0r/>.