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Human performance and safety in Arctic environments

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ABSTRACT
The Arctic environment is exotic, cold, dark, isolated and remote, with a lack of infrastructure common in many other areas of the world. This report gives an overview of theoretical and applied knowledge on how humans may react and master challenging situations and environmental aspects in the Arctic.

The report is written with the intent to be used by students and practitioners at Svalbard in a master's programme at UNIS.

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1 Introduction

1.1 Why take Human Performance into account?

The Arctic environment is exotic, cold, dark, isolated and remote, with a lack of infrastructure common in many other areas of the world. The Arctic border is most commonly defined as the region where the mean temperature of July is below 10 °C , which includes the Arctic Ocean, Svalbard, Greenland, Alaska, Canada, and Russia.[1] The knowledge and understanding of the specific environmental challenges and risks in the Arctic are necessary to learn about to avoid risky situations, accidents and cope with potential human reactions, both for the local communities and for those who wish to travel to and work in these environmentally harsh and sensitive areas. Embedded in this, is the more profound need for awareness, knowledge and understanding of human psychology and physiology to consider human capabilities, limitations and effects when working or engaging in leisure activities in harsh environments to avoid harm and accidents.

Cold environments, such as the Arctic, are seen as more dangerous than working in warmer climate. However, research has found that the frequency of accidents versus temperature curves follow a U-shape where the best performance with the lowest frequency of accidents is at approximately 20 (Anttonen et al. 2009). Thus, both heat stress and cold stress influence performance of individuals. Cold environments affect both physical and cognitive performance of the human by reducing manual skills and alertness, discomfort and reduced decision-making ability (Balindres et al. 2016; Mäkinen, 2007). This implies that cold environments can lead to human errors and accidents. The human error perspective is in line with how several operational environments such as aviation, oil and gas, and nuclear are interested in the assessment of human performance to avoid human errors. By extending this perspective to look at the *normal variability of human perf*ormance, the strengths (as well as the weaknesses) of individuals and systems to overcome demanding, extreme, ambiguous and unanticipated situations can be emphasized.

Living, working and travelling in the Arctic means that the adaptive capability of the human is stretched to the limit due to extremes of cold, darkness/daylight and isolation. Adaptation to cold environments has been of interest in many studies (Launay and Savourey, 2009; Mäkinen, 2007). Studies have also shown individual differences in how and what symptoms individuals experience and report (Palinkas and Suedfeld, 2008). A "one size fits all" approach will not cover the complexities of human adaptation to extreme environments, but there are some general human, group and environmental characteristics that can be explained to develop strategies and understand more about what influences human performance.

To identify the risk control strategies and safety measures to avoid and adapt to threats, constraints and conditions facing individuals and groups in the Arctic, there is a need for a different approach than the organisational accidents approach (see Reason, 1997; Rosness et al. 2010). As many have pointed out, including Reason (2013), individual and organizational accidents have different causal relationships. The individual accidents (which are of main relevance for this report) are more frequent and usually have limited consequences (lost time, injuries or damage to equipment/assets) in comparison to organisational accidents (explosions, crashes, collisions etc). Individual accidents occur in systems where there are few defences and can be attributed to limited causes such as human slips, trips and lapses, and usually involve failure of personal protection which can be either mental or physical (Reason, 2013).

1.2 What influences human performance?

The Arctic environment, as any other operational environment, is a system in which performance of the human must be both adaptive, correct and timely embedded in the system for a successful outcome. *Human*

[1] See Bellamy (2010) for more information and a map.

performance is seen as the active action/behaviour of individuals for a given task or activity and *not* the consequence(s) or result(s) of an action. Although the current report mainly focuses on describing the individual, group and external environment aspects of the system that influences human performance and safety in the Arctic, the organisational dimension should not be overlooked. An organisation can strongly influence individual and group behaviour and establish and promote focus on safety, health and working environment.

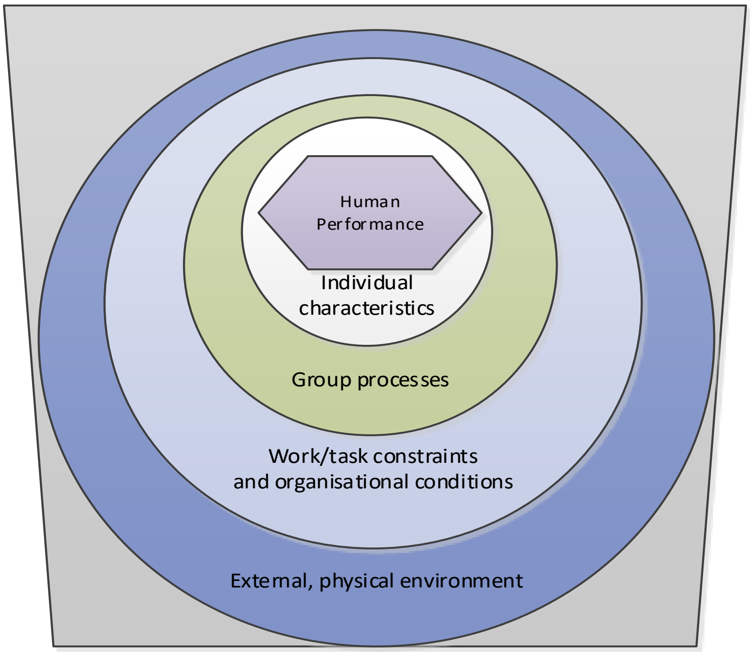

Figure 1 Human performance and safety in Arctic environments – overall influencing aspects

As can be seen from Figure 1 the influencing aspects have been grouped into individual characteristics (physiological and psychological), group processes, work/task constraints and organisational conditions, as well as external physical environment. The need to investigate the influencing aspects or contributing factors to error as well as those factors that improve the ability to perform well in an environment is emphasized such as training, awareness and strategies for coping with threats and improvement of decision-making processes.

Individual characteristics is the knowledge, skills, physical properties, abilities and other characteristics of the individual worker.

Group processes can influence decisions and actions in ways that are not predictable from the characteristics of individuals.

Work/task constraints and organisational conditions are constraints and factors such as planning, organizing, difficulty, time (time of day and length), equipment, policies, management, procedures, selection and training. These are important because they can have a strong impact on safety, and they are often easier to change than the individual characteristics.

External physical environment includes sources of danger and a number of constraints. In contrast to work constraints and organisational conditions, there is very limited scope changing the physical environment. Many factors are beyond human control (e.g. darkness, cold), and other factors cannot be changed due to legal restrictions (e.g. wildlife).

In the Arctic, the external physical environment has a potentially strong effect on the human being and the interaction between several of these aspects will be detailed in the following sections. Both negative and positive health, safety and performance outcomes of working and living in the Arctic will be covered based on a literature review.

1.3 Structure of the report

This report will briefly introduce some Arctic environmental challenges and risks[2]. The main goal is to make the reader more aware of human capacities and limitations as seen from mainly a psychological perspective when encountering such an extreme environment. Secondly, it should enable the reader to be more prepared and to reflect on how individual behaviour and collective behaviour in groups influence the decisions made and what actions should be taken to deal with environmentally challenging and possibly risky situations to avoid harm and accidents.

Chapter 2 will present background knowledge on Arctic environmental challenges and risk. In chapter 3, different aspects of human performance and limitations are explained whereas in chapter 4 some of the human psychological and physical symptoms and reactions that may be experienced in these environments will be further elaborated. Chapter 5 touches upon the topic of human resilience vs system resilience, whereas in chapter 6 the diversity of erroneous actions will be explained.

The report is written with the intent to be used by students and practitioners at Svalbard in a master's programme at UNIS. A few of the questions that we will try to reflect on in this report are:

- How do we sense, think, react and behave in harsh environments?
- What are the potential physiological and psychological symptoms and reactions that we should be aware of?
- How can this influence the decisions that are made?
- How can this influence safety?

2 Arctic environmental challenges and risks

Knowledge and understanding of the specific environmental challenges and risks in the Arctic are necessary to avoid risky situations and cope with potential human reactions. This is true for both the local communities and for those who wish to travel to and work in these environmentally harsh and sensitive areas. Arctic environments are characterised by hash and rapidly changing weather, lack of natural sunlight in winter and continuous daylight in summer, challenging terrain, hazardous wildlife and remoteness.

2.1 Fluctuating weather

Because of the encounter between warm water and air from the south and cold water and air from the Polar regions, the weather in large parts of the Arctic is very unstable. The results can be rapid changes and large local variations, which may often pose danger to human health and safety.

Very *low temperatures* can be experienced in much of the Arctic, but there is considerable variability with both location and season. In winter, the average temperature in most parts of the Arctic is below 0°C. Several studies have shown that the exposure to cold temperatures reduces both physical and cognitive performance

[2] The list of Arctic environmental challenges and risks are not exhaustive.

(e.g. Balindres et al. 2016; Mäkinen, 2007). The excessive heat loss from the body that can be experienced in the cold may also be a health hazard due to the risk of hypothermia and frostbite, and it can lead to breathing difficulty, muscular stiffness and lowered metabolism.

The unstable weather in the Arctic often involves sudden and unexpected changes in wind speed and direction. Thus, in addition to the measured temperature, one must be aware of the meteorological effect of *wind chill*. The wind chill factor is explained as "the cooling sensation due to exposure to the wind-temperature environment" (Ahmad et al. 2016, p. 325) and is dependent on both air temperature, wind velocity and humidity. It is created as passing flows of lower temperature air sweep away the thin film of heat that our bodies create to keep us warm in cold climates. The higher the wind velocity, the higher the heat loss and stronger the wind chill factor (Ahmad et al. 2016). The wind chill temperature is the calculated air temperature that, in the absence of wind, would create the same skin surface heat loss as would be calculated from the actual windy conditions (Osczevski and Bluestein, 2005).

Polar lows, also called arctic hurricanes, are small but intense maritime cyclones that form in cold air over the oceans in the Arctic. They produce severe weather, and although most will decay rapidly when reaching land, some produce blizzard conditions over land. Polar lows are relatively short-lived, but since they are often also experienced as "appearing out of nowhere" they may pose sudden danger to humans if not sufficiently prepared. One may also encounter severe weather due to other strong winds, such as cold fall winds. These occur as cold air spill down a slope or over a mountain range, and the wind speed may change rapidly.

According to the U.S. National Weather Service a *blizzard* is defined as a storm lasting at least three hours, with sustained wind or frequent gusts of 35 mph (16 m/s) or more, in combination with considerable falling or blowing snow that reduces visibility to less than one-quarter of a mile (0.4 km) (National Weather Service, n.d.). Blizzards are usually accompanied by low temperatures. Many lives have been lost in blizzards worldwide, due to cold temperatures and poor visibility.

Fog can also be a hazard to human safety due to poor or potentially close to zero visibility. Fog in the Arctic is created due to heat exchange between the air and the sea, or between warm seawater and colder water from glaciers. This is most common in the summer when the sea water is warmest.

2.2 Light and darkness

Located at the northernmost part of the planet, the Arctic is characterised by little or no natural sunlight in winter and continuous daylight during summer. Polar night is a period of darkness that occurs when the sun stays below the horizon by at least 6° during an entire day. In Longyearbyen in Svalbard, the period of polar nights lasts from November 11th till January 30th. The period of midnight sun here lasts from April 20th till August 23rd (botanikk.no, 2012).

The light may affect humans in numerous ways. As examples, darkness and flat light may introduce physical risks of getting lost or running into dangerous terrain. Both darkness during winter and continuous daylight during summer may cause lack of sleep and poor sleep quality (e.g. Palinkas and Suedfeld 2008; Pattyn et al. 2017). Results from a study by Friborg et al. (2014) show that sleep problems, fatigue, emotional problems and health issues are more commonly reported during the winter months (darkness) than in the summer months (light). See Chapter 4 for more about seasonal mood fluctuations, and fatigue and sleep loss.

2.3 Challenging terrain

Offering a diverse landscape, including tundra, glaciers and steep mountains, the Arctic terrain can be challenging to move around in. The *tundra* is characterized by extremely cold temperatures, permafrost and snow covering during most of the year. When traveling or inhabiting the tundra, humans are exposed to several dangers. The cold temperature in the tundra, which is often combined with extreme winds, may cause frostbite or hypothermia. The tundra is often also challenging to navigate, as blizzards can obscure the landscape and reduce visibility. In addition, the landscapes are often relatively uniform, and the high latitudes make the light refract in a way that may distort the perception of distance. What is more, one may encounter predatory animals, such as polar bears, as these inhabit the Arctic tundra (Harris, n.d.).

Much of the Arctic land area is covered with *glaciers*, most of which are classic calving glaciers that move at a steady pace. Others are termed surging or pulsating glaciers, and are only found in Svalbard, on the islands in Arctic Canada and in Alaska (Jaklin, n.d.). Such glaciers normally move at a very slow pace for decades at a time. Then, meltwater formed under the glacier makes it advance rapidly, moving several meters a day, before retreating again. Due to the continuous formation of crevasses, it may be extremely dangerous to walk on fast-moving surging glaciers (Vogt, 2016). Classic glaciers may also pose danger to humans. In August 2007 seventeen British tourists were injured, some of them seriously, during an Arctic cruise in the sea off the Svalbard Islands. The vessel was sailing close to the Horn Glacier when it suddenly calved, sending ice blocks crashing onto the deck as well as in the sea, causing huge waves. Five years later, a woman died after being hit by a chunk of ice when the Esmark Glacier in Svalbard calved.

The Arctic region also features beautiful but dangerously *steep mountains*. Traveling in these mountains, either by foot or driving an ATV or snowmobile, one must take certain precautions related to the risk of rockslides and avalanches, as well as the risk of falling off mountains.

Importantly, the challenging terrain in the Arctic is often subject to tremendous change throughout the year due to shifting temperatures and weather conditions. The risk of avalanches may increase due to wind and heavy snowfalls. Massive snow and ice melting in the summer leads to increased river levels and a lot of wetland. In addition, the melting of the permafrost may lead to greater instability in steep terrain and thus increase the likelihood of land- and rockslides. In Svalbard, the melting of the permafrost is continuously monitored (MOSJ, 2018).

2.4 Wildlife

Due to the climate, which is characterized by long, cold winters and short, cool summers, there are relatively few mammals in the Arctic. However, several of the ones that do survive in this environment pose danger to human beings living or traveling there. These include *predatory wildlife* such as polar bears, grizzly bears, walruses and arctic wolves, but also animals that that may be *carriers of diseases*, such as arctic foxes. In Svalbard, carnivorous predators that may be dangerous to humans include the polar bear, arctic fox and the walrus.

Polar bears can be found on ice-covered waters all over the Arctic and are most commonly observed on sea ice habitat next to continental coastlines or islands. They hunt throughout the year, and although mostly feeding on seals, polar bears also take down larger pray. A study by Wilder et al. (2017) showed that a total of 73 attacks on humans by wild polar bears have been documented worldwide in the period from 1870 to 2014. These attacks resulted in 20 human fatalities and 63 human injuries. According to the study, adult male bears that are nutritionally stressed were the most likely to pose threats to human safety (Wilder et al. 2017). The extent and thickness of the Arctic sea ice have declined over the last decades (Stroeve et al. 2014), and in anticipation of continued climate change impacts. Wilder et al. (2017) suggest that wildlife managers prepare for more encounters between humans and polar bears throughout their range. According to section

30 in the Svalbard Environmental Protection Act, "it is prohibited to lure, pursue or otherwise seek out polar bears in such a way as to disturb them or expose either bears or humans to danger." Almost every year a polar bear is killed in Svalbard after confrontations with humans or due to safety considerations in the settlements (botanikk.no, 2012). Due to the danger of encountering polar bears in Svalbard, people travelling outside the settlements must be equipped with appropriate means of frightening and chasing them off. The Governor of Svalbard thus recommend carrying firearms outside the settlements (The Governor of Svalbard, 2016).

Walruses are large sea mammals that are very social, and they are normally found in large groups. Although walruses appear undisturbed by the presence of humans while on land, the large males are extremely territorial and will try to chase off any intruders. One should never closely approach a group of walruses, and one should keep in mind that the walrus is a good swimmer and may attack inflatables and kayaks at sea (botanikk.no, 2012).

Traveling in the Arctic, one should also be aware that animals may be carrying contagious diseases. Tapeworm is a parasite that causes permanent liver damage and, if left untreated, is lethal to human beings. There have been several reported incidents of infected humans in later years. In the Arctic, human infections are caused by contact with the faeces of the arctic fox or domestic dogs. Small rodents can function as intermediate hosts, and in Svalbard the only intermediate host is the sibling vole (Fuglei et al. 2008). In addition to being potential hosts to the tapeworm, the arctic fox may also carry other contagious diseases such as rabies. The first documented outbreak of rabies among the arctic foxes in Svalbard was registered in 1980. Clinical rabies, which affects the central nervous system, is close to 100 percent fatal in humans. However, very few cases of human rabies have been reported in the Arctic (Follmann et al. 1994).

2.5 Isolation and remoteness

Although there are some settlements in the Arctic, most of this polar region is completely uninhabited. It is therefore important to acknowledge and understand how the extreme remoteness and isolation experienced when traveling or staying in these areas may affect human beings. Sandal et al. (2006) have reviewed literature on psychosocial adaptation in isolated and confined extreme environments, arguing that "long-duration missions may involve chronic exposure to many stressors that can negatively impact behavioral health, performance and even safety" (p.281). Another study discusses how remoteness, in combination with low temperatures, wind and darkness, are the major factors affecting the ability to perform tasks correctly within allotted time (Balindres et al. 2016). The experience of physical isolation does, however, also have positive aspects. The remoteness and isolation are an attractive feature for many to get away from time pressure and everyday stress experienced in many other parts of society. Particularly, polar personnel have reported significant positive effects of sojourn in polar regions through personal growth in successfully overcoming challenging situations and finding pleasure in these types of situations (Leon et al. 2011). This can also be related to a preference for experiencing smaller communities where a culture for looking out for and caring about others is prevalent, as well as experiencing camaraderie and personal growth. In addition to the effects on the psychological and psychosocial functioning of humans, remoteness may also complicate search and rescue in case of emergencies.

3 Human performance and limitations

The ability to sense and avoid harmful environmental conditions is necessary for the survival of all living organisms. Survival is also aided by an ability to codify and learn from past experiences. Humans have an additional capability that allows them to alter their environment as well as respond to it. This capacity both creates and reduces risk

(Paul Slovic, 2000 p. 220).

This chapter will provide a simple overview of some psychological and physiological human performance characteristics and behaviours such as sensory apparatus, perception, cognitive attention, group processes and decision making. There is an emphasis on decision making in both normal and crisis situations, with examples as this is an important part of dealing with risks in field settings. The characteristics described will be influenced and affected by exposure to cold, stress, fatigue and other factors as will be further discussed in chapter 4.

3.1 Sensing the environment

In facing natural physical hazards or objects human beings must rely on their sensory apparatus, cognitive skills and understanding of the elements in the environment. As human beings we have several different senses that enable us to detect the presence of an object or event, or a change in an object or event. These senses are 1) vision; 2) hearing; 3) smell; 4) taste; 5) touch (or skin senses); and 6) body senses (Atkinson et al. 1996). As vision is our most important sense, more than half of the brain is said to be involved in visual functioning of some sort. Visual perception is what enables us to use information acquired through two-dimensional (2-D) arrays of light on the retinae by encoding this information, represent it and lastly interpret the information (Wagemans et al. 2005). The skin senses, also referred to as touch, includes three distinct responses to pressure, temperature and pain. Particularly, the ability to sense even small changes in the skin temperature is important as maintaining body temperature is crucial for survival in both cold and extremely hot environments. The adaptive ability of the temperature sense entails that after a few minutes the stimulus does not feel warm or cold for moderate changes in temperature (Atkinson et al. 1996).

3.1.1 The spectacular performance of human vision

The performance of normal vision in children, adolescents and young adults is in many ways spectacular (Davson, 1972):[3]

- We can distinguish details in the order of one arc minute. This corresponds to 1/30 of the diameter of the sun and the moon when seen from the earth and is roughly what we refer to as "20/20 vision". Adequate illumination and high detail contrasts in the stimuli are required to achieve this acuity. Visual acuity is reduced with low light and with reduced detail contrasts.
- The brightest and the darkest light signal that the eye can sense are a factor of roughly 1 000 000 000 apart. At any given moment of time, the eye can sense a contrast ratio of 1:1000.
- Children and adolescents can focus sharply on distances ranging from 20 cm or less to infinity.
- We can discriminate in the order of a million different colours (i.e. different combinations of hue, saturation and brightness).
- We can translate tiny differences in the pictures projected on each retina[4] into accurate perception of depth.

[3] See also Wikipedia articles on "Adaptation (eye)", "Color vision", and "Stereopsis".
[4] The retina is the layer of light-sensitive cells in our eyes.

- The field of vision is about 180 degrees wide. Visual acuity is much lower for objects outside the central part of the field of vision, but we are sensitive to movement of objects.

From a safety point of view, we need to be aware of conditions when the performance of human vision is less than optimal. We will discuss some of these in the following sections.

3.1.2 Night vision

The Arctic is characterised by little or no natural sunlight in winter. We therefore need to be aware of how the visual performance changes during low light conditions.

The visual system undergoes profound changes each time we adapt to low light levels. A distinct set of light sensitive cells called "rods" take over from the cones, which are active under higher light levels. The rods are "wired" (through neural connections) to provide high light sensitivity rather than high visual acuity or colour discrimination. This has several implications for visual performance:

- Visual acuity is reduced by approximately a factor of ten.
- The ability to discriminate colours is lost.
- It takes 20-30 minutes to adapt to low light if the eye has been exposed to bright light. Adaptation the other way, from low light to bright light, takes about five minutes.
- The rod system is most sensitive to blue and violet light, whereas the cone system is most sensitive to green and yellow light.
- The fovea, i.e. the point of the visual field with highest acuity during daylight conditions, is blind in night vision. Therefore, to view a dim star on a moonless night you have to direct your gaze slightly at the side of the star.
- When looking at distant objects in low light conditions or fog, the eyes tend to focus closer than the object we look at. This phenomenon, which is called "night myopia" or "empty field myopia", can lead to further reduced visual acuity and to misjudgements of the size and distance of objects (Kantowitz and Sorkin, 1983).

Note that it takes 20-30 minutes to readapt if your eyes are exposed to an episode of bright light during low light conditions, for instance if you need to examine a detailed map during an expedition in low light conditions. However, you can circumvent this problem by using red light or red glasses when you are exposed to brighter light. Because the rods have low sensitivity to red light, they will remain at least partly adapted to low light.

3.1.3 Effects of ageing

A universal effect of ageing is the gradual deterioration of the eyes' capacity to focus on close distances. People with otherwise normal vision will typically need reading glasses around the middle of their forties.

Many people experience reduced capacity to distinguish details with low contrast levels, such as grey letters on a light grey background. This is usually caused by an increasing opacity of the lenses. Such opacity also makes people susceptible to being dazzled by bright light sources, for instance when driving against the setting sun.

The capacity to discriminate colours also decreases with old age. Ageing is also associated with increased prevalence of pathologic conditions of the visual system. Pathologic conditions may, e.g., lead to

- Reduced visual acuity;
- Reduced field of vision;
- Blind spots in the field of vision;
- Poor night vision.

3.1.4 Variations in colour perception

Colour blindness affects about 8 % of all males and 0,5 % of all females of Northern European descent.[5] The most common forms involve a reduced capacity to discriminate red and green hues. About 1 % of males are affected by protanopia. This rather severe form of colour blindness is caused by the absence of red-sensitive cones. People affected by protanopia have difficulties distinguishing between blue and green colours, and between red and green colours, and pure reds appear as black.

Colour blindness is an inherited condition and no medical treatment exists. It is therefore common to screen people based on their colour perception for jobs where accurate colour discrimination is essential (e.g. train drivers and pilots).[6]

Colour perception can also be affected by the quality of illumination. Natural daylight contains a balanced mix of all hues in the spectrum and thus enables optimal colour discrimination. Artificial light sources that emit light of only one hue do not enable any colour discrimination.[7]

3.1.5 Variations in depth perception

Depth perception refers to the capacity to judge how far an object is from your eyes. Accurate depth perception helps you move safely in difficult terrain and it is also significant for your capacity to navigate in the terrain, e.g. judging distances to a given point in the terrain and judging the gradient of slopes. Indirectly, depth perception also influences your ability to judge the size of objects; if you underestimate the distance to an object, you will also underestimate its size.

Since our two eyes are positioned a few centimetres apart, the pictures projected on the two retinas will be slightly different. These differences are related to the distance to the objects that are projected on the retinas. *Stereoscopic depth perception* refers to our capacity to judge distances based on such differences. This capacity is exploited in 3D-cinemas, where polarising goggles are used to present slightly different pictures to the two eyes. Stereoscopic depth perception is very accurate under optimal conditions, and can function at ranges up to more than 100 meters (Davson, 1972). However, individual differences are large. With only one eye, very low visual acuity on one eye, or deficient coordination of the eyes (e.g. squinting) the capacity of stereoscopic vision is lost, and the person has to rely on monocular distance cues.

Monocular distance cues are the cues that work with a single retinal image (Kantowitz and Sorkin, 1983). These include

- interposition, i.e. if object A is partially covered by object B, then object B is closer to the observer than object A;

[5] See Wikipedia article on "Color blindness".
[6] Coloured spectacle lenses or contact lenses can give some improvement in the capacity to discriminate some colours, but they will not create normal colour vision in colour blind persons. Various apps for smartphones and tablets are also available which allow colour blind persons to switch in colour filters to help distinguish between, e.g., red and green.
[7] Low pressure sodium lamps emit only yellow light. These were common in street lighting in the sixties and seventies, but they have now largely been replaced by light sources with a richer and more balanced spectrum.

- linear perspective, e.g. the convergence of parallel lines with distance;
- apparent size, i.e. the smaller the size of a familiar object on the retina, the larger the distance;
- textures that become finer with increasing distance;
- effects of haze, which involves that distant objects loose contrast and become bluish;
- movement parallax, which is based on the differential speed of objects across the retina; this phenomenon is often salient when you look out of the windows of a plane during the last few minutes before landing.

Monocular distance cues can be sensitive to night myopia or empty field myopia (paragraph 3.1.2 above). If the eyes focus on a point that is closer than the object we are looking at, then the projection of that object on the retina will become larger. The object will then appear closer than it actually is if we judge the distance by its apparent size.

Distance judgements based on the effects of haze can be inaccurate in particularly clear weather conditions. Distant landmarks may then appear closer than they actually are because our view of them is affected by haze.

3.2 Situation awareness in the wild is less complex

In the natural, physical environment there are many cues that the individual needs to attend to and understand to make a decision and perform an action. When we talk about cognition and cognitive performance these relate to mental processes such as information processing, thinking, reasoning, decision making, memory and learning. The awareness of the critical risk factors in a work environment for preventing both industrial and occupational accidents have been studied highlighting the cognitive skill of situation awareness (SA) (Sneddon et al. 2013). SA has been defined in many ways, but the most cited definition is Endsley (2000, p. 5) as "*the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future*". Based on the research, the unfamiliar, beginners or novices in an environment might be able to perceive or attend to the elements in the environment but are not able to understand the meaning of the risk in the current context or be able to comprehend and predict how a situation will develop. Particularly, the ability to project what can happen in the future based on the current information of events is what separates skilled experts and experienced personnel from less experienced personnel. The concept and definitions of SA has been criticised for being too focused on awareness and somewhat neglecting the importance of the situational and context specific information and knowledge (Pew, 2000). On one side, the individual is viewed as a passive observer and information receiver, but others also argue that SA has a more dynamic nature and it is the individual's interaction with the environment that makes us able to achieve and maintain situation awareness through modification of internal schemata of what the world looks like (Stanton et al. 2013).

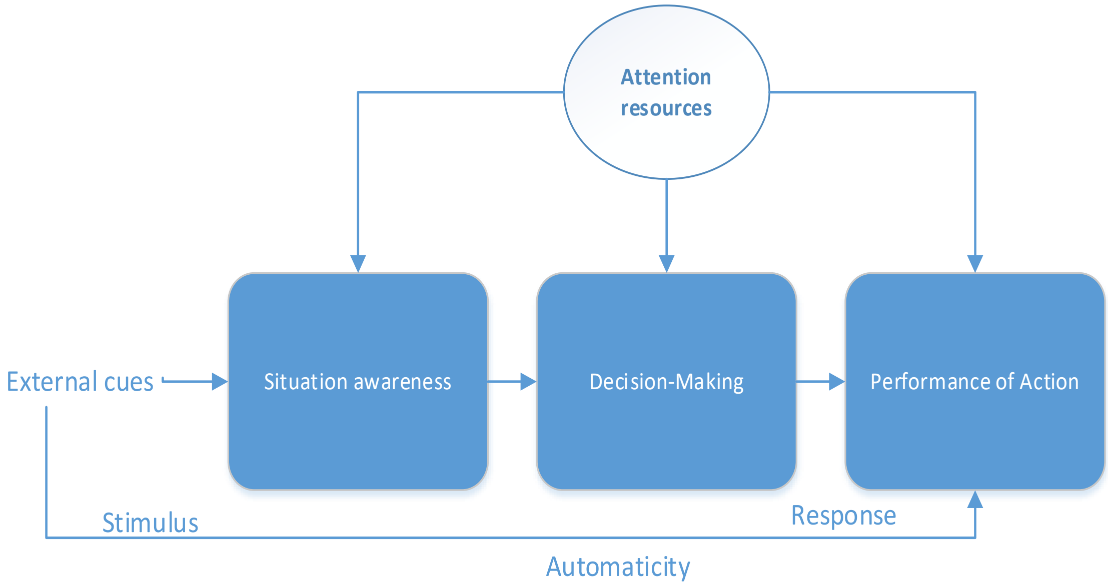

Figure 2 Automaticity in cognitive processes (adapted from Endsley 2000, p. 22).

As figure 2 shows, many responses to external cues are automatic such as for many of the actions when driving a car or snow-mobile for experienced drivers. For less experienced drivers and those unfamiliar with the current environment, however, the cognitive process is not so automated and the limited attention span and ability to acquire SA is an important part of the knowledge we have about the situation before making the appropriate decision and action to avoid risk or handle a situation.

If we compare the process of situation awareness in a cold, dark, snowy environment with a control room that has enormous amounts of data available to the operator, SA is clearly less complex in the wild based on the data available. However, the outdoor environment changes very rapidly in the Arctic and the alertness and understanding of the Arctic environmental risks and its consequences is vital to prevent harm or accidents. The lack of cues from the environment can also lead to a poorer SA and thus a poorer *operational picture*. Cognitive skills such as SA are known to be affected by conditions such as fatigue and stress in the work place (Sneddon et al., 2013). See section 4.2 and 4.3 for more about fatigue and stress. The effects of cold on cognitive performance is however non-conclusive. It seems that cold might have a more negative effect on more complex cognitive tasks that involves short-term and working memory, but in very cold temperatures the long-term memory can also be affected. It also seems that individuals are more *awaken* in cold environments, especially when it comes to more tedious tasks that require a lot of attention which leads to better performance (Færevik et al. 2016).

3.2.1 Varieties of attention

We often assume that one word is associated with one and only one "thing" or phenomenon. This is hardly the case with the word "attention". Lay persons and experimental psychologists use the term in a variety of different contexts and with a variety of meanings (Parasuraman, 1986). Here are some examples:

- *Vigilance* refers to our capacity to detect infrequent and weak signals, such as faint flashes on a radar screen, in a task requiring prolonged observation. This capacity has been studied intensively in the laboratory.
- *Focused attention* refers to the ability to narrow down the scope of attention so as to avoid interference or distraction from other stimuli. You may think of two people carrying on a conversation in a noisy cocktail party.

- *Divided attention* means that a person attends to two or more sources of information at the same time. Divided attention is typically an aspect of *multitasking*, i.e. the performance of two or more tasks at the same time. Driving a car in crowded street typically involves multitasking and dividing attention between a number of different information sources.
- We often use the term "inattention" in everyday language to characterise or explain *action slips*, i.e. episodes when our actions do proceed as planned, when we fail to do what we intend to do. You may, for instance, forget to put sugar in your tea because you are distracted or think about something else.

In the remainder of this chapter, we will discuss vigilance and divided attention. We will return to action slips in Chapter 6.

3.2.2 The vigilance decrement

As already mentioned, "vigilance" or "sustained attention" refers to performance of tasks involving detection of weak signals presented at infrequent intervals for prolonged periods of time without rest. Vigilance research was initially motivated by performance problems in watch keeping and monitoring tasks (e.g. radar operators) during the second world war. Temporal uncertainty is a key characteristic of vigilance tasks; you do not know when the next signal will appear.

The central finding in vigilance research is that the detection rate decreases after 20-30 minutes of observation. This phenomenon is called "the vigilance decrement". To achieve optimal performance in vigilance tasks such as watch keeping, inspection or monitoring, you should therefore limit the time span of continuous vigilance to 20 or 30 minutes. You can do this by introducing breaks or other job-related activity. It has been proposed that music presented at random time intervals (rather than continuously or at fixed time intervals) may also counteract the vigilance decrement (Parasuraman, 1986).

3.2.3 Divided attention, automatic processing and slips

Divided attention means that we try to attend to two or more sources of information ("channels") at the same time. A salient example of divided attention is the so-called "cocktail party effect". You attend to a single conversation in an environment where dozens of conversations run in parallel. However, in the middle of this conversation, you detect that your name was mentioned in some other conversation that you did not deliberately attend to. This suggests that the background noise that you did not deliberately attend to was subject to *automatic processing*.

Such automatic and non-attended processing dramatically enhances our capacity to handle information, since there are rather narrow limits to how much we can attend to deliberately at the same time. The capacity for automatic processing is influenced by training (Schneider et al. 1984). An important part of learning to drive a car safely is to automate a large part of the information processing related to handling the vehicle (e.g. operating the pedals and the steering wheel) so that you can free attentional resources for scanning the traffic environment. Automatic information processing is also a precondition for performing tasks that require complex coordination of movements smoothly, for instance running down a flight of stairs.

Automatic processing is thus a precondition for safe and smooth performance of many complex tasks. Automatic processing also enables us to detect signals from sources that we did not deliberately attend to, as illustrated by "the cocktail party effect". At the same time, automatic processing is at the root of a large group of erroneous actions called "slips" (Reason, 1990). Slips involve a mismatch between what we intend to do and what we actually do. They typically occur when deliberate attention is directed at something other than the present task. Slips typically involve that an irrelevant but "strong" action pattern from the individual's repertoire is intrudes into task performance. This can happen because our attention directed at something else. The good news is that many slips are detected and corrected rapidly. For a broader view of erroneous actions, see chapter 6.

To summarise, divided attention involves attending to more than one information source at the same time. Divided attention usually (perhaps always) involves automatic information processing. Automatic information processing can be enhanced by training. Automatic information processing is a precondition for performing tasks requiring complex coordination. Automatic processing can also free attentional resources, for instance allowing a skilled driver to pay more attention to the traffic environment. At the same time, automated action patterns can be susceptible to slips, often in the form of "strong" action patterns intruding into a context where they are not appropriate.

The following are examples of practical implications of research on divided attention and automatic information processing:

- Divided attention can work quite well if one source of information is visual and another source of information is auditory. For this reason, artificial voice is sometimes used in the cockpit environment to present important information in situations where the pilots focus on visual information for their primary task (e.g. during final approach and landing).

- Training can be used to automate some aspects of task performance in order to free attentional resources, as illustrated by the car driving example.

- Checklists can be used to "switch off automation" in task sequences where slips are highly undesirable. Effective use of checklists requires two persons, and explicit confirmation should be given for each task step that is performed.

3.3 Group processes

The bulk of research on decision making in groups has been done with ad-hoc groups where people have been collected just for a single experiment, rather than with natural groups where people have interacted over time. Also, much of the research has been done in indoor settings (classrooms, meeting rooms, psychological laboratories) where very little is at stake, rather than in field settings where decision-making can be a matter of life and death. This is something to reflect on when in the field where there is a need for continuous identification and mitigation of risk which requires to think ahead and sometimes make quick decisions.[8]

3.3.1 Group social norms

The endeavour of knowing how we respond in various situations and in relation to other people is something which is part of social psychology that studies how people think about, influence and relate to each other (Sutton and Douglas, 2013; Smith and Mackie, 2000). Interaction in groups has been shown to lead to formation of *social norms* in the group that cause group members to become more and more alike. Social norms can be defined as "generally accepted ways of thinking, feeling, or behaving that people in a group agree on and endorse as right and proper (Smith and Mackie, 2000 p. 173). It has also been referred to as "the way we do things around here" in a similar way as culture and this also explains how individuals have a tendency to over time *conform* to the group norms and is guided by other people' s thoughts and reactions.

[8] For more on Field Safety, see Alpay and Paulen (2014).

3.3.2 The risky shift, diffusion of responsibility and attitude polarisation

What happens if a given decision is taken by a group rather than an individual? Will the group decision reflect an "average" of the decisions that each of its members would have taken if making the decision alone? Or will the group be more prudent than "the average member"?

Empirical studies in the sixties and early seventies repeatedly found that *groups were more prone to take risks than individuals*.[9] This phenomenon was called "the risky shift". The most popular explanation was that the group setting allowed for a *diffusion of responsibility*. The idea is that if you make a decision alone, then you bear the whole responsibility for its consequences. If ten people in a group make the same decision, then each group member does not feel that he or she bears the burden of responsibility alone.

Later research work has found exceptions to the risky shift, and also examples of cautious shift where the group as a whole makes more prudent decisions than the member would have made on an individual basis. Later research has also suggested that group discussions may lead to *attitude polarisation*; i.e. the attitudes of group members tend to turn more extreme as a result of group discussions. Conspicuous examples of this phenomenon can be found in the comments fields and discussion groups on internet.

From a practical point of view, it is not necessary to know about all the subtle nuances of the academic discussions about the risky shift. What you need to know is that groups in many cases make decisions that are more risky than decisions made by individuals. If you are part of a group that makes a decision where a lot is at stake, you should therefore ask yourself or other group members: "Would you make this same decision if you alone had to bear the full responsibility of its consequences." You could also try to look back on the discussions in the group and try to decide if the group has been drifting towards taking more risk during the discussion. If the conditions permit, you may also ask the group members to record their opinions on a piece of paper before the group discussion starts. You may then go back to the initial individual opinions towards the end of the group discussion to check if the group has moved in the direction of accepting higher risk.

3.3.3 Groupthink

The risky shift, which we discussed in the previous paragraph, can occur in ad hoc groups as well as in natural groups where people have interacted for a long time. The phenomenon called "groupthink" only occurs in highly cohesive groups where the members have interacted over long time and developed norms, rationalisations and even illusions that are peculiar to the group (Janis, 1982). The "groupthink" concept was developed based on a study of disastrous political decisions that were made in groups with a strong pressure towards conformity. The decisions studied included advisory group support to Neville Chamberlain's policy of appeasement of Hitler in 1937 and 1938, the support of President Kennedy's inner circle to the invasion of the Bay of Pigs in Cuba, and the support of President Johnson's advisers for escalating the war in Vietnam. These were highly cohesive and concurrence-seeking groups were the members used their cognitive resources to develop shared rationalisations that bolstered a proposed choice, rather than examining alternative options and identifying the risks associated with the preferred choice.

Janis and Mann (1977, p. 130-131) listed eight symptoms of groupthink based on these studies:

1. an illusion of invulnerability, shared by most or all of the members, which creates excessive optimism and encourages taking extreme risks;
2. collective efforts to rationalize in order to discount warnings which might lead the members to reconsider their assumptions before they commit themselves to their past policy decisions;

[9] See Davis et al. (1992) for a discussion.

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3. an unquestioned belief in the group's inherent morality, inclining the members to ignore the ethical or moral consequences of their decisions;
4. stereotyped views of rivals and enemies as too evil to warrant genuine attempts to negotiate, or as too weak or stupid to counter whatever risky attempts are made to defeat their purposes;
5. direct pressure on any member who expresses strong arguments against any of the group's stereotypes, illusions or commitments, making clear that such dissent is contrary to what is expected of all loyal members;
6. self-censorship of deviations from the apparent group consensus, reflecting each member's inclination to minimize to himself the importance of his doubts and counterarguments;
7. a shared illusion of unanimity, partly resulting from this self-censorship and augmented by the false assumption that silence implies consent;
8. the emergence of self-appointed "mindguards" – members who protect the group from adverse information that might shatter their shared complacency about the effectiveness and morality of their decision.

Groupthink typically leads to deficient decision-making. Characteristic problems are incomplete survey of decision alternatives, incomplete survey of objectives and goals, a failure to examine the risks of the preferred choice, poor information search, bias in processing the information at hand, and a failure to work out contingency plans. Groupthink may also lead to violation of ethical or moral norms that one would expect to be central to the group members and/or to the people they represent.

If you study the list of symptoms carefully, you may realise that some of the symptoms tend to prevent the members of the group from detecting its malfunctioning. For instance, self-censorship (symptom 6) tends to promote the idea that there are no counterarguments and no reasons for doubt, and therefore nothing has been suppressed. It is therefore difficult for the group to detect and break out of groupthink on its own.

It is probably easier to prevent groupthink than to break out once groupthink is firmly established. To prevent groupthink, we need to know what factors make a group process susceptible to groupthink. Janis and Mann (1977, p. 132) listed five antecedent conditions, i.e. conditions that tend to dispose a group for developing groupthink:

1. high cohesiveness;
2. insulation of the group;
3. lack of methodological procedures for search and appraisal;
4. directive leadership;
5. high stress with a low degree of hope for finding a better solution than the one favoured by the leader or other influential persons.

By turning each antecedent condition on its head, you may create a recipe for preventing or counteracting groupthink:

1. Introduce newcomers into the group now and then, and make sure that the newcomers are in a position to challenge the prevalent norms, interaction styles and outputs of the group.
2. Expose the group to the outside world, for instance by having others review the outcomes and the work in progress and ask critical questions.
3. Introduce a minimum of structure into the decision processes, for instance requiring the group to document the alternatives considered and the criteria for reaching a choice.
4. Select a group leader who has demonstrated a capacity to elicit different voices and to halt attempts to suppress objections and concerns.
5. Remove unnecessary strains on the group and promote an expectation that there may still be a better solution which we have not yet thought of.

It is also a good idea to promote a social climate where people perceive disagreement as a resource rather than a problem. There are many settings for group discussions where it is not necessary to reach consensus, or at least it is not necessary to strive for consensus during the initial phases of the discussion. Such settings provide an opportunity for exploring the value of disagreement. As a facilitator or group leader, you may instruct the group *not to strive for consensus, but rather to record the diverging opinions.* This can be a refreshing experience for the group members, because most group settings in working life are characterised by a pressure to reach consensus and turn to action as quickly as possible.

3.4 Decision making

3.4.1 Many decisions are implicit rather than explicit

It is common to think of decision-making as an explicit process where somebody defines an issue or a problem, identifies decision options, identifies the possible consequences of choosing each decision option, weighs pros and cons, and states a conclusion. In practice, decisions in business and industry settings are often made by groups of individuals, and they often evolve over time in a process with no obvious starting point and end point. Decisions in operative settings, for instance on flight decks or during expeditions, are often indistinguishable from action. When driving a car, you regulate the speed with the accelerator and brakes. Most of the time you do not make explicit decisions about adapting the speed to local conditions such as curves – you just do it. Perhaps you pay some extra attention each time the speed limit changes.

Most of the time, such implicit decision-making works well. The alternative, for instance performing a careful analysis to decide on the optimal speed each time your car enters a curve, is not only tedious. It might even take so much attention from the other aspects of driving that it would make you a more dangerous driver. Therefore, *we do not recommend a particular "ideal" decision procedure to be applied uncritically across all possible settings and situations*. Instead, we shall outline some typical patterns of decision-making in different settings and discuss how these patterns of decision-making can sometimes lead to decisions which the decision maker later regrets.

3.4.2 Decision processes are shaped by the decision setting – the sharp end versus the blunt end

Compare a decision by the Norwegian Parliament to pass a new law with a decision made by a group of researchers in the field about whether to aborting an expedition due to adverse weather conditions. The physical settings (the national assembly building versus the arctic wilderness) are obviously different. The organisational settings and the chain of actions and interactions leading to a decision outcome are also highly different. If somebody were to evaluate the two decisions at a later point in time, they would probably use rather different criteria. A decision to pass a law might, for instance, be evaluated according to its calculated costs and benefits and its popularity with the public, whereas as a decision about terminating an expedition might be evaluated according to its effects on the survival, health and well-being of the participants.

As different settings and environments impose different constraints on the decision-making process and the decisions made, a better understanding of these constraints will aid in providing decision support and explain apparent irrational and reckless decisions (Rosness, 2009). As a first step towards understanding the impact of decision settings, we may distinguish between the sharp end and the blunt end. The *sharp end* refers to settings where the decisions can have a direct impact on the likelihood that an accident will occur. These settings are often physically close to the source of danger – for instance decisions made in the field during an expedition, or decisions made at the bridge of a ship. However, some decision settings, such as air traffic control centres or rescue coordination centres should be considered sharp end settings because the causal chain between the actions of the operators can have a direct impact on the occurrence of accidents or their outcomes.

In contrast, decisions made in *blunt end* settings have a more indirect impact on the likelihood that an accident will occur. A decision by a company board to impose "aggressive" cost reductions on its plants is not likely to be the immediate cause of a disaster. However, a cost cutting decision can lead to inadequate maintenance, insufficient staff levels, removal of key personnel or a failure to invest in the safest available technology. Such changes can set the scene for an accident.

The main emphasis in the discussion below in section 3.4.3 will be on decision settings at the sharp end.

3.4.3 Decision-making at the sharp end

What, then, are the typical ways we make decisions during field work, in a cockpit, or when driving a car? These are some of the common characteristics of decision-making at the sharp end:

- *Many decisions are implicit and more or less automated,* as when you adapt the speed of a car to local conditions, as discussed in paragraph 3.4.1. Such automation is a precondition for carrying out tasks of some complexity in a smooth and efficient manner. Automation frees some of the capacity of your attention so that it can be used for other purposes. An un-trained car driver who has to pay a lot of attention to basic operations such as changing gears will have less attention to spend on scanning the environment and spotting potentially risky situations.
- *More complex decisions made by experienced people often relies on pattern recognition.* You may think of a chess master who immediately spots that the configuration of pieces she faces occurred in one the hundreds of games that she has memorised. Pattern recognition typically allows for speedy handling of complex situations. However, decision-making based on pattern recognition can go wrong in exceptional situations where the pattern of clues does not have its usual meaning. You may think of a physician facing a patient with a rare disease where the pattern of symptoms resembles a more common disease.
- *Most decision makers spend most of their time and attention on keeping the activity running smoothly.* They coordinate tasks, find the best way to perform the next steps, try to avoid disruptions, or solve problems that may occur. Most of the time, people will spend most of their attention and effort on issues other than safety. This is not because they are careless or "have a poor safety culture", but because they have a job to do, and that job requires their attention. This implies that under many circumstances, they will not spot a new danger immediately, because their attention is somewhere else.
- *Decision makers at the sharp end usually have information about a limited part of the environment or system they are operating within*. A dangerous animal may be hidden by the terrain; a pilot is not aware of all other aircraft in the vicinity; a technician in a process plant is not aware of all other activities taking place in the plant. Decision makers at the sharp end therefore seek the best way to perform their tasks, based on incomplete information. This is called *local optimisation.*
- *Decision makers at the sharp end may face situations where the plans or standard procedures are not applicable or irrelevant.* People who write plans, procedures and safety instructions are not always able to foresee all possible situations that may occur and all the dilemmas facing people at the sharp end. Moreover, many plans and procedures would be too long and complex if they were to cover all eventualities. As a consequence, *decision makers at the sharp end may turn to improvisation or even experimentation.* "Improvisation" means that they devise a plan on the spot and execute it immediately. They may even start execution before they have finished planning, and modify their plan based on the new insights they gain while executing the plan.

The above characteristics of decision-making at the sharp end can be viewed as adaptations to the demands of the task and the environmental constraints. Automated decision-making, for instance, enables us to handle tasks that would otherwise exceed the capacity of our attention. However, adaptations that work well most of the time may lead to unwanted consequences on some occasions:

- Decision makers may fail to detect a signal of danger because they spend most of their attention on keeping the activities run smoothly.
- An experienced decision-maker may rely on pattern detection and fail to realise that a familiar pattern of clues may have an unusual meaning in this particular case.
- Decision makers may improvise because they consider the plans inappropriate, and it may then turn out that the plans they made up on the spot did not take into account all dangers in the situation.

As counter-measures to these problems you may

- Make it a habit to scan the environment for dangers at specific intervals and/or in specific situations;
- Seek contradictory evidence each time you diagnose a situation based on over all patterns;
- Take a little extra time to think of undesirable sides effect each time you have to improvise, and if feasible ask someone else to scrutinise you improvised plan before you execute it.

3.4.4 Decision making in crisis situations is often affected by defence mechanisms

Crisis situations share two characteristics. The first one is the possibility of a highly undesirable outcome, for instance loss of life. The second one is that the time to act is short. This combination of features can to lead to high levels of stress and may thus affect the quality of decision-making. According to Janis and Mann (1977) a subtler mechanism may also affect decision-making: *Crisis situations may trigger psychological defence mechanisms, which affect the quality of decision-making.* Very high levels of arousal can be very unpleasant. *The defence mechanisms give a temporary relief from unpleasant stress levels, but this relief may come at the price of a somewhat distorted understanding of the situation.* We are not usually aware of how defence mechanisms influence our understanding of the situation. Therefore, they may lead us to choose a course of action that we would not choose if we had an unbiased understanding of the situation. *The reduction of stress level may thus come at the price of less successful coping with the crisis.*

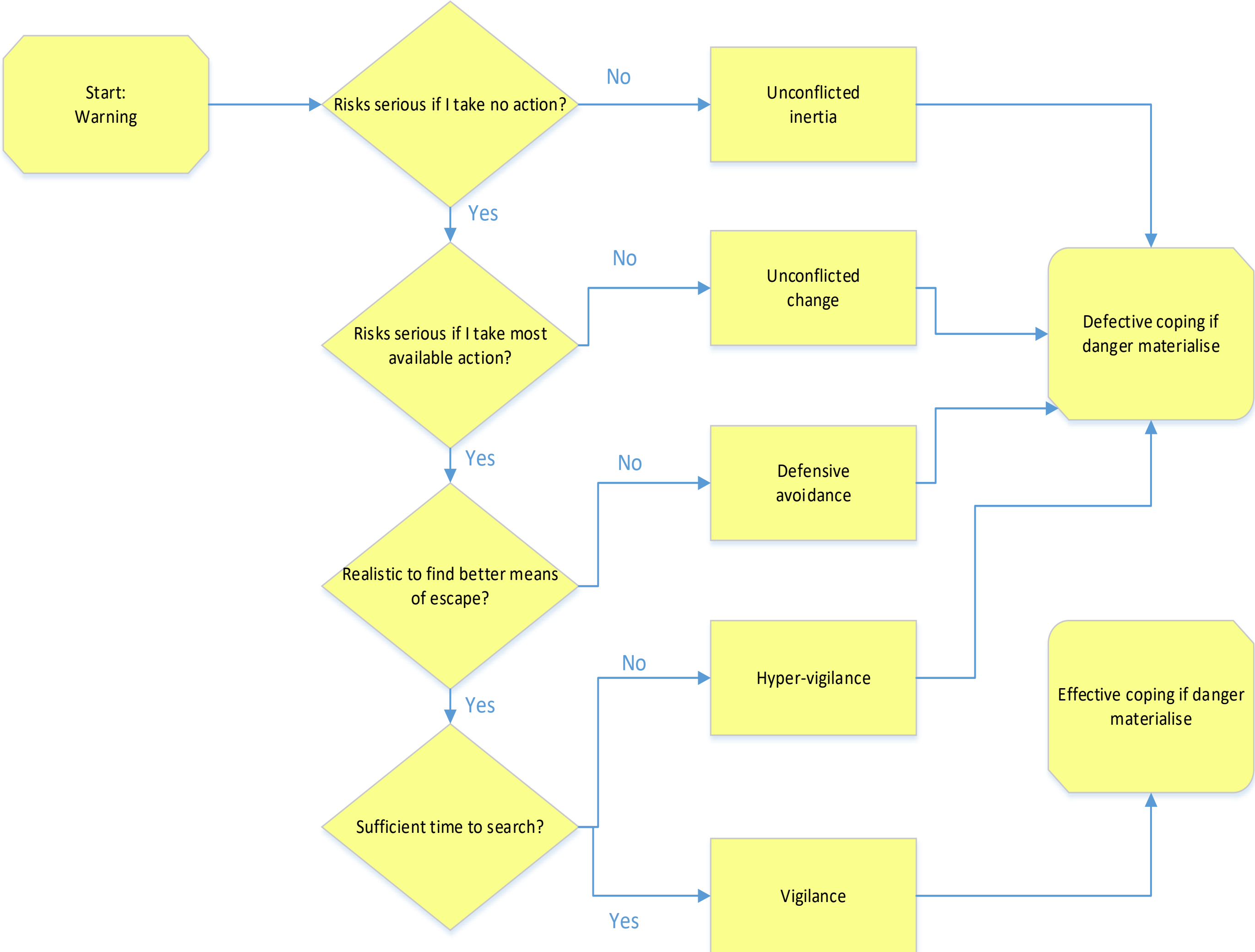

Figure 3. Defence mechanisms that affect decision making in crisis situations. Adapted from Janis and Mann (1977) p. 55.

Janis and Mann distinguished four different ways in which defence mechanisms may influence decision making at the face of a crisis (Figure 3). In each case, the starting point is a warning signal from the environment:

1. *Unconflicted inertia occurs when the initial warnings fail to arouse sufficient stress to evoke vigilant appraisal or action.* The initial warnings may be ambiguous, and in the case of unconflicted inertia, only the most optimistic interpretation of the warning is considered. Unconflicted inertia may lead to defective coping because time is lost and the situation may escalate.
2. *Unconflicted change implies that the decision maker perceives a need to act, and then chooses the first course of action that he or she can think of*. If this happens to be the best course of action, then all is well. If not, the situation may escalate further.
3. *Defensive avoidance occurs when the decision-maker recognises the need to act, but does not believe it is possible to find an effective course of action to cope with the crisis*. He or she believes that no options are better than doing nothing at all. In the extreme case, the decision-maker will avoid cues that stimulate anxiety and other painful feelings and engage in behaviours that take attention away from the crisis. In less extreme cases, the decision-maker may pass the responsibility for responding to the crisis to someone else.

4. *Hyper-vigilance typically occurs when people believe that there is a way out, but that there is insufficient time to make a careful search for and evaluation of information and advice.* In its extreme form, this corresponds to what we call panic. You may think of situations where many people are trapped by a rapidly approaching fire. In such situations, people may act on simple-minded decision rules such as "Do whatever the others around you are doing". More generally, high emotional arousal has the greatest impact on the most "demanding" or "sophisticated" cognitive tasks.

However, there is a fifth path through the model, which Janis and Mann labelled "vigilant decision-making". *Vigilant decision-making is characterised by a careful appraisal of the situation and a careful search for the best decision option.* An idealised description of vigilant decision-making can be found in Box 1 below. As indicated by the diamond-shaped boxes in Figure 3, Janis and Mann specify four prerequisites for vigilant decision-making (p. 62):

1. awareness of serious threat if no protective action is taken;
2. awareness of serious risks if the most salient protective action is taken;
3. high or moderate confidence that a satisfactory solution exists and can be discovered;
4. high or moderate confidence that the as yet undiscovered satisfactory solution can be found within the available time.

In most crisis situations, vigilant decision-making is more likely to lead to successful coping according to Janis and Mann. There are, however, some exceptions. When a crisis escalates very rapidly, such as a rapidly approaching fire, there may not be enough time to deliberate about the best option, and the rapid reaction associate with hypervigilance may prove more effective.

Knowing about these defence mechanisms can help us recognise situations where they may threaten to affect decision-making. Being aware of the mechanism "unconflicted inertia" may lead us to reconsider the interpretation of an ambiguous sign of danger and ask for the most pessimistic plausible interpretation. Knowing about "unconflicting change" may lead us to ask if there may be better alternatives before we select the first protective action that we may think of, and we will perhaps start thinking about a "Plan B" that can be implemented if "Plan A" fails. Knowing about "unconflicting change" may also lead us to look for and deal with negative feedback when we implement a decision – we will look for signs that the "Plan A" did not work as expected, and consider if "Plan B" is more promising.

Good planning can also reduce negative impacts of defence mechanisms on decision-making. The key is to plan for contingencies: What unexpected and/or unwanted situations can occur? How can we detect them early? How can we handle them? Being aware of what situations may occur, puts us in a better position to recognise them when they occur. Having reflected on how to handle contingencies gives us a readily available repertoire of actions ("Plans B and C") and makes it more likely that we select an effective course of action.

Training for contingencies can help in similar ways as contingency planning. Moreover, training can help us avoid extreme arousal and thus reduce the likelihood that the defence mechanisms will be activated in the first place.

Box 1 Criteria for vigilant decision-making

Seven criteria for vigilant decision-making according to Janis and Mann (1977, p. 11):

The decision maker, to the best of his ability and within his information-processing capabilities

1. thoroughly canvasses a wide range of alternative courses of action;
2. surveys the full range of objectives to be fulfilled and the values implicated by the choice;
3. carefully weighs whatever he knows about the costs and risks of negative consequences, as well as the positive consequences, that could flow from each alternative;
4. intensively searches for new information relevant to further evaluation of the alternatives;
5. correctly assimilates and takes account of any new information or expert judgment to which he is exposed, even when the information or judgment does not support the course of action he initially prefers;
6. re-examines the positive and negative consequences of all known alternatives, including those originally regarded as unacceptable, before making a final choice;
7. makes detailed provisions for implementing or executing the chosen course of action, with special attention to contingency plans that might be required if various known risks were to materialize.

Note that these criteria may not be fully applicable to situations that require rapid action.

What would an ideal decision process in a crisis situation look like? There is no general answer to this, because *both crises and the resources to handle them can be very different*. Some crises require action within seconds, whereas others can be handled over days or weeks. Janis and Manned proposed seven criteria for vigilant decision-making. These are shown in Box 1 above. These criteria make good sense if the time to act is in the order of hours or more. Situations that require rapid action call for simpler decision processes. Extremely rapid decision-making relies on a capacity to recognise a threat spontaneously (so-called pattern detection) and respond more or less automatically. This requires realistic training. Situations that allow us several minutes to react make it possible to take some steps to avoid the pitfalls described above:

- If you face a danger signal, try to identify the worst-case scenario, i.e. the most pessimistic interpretation of the situation and its possible outcomes. This counteracts "unconflicted inertia".
- Try to identify more than one possible action. This counteracts "unconflicting change" and may provide you with a "Plan B" in case your original plan fails.
- Continue scanning for new information as you carry out the decided actions, in particular information that may challenge your interpretation of the situation or your choice of action.
- If part of a group, take time to share information and justifications for your choice of action with the other group members and give them reasonable time to share their concerns about your interpretation of the situation and your choice of action.

3.5 Manual and physiological performance

3.5.1 Manual and physiological performance is affected by the cold

The human thermal environment is defined by six fundamental factors which determines the human body's ability to maintain thermal balance (Færevik et al. 2013);

- air temperature
- air velocity
- humidity
- radiant temperature
- metabolic heat production through physical activity
- clothing

Human beings are highly exposed to cold in these areas, and this exposure can be from not only cold air (temperature/wind) but also from water and through touching cold surfaces. Manual performance is an important aspect of work execution where optimal hand functioning is dependent on several physiological factors which again will be influenced by the surrounding environment. It has been well documented that cooling of the hands leads to reduced manual performance, and that a reduction in manual performance increases the risk of human error (Færevik et al. 2016; Anttonen et al. 2009). 15 °C has been suggested as a threshold-value where a lower skin temperature indicates a reduction in manual performance.[10] By keeping warm through physical activity, clothing or shelter, manual performance in cold environments is most often not reduced. However, it is necessary to use gloves or mittens for protection and this can reduce the precision in the work that needs to be carried out depending upon the nature of the task.

Overall physical performance consists of endurance, muscle function and physical properties, and cold and thereby cooling of the body, will most likely affect all of these physical properties. The thermal responses vary depending upon factors such as age, gender, amount of subcutaneous fat, health, fitness, medication, previous adaptation etc (Mäkinen, 2007). A good physical stamina is an important factor not only for good health, but also so that the individual is able to have a higher work intensity and thermal heat production over time compared to those that do not have a good physical stamina. It also leads to a more effective regulation of body temperature and sensitivity to changes in the environment (Færevik et al. 2016). Studies have shown a lower metabolic heat production rate in elderly individuals where they failed to maintain core temperature. This entails that elderly individuals can be more susceptible to hypothermia than younger individuals (Færevik et al. 2013).

3.6 Psychosocial influences on performance

3.6.1 Psychosocial risks and hazards

In promoting occupational health and safety, the understanding that psychosocial factors can have a strong influence on both the mental and physical well-being of workers is steadily increasing. There have been a number of studies looking at the psychosocial challenges in isolated, remote and extreme environments in Antarctica (see Sandal et al. 2006; Palinkas and Suedfeld, 2008). However, there is a lack of studies specifically tailored for environments that are not a part of long-duration expeditions (see Færevik et al. 2016).

If we consider *psychosocial risk* in the Arctic, this is seen as the likelihood that psychosocial factors will have a hazardous influence on worker's/individual's health through their perceptions and experience and severity of ill health that can be caused by exposure to the hazards (BSI, 2011). It is the perception and subjective understanding by individuals which is considered when "measuring" psychosocial factors. Different categorizations of psychosocial hazards can be found. Below, we list 10 areas with key issues that can be fitted to an organization/workplace when identifying hazards (based on BSI, 2011):

1. Job content

[10] See ISO 8996 *Ergonomics of the thermal environment* for more information.

    a. lack of variety or short work cycles,
    b. fragmented or meaningless work
    c. high-uncertainty,
    d. under-use of skills
2. Workload and work pace
    a. work overload and underload,
    b. time pressure,
    c. continual deadlines
    d. Work intensity
3. Work schedule
    a. shift working
        i. night shifts,
        ii. inflexible work schedules,
        iii. unpredictable, long or unsociable hours
4. Control
    a. low participation in decision-making,
    b. lack of control over workload
    c. limited break opportunity
5. Environment and equipment
    a. inadequate availability of equipment, suitability or maintenance,
    b. poor environmental conditions[11]
6. Organizational culture and function
    a. poor communication,
    b. low levels of support for problem-solving and personal development,
    c. lack of definition of, or agreement on, organizational objectives
7. Interpersonal relationships at work
    a. social or physical isolation,
    b. lack of social support,
    c. poor relationships with superiors,
        i. interpersonal conflicts
8. Role in organization
    a. role ambiguity,
    b. role conflict,
    c. responsibility for people
9. Career development
    a. career stagnation and uncertainty,
    b. poor pay,
    c. job insecurity,
    d. low social value to work
10. Home – work interface
    a. conflicting demands of work and home,
        i. low support at home,
        ii. dual career problems

Psychosocial hazards that have a potential to cause psychological, social and physical harm should be identified for the Arctic cold work environment, which has also been highlighted by previous studies in the literature. Most psychosocial hazards are situation specific and workplace specific. There will also be individual differences in the same environment on which hazards, if any, is or might cause harm to workers. Studies on the effects of psychosocial aspects of work and other conditions have mainly been interested in

[11] This can both be external and other working environmental issues such as poor lighting, excessive noise, cold etc.

the impact on stress which can result in emotional and health issues. However, as Leon et al. noted positive effects on health and motivation can also be found. It is highly likely that there are positive factors in this environment that compensate for negative impact by the cold environment. See chapter 5 for more on resilience.

4 Psychological and physical symptoms and reactions

As a starting point, we can say that different people react in different ways to the same situation. These individual differences are shown through differences in abilities, personality, how to cope with a situation as well as bodily reactions in interaction with the environment. Various psychological symptoms have been experienced during polar expeditions and these include somatic symptoms (i.e., fatigue, headaches, weight gain), disturbed sleep, impaired cognition (i.e., impaired memory, attentiveness difficulty which can be seen as reduced accuracy and increased response time), negative affect (i.e., depressed mood, anxiety, anger and irritability) and interpersonal tension and conflict (Palinkas and Suedfeld, 2008). Below, we will describe in more detail some of the symptoms and reactions human beings can experience when working and living in harsh environments. Many of these symptoms and reactions are also simply a part of being a human being having to cope in some way or another with internal and external stressors or events.

4.1 Emotions and feelings

4.1.1 Emotional effects of threat

Failures and various stressors both internally and in the environment can elicit negative emotions and influence both our psychological and physical health. What is referred to as our *sense of self* is made up of the way that we negatively or positively feel about ourselves (*self-esteem*) and the knowledge we have about our personal qualities (*self-concept*). In much the same way that we form impressions about others through watching behaviour, look for reactions, interpret and collect information, we also form an impression of our selves. Significant threats to our sense of self can be categorized into three types of events (Smith and Mackie, 2000)[12]:

- *Failures* such as not passing an exam, driver's test or poor performance at work,
- *Inconsistencies* such as illness in a usually healthy person, and
- *Stressors* such as time pressure, workload, major and minor crises and hassles, boredom, cold, remoteness etc.

These threats can all elicit negative emotions which includes anxiety and depression. It is usually those threats that we appraise as *uncontrollable* which can lead to the most devastating negative emotions. Furthermore, it is also those that react with negative emotions to a threat than are the most likely to experience physical symptoms in addition to psychological symptoms and reactions. See section 4.3 for more about stress and particularly paragraph 4.3.3 for more about Type A personality.

Different coping strategies are used to overcome threats, and these have been referred to as:

- *Emotion-focused coping* which includes escape, distraction, redefinition of the importance of the event or working through the threat (self-expression).

[12] For more information about social psychology in general, see Smith and Mackie (2000), and Sutton and Douglas (2013).

- *Problem-focused coping* which includes direct response to the threat through reinterpreting the event as nonthreatening, seeking to take control or directly attacking the problem.

Individuals that are a part of polar expeditions prefer the active and problem-focused strategies towards coping. However, also sharing emotions with others and seeking social support is a coping strategy that has been used but with more mixed results (see Leon et al. 2011). Individuals who believe they can make things happen and control events in their life are found to be more active in cognitive processing of information to achieve their goals (Lefcourt, 1982). A consequence of expecting not to have an influence on the way that situations or events develop is that these individuals are less likely to exert or persist to try to solve problems or achieve goals. This frame of thought is central in Albert Bandura's (1986) self-efficacy model. Studies have shown that high self-esteem and strong self-efficacy beliefs contribute to personal strength and resilience (Bandura, 1997). Human resilience has been extensively studied within psychology to highlight the positive and strengths of individuals to overcome difficulties in life. See section 5.1.2 for more on resilience. It is however important to consider that individuals that are externally oriented is that way because the performance of the task at hand relies on the performance or effort of others.

4.1.2 Seasonal mood fluctuations

As already mentioned, the amount of daylight is presumed to influence our psychological functioning that can lead to both problems socially and at work. One of the most researched topics is a diagnosis known as seasonal affective disorder (SAD) (Friborg et al. 2014). SAD is a seasonal major depression that usually occurs annually at the same time each year with symptoms such as sadness, anxiety, irritation, decreased activity and libido. This is usually during winter, with a complete remission of symptoms during the summer. SAD has been reported to occur during summer, but more seldomly (Brennen et al. 2005; Brennen et al. 1999). The reason as to why this depression occurs was believed to be associated with a physiological response to a reduction in amount of daylight by disturbing circadian rhythms in melatonin release, but studies have shown that this link is weak (Brennan et al. 2005). The tendency to experience seasonal changes in mood and behaviour has been referred to as *seasonality* and a milder form of seasonal changes in mood has been labelled subsyndromal SAD (S-SAD) or winter blues. On a continuum of seasonal mood fluctuations, one can say that SAD is a major depression at one end and those that experience no seasonal change is at the other end (Brennan et al. 2005). Common treatment is light therapy or medicines like antidepressants. Light treatment is done by exposing patients to artificial light in the morning. Depression may not directly impact safety performance but can be considered a contributing factor (Morales-Muñoz et al. 2017 in Gjørtz and Skjerve, 2017). There seems to be a need for more information on what are the best conditions for maintaining circadian rhythms in Arctic environments, and what amounts of light treatment and use of melatonin may be needed compared to the ambient light that is present (Arent, 2012).

4.2 Fatigue and sleep loss

Sleep problems and fatigue are the most common health issues reported among those who have stayed for longer periods in Arctic environments. Even moderate levels of sleep distortion and fatigue can impair performance and increase the risk of erroneous actions for routine tasks, repetitive tasks or tasks that require prolonged alertness (Parkes, 2007; Belenky et al. 2014). As the human 24-h circadian rhythm is dependent on light, the lack of natural sunlight in winter can have a strong influence on sleep problems and depressive illness (Arendt, 2012; Marqueze et al. 2015).

Studies of sleep loss in humans have shown that extended wakefulness degrades performance, recovery sleep restores performance, and that approximately 8 hours of sleep (range 7-9 hours) in every 24 hours is optimal for sustaining complex mental operations and performance (Belenky et al. 2014). The risks related to sleep loss can be divided into short, mid, and long-term risks. The short-term (minutes, hours, days) risks include degrading performance that leads to errors, incidents and accidents. Sleep loss for weeks or months (mid-term) degrades planning, strategic thinking and making good life decisions. In the long-term (years), sleep loss leads to weight gain, metabolic syndrome, type II diabetes, and inflammation and hypertension leading to cardiovascular disease. Furthermore, sleep loss may also lead to mild cognitive impairment (Belenky et al. 2014; Palinkas and Suedfeld, 2008). There are however individual differences when it comes to the sensitivity and vulnerability to sleep loss. Interestingly, self-reports and subjective sense of sleepiness has been found to *not* be a good predictor of actual performance and there are also age differences in that older individuals respond quicker than younger individuals in conditions of sleep loss (see Belenky et al. 2014). As such, preventive measures should be taken to avoid putting people at risk in demanding situations if sleep loss has been identified as an issue of concern.

Fatigue is increasingly reported as an issue in many areas of work life. The statement "I am tired", is used to subjectively define fatigue whereas objectively we use degraded performance as a measure. Particularly, reaction time and how much time is needed to complete a task has been shown to be affected by fatigue. Sleep loss (and time awake) is one of the components that can lead to fatigue together with circadian rhythm (time of day) and workload (i.e., time on task, task intensity, task complexity) (Belenky et al. 2014). The exact interaction between these components is still under debate and there are differences in what types of cognitive effects are found. But in those situations where the consequences of degraded performance are high, obtaining sufficient sleep and introducing breaks as risk reducing measures can be crucial to avoid error and obtain successful performance.

4.3 Stress

4.3.1 What is stress? The flight/fight response

Stress can be defined as "the adverse reaction people have to excessive pressures or other types of demand placed on them" (Health and Safety Executive, 2017). Pressures that tend to produce stress are referred to as *stressors*. *Acute stress* refers to the immediate reaction to excessive pressures, for instance a situation that you perceive as very dangerous. *Chronic stress* refers to reactions to pressures that are present over a prolonged period of time, typically several months. We usually have chronic stress in mind when we speak about occupational stress. However, acute stress can have a strong impact on our capacity to cope with a dangerous situation. We will mainly discuss effects of acute stress in this section.[13]

Both acute and chronic stress are consequences of *the flight/fight response* (Flin and Slaven, 1996; Kantowitz and Sorkin, 1983; Glendon and McKenna, 1995). The fight/flight response is a pattern of physiological reactions that occur when we perceive a threat in the immediate environment. The function of the response is to prepare the body to produce an energy surge that allows us to quickly flee from the situation or to fight the aggressor. This pattern of reactions non-specific, i.e. it is more or less the same regardless of what situation you react to.

1. The body first goes through a brief *shock phase* characterised by depressed blood pressure, lowered body temperature, loss of muscle tone and fast heartbeat. The shock phase corresponds to the time it takes for the body to redirect resources to prepare for "flight or fight". The body's capacity to react is typically depressed in the shock phase, but this usually has limited significance because the phase is of very short duration.
2. The shock phase is soon followed by the *countershock phase*, as the body rebounds and is ready to fight or flight. This phase of heightened arousal is characterised by a range of physiological changes

[13] Information material and guidance for handling occupational stress can be found at the website Health and Safety Executive UK: http://www.hse.gov.uk/stress/index.htm. See also Flin and Slaven (1996) and Glendon and McKenna (1995).

such as pupil dilation, reduced salivary secretion (dry mouth), inhibited gastric activity, hyperventilation and/or irregular breathing, increased blood pressure and pulse rate, increased muscular tension, and perhaps involuntary vocalisation (crying out). This is the phase we have in mind when we speak about "acute stress".
3. If the stressors remain over time, the body will enter the *stage of resistance*. It will to some extent adapt to the stressors, and the symptoms of stress will be reduced.
4. If the stressors are severe and they are applied for a prolonged time, the body will reach the *stage of exhaustion* where symptoms of stress reappear. At this stage, both mental and physical health effects may occur, such as headache, digestion problems, elevated blood pressure, anxiety, depression and sleep disruption. These are the reactions we refer to when we speak about "chronic stress".

Our main concern in this report will be with the effects of heightened arousal on our capacity to deal with risks. This corresponds to the countershock phase.

4.3.2 Effects of acute stress on performance

The fight or flight reaction is adapted to an environment where we need to react in a physical manner to a threat. This is why the muscles receive more blood and gastric activity is inhibited during the countershock phase. Unfortunately, this reaction is not always helpful for an individual or group who needs to reduce a threat by thinking clearly and devising a plan of action. The following are some typical impacts of high arousal level on performance:

- *Increased capacity to react in a physical manner.* This corresponds to the biological function of the fight or flight reaction. Your reactions will typically be faster and more forceful.
- *Narrowing of attention.* At very high levels of arousal, the range of cues that are processed becomes restricted. A pilot may, for instance, pay attention exclusively to some particular instrument that appears to malfunction, and fail to attend to an altimeter that shows that the plane is rapidly losing height. Narrowing of attention may be beneficial in simple situations, but can be detrimental in complex situations that require attention to many cues.
- *"Cognitive tunnel vision".* This implies a reduced capacity to consider side effects of a proposed action.
- *Response perseveration*, which is a tendency to repeat a certain response to the situation, even after it has been tried and found not to work.

4.3.3 The complex relationship between stressors and stress

The relation between stressors and stress – between the strains and challenges we face and the effects they produce – are not simple and universal. First, *the relationship between arousal and performance or well-being is not linear*. Moderate amounts of arousal – sometimes referred to as "eustress" – are typically perceived as more pleasant and motivating than total absence of pressures and challenges. Moderate amounts of arousal are also associated with improved performance. Very high levels of arousal are associated with poor cognitive performance (e.g. poorer decision-making) and can be perceived as highly unpleasant.

Similar situations can be associated with positive arousal and motivation for one person, and with highly unpleasant anxiety for another person. Here are some of the factors that modify the relationship between stressors and stress:

- *Judgment of demands and resources*. Stress occurs when we perceive the demands of the situation to exceed our coping capacity, i.e. our capacity to deal with the situation. Chronic stress is particularly common with jobs that combine high demands with low capacity of the person to control the situation.

- *Defence mechanisms*. Defence mechanisms are psychological mechanisms that may counteract unpleasant levels of arousal but at the same time may lead to defective coping. Defence mechanisms that may influence decision-making are discussed in Paragraph 3.4.4.
- *Social support.* Social support tends to reduce the immediate negative impact of arousal on performance as well as adverse long-time effects of stress. Social support can come from the family, colleagues or others, depending on the situation. *Loneliness and lack of contact with others* is usually associated with increased fear. However, in some extreme cases, such as crowds being trapped by a fire, fear can be "infectious", and panic may result.
- *Training and experience.* Training can obviously improve coping by providing the skills and knowledge necessary to handle the situation – e.g. knowing how to build an emergency bivouac in the snow. Moreover, training can make the appropriate response more salient and available to a highly aroused person who is unable to think of many alternative action plans. Training can also increase your confidence that you will find a way to cope with the situation, and thus protect you against extreme levels of stress (including panic) and also against defence mechanisms that would have led to poor coping (see Paragraph 3.4.4).
- *Personality.* The effects of personality seem to be most clear-cut with regard to chronic stress. So-called Type A-behaviour has been found to be associated with conditions disposing for coronary heart disease, such as hypertension, increased cholesterol levels, accidents, lack of exercise and poor family conditions. Typical Type A behaviour is defined by characteristics such as extreme competitiveness, aggressiveness, impatience, restlessness, and feelings of being under time pressure.

See paragraph 3.4.4 for a discussion of what you can do to improve decision-making in potentially stressful crisis situations.

4.4 Hypothermia

Research on the effects of cold and hypothermia on human physical performance have been identified as influencing physical endurance, muscle function and physical capacity. *Hypothermia* is defined as the condition where the body temperature falls below 35°C and develops when the body's heat loss exceeds its heat production. There are three phases of hypothermia ranging from mild (32-35°C), moderate (28-34°C) to severe hypothermia (below 28°C) [14] (Schaider, 2015 in Gjørtz and Skjerve, 2017). Mild hypothermia leads to shivering that increases heat production, increased heart rate, contraction of the blood vessels and abnormal breathing. In the moderate phase, shivering usually gradually decreases and heat production declines. The persons consciousness is clouded, the muscular coordination is impaired as well as impaired judgement which may cause a person to take his or her clothes off (Gjørtz and Skjerve, 2017). Severe hypothermia is a potential fatal condition. Immersion hypothermia is also a condition which can occur if the body or parts of the body is under water. Water retreats heat 20-25 faster than air, which makes immersion hypothermia particularly dangerous (Turk, 2010).

The risk factors for hypothermia are both environmental conditions (e.g., low temperatures, damp conditions and wind) and individual conditions (e.g., insulation of the body, ability to protect against the cold and body's capacity to compensate for heat loss). It is difficult to give precise figures for "dangerous" conditions as the duration of exposure to the cold and individual factors play a determining role in the risk for development of hypothermia (Turk, 2010). Other factors that increases the risk of hypothermia are inadequate and particularly wet clothing, thinner individuals are more exposed than obese due to body fat, low muscle mass as this can result in decreased muscular heat production and potentially reduced mobility,

[14] In Færevik et al. 2013, severe hypothermia is defined as below 30°C.

use of alcohol and drugs as this may impair a person's judgment and thus the ability to find shelter or otherwise protect against the cold. Alcohol is also seen as a risk factor through other bodily physical reactions (Turk, 2010). [15]

5 Human resilience vs system resilience

5.1.1 Normal performance variability is a part of successful performance

Most often the negative effects imposed on human beings during expeditions or from working in the Arctic are expressed in the literature, but there are also positive or salutogenic outcomes which comes from the successful coping with stress and personal growth (Palinkas and Suedfeld, 2008). The English term "resilience" comes from the Latin verb *resilire* which means "to leap back". There is a vast amount of research on *resilience* (Windle et al. 2011; Longstaff, 2013), and the origin of the concept of resilience stems from the social sciences of human and organisational factors. Within safety research the Resilience Engineering perspective (Hollnagel et al. 2006; Rosness et al. 2010) has been a prevalent perspective into new ways of thinking about resilient organisations and organisational accidents. Specifically, through emphasising normal variability and underspecified performance as a premise for understanding why we are not able to anticipate or specify every work operation or process in advance, it has given new insights in how to explore how a system is able to cope with variations and disturbances. Flin (2006) further argued that there is also a need for managerial resilience in safety management by emphasising the need to and ability to deal with conflicts between safety and primary performance goals (usually production goals) in the organization. Also, by studying normal work there are more successes than failures to learn from which has changed the focus in some empirical studies of safety. Safety is something an organization *does,* rather than something an organization has (Hollnagel et al. 2006).

5.1.2 Human resilience in the face of adversity

Human resilience or psychological resilience is another perspective on how to understand what can influence safety and particularly how resilience can affect performance and reactions to stress and other conditions from an individual, psychological viewpoint. Systematic studies of human resilience can be traced back to shortly before the 1970s and focused mostly on young individuals (Masten and Obradovic, 2008). Resilience has been defined in many ways, but often described as a universal construct to acknowledge an individual's capacity to maintain psychological and/or physical well-being in the face of stress (Rosenberg et al. 2015). Or similarly, as the ability to cope with internal and external stressors (Sarubin et al. 2015). The enormous interest in studying resilience resides in the fact that it is seen as a *protective factor* and *positively related to mental health*. It has thus shown to reduce the risk of developing mental disorders which includes depression, anxiety and posttraumatic stress disorders (Sarubin et al. 2015; Hu et al. 2015). The aim in many studies is therefore to develop tools and intervention programmes to measure and/or enhance the capacity for resilience.

A more comprehensive definition has been proposed by Windle et al. (2011 p. 2) as "the process of negotiating, managing and adapting to significant sources of stress or trauma. Assets and resources within the individual, their life and environment facilitate this capacity for adaptation and 'bouncing back' in the face of adversity. Across the life course, experience of resilience will vary". This definition is based on analysing 270 research articles on the subject, and the vast number of different definitions makes it difficult to evaluate and compare research findings. However, the aspect of including external assets and resources as necessary in adaptation and being able to leap back from difficulties is an important distinction. By including

[15] See Turk (2010) for more information about risk factors for hypothermia.

family, friends, co-workers, organisational resources etc this ability to adapt is *not only* dependent on the individual itself. The different orientations towards psychological resilience can be grouped into[16]:

- *Trait orientation (or trait resilience)* where resilience is seen as a personality trait where this personality helps individuals in coping and adjusting to adversity or traumatic events.
- *Outcome orientation* where resilience is a function or behavioural outcome that help individuals to both overcome and recover from adversity.
- *Process orientation* where resilience is a dynamic process and individuals can adapt to and recover rapidly from adversities.

Differences or variations can be found when it comes to dealing with extreme environments and stressors in these environments. As an example, the Connor-Davidson Resilience Scale (CD-RISC)[17] measures trait resilience through personal qualities such as personal competence, trust/tolerance, effects of stress, acceptance of change and secure relationships, control, and spiritual influences. It is beyond the scope of this report to discuss different scales and tests for universal traits. But it is interesting to consider which negative and positive indicators can tell us something about how and which individuals seem to cope, act and recover better than others when encountering environmental and other stressors, and those that seem to thrive when encountering challenges.

Adaptation is a fundamental characteristic of resilience. Cold has been described as a stressor that humans living in high latitude environments adapt well to in terms of reducing the physiological strains on the body. The most common adaption to cold is *habituation* where the human is repeatedly exposed to whole-body cooling, but where the cooling is not substantial (Mäkinen, 2007). The human resilience capacity for both psychological and physiological strain is of interest to study further. It seems that it may be the key to explaining resistance to risk across the lifespan, how challenges are dealt with and that resilience may be an important factor for health, safety and well-being in small groups, organizations and communities.

6 The diversity of erroneous actions

Since the Three Mile Island nuclear reactor accident in 1979 where operators failed to diagnose a stuck open valve due to poor training and HMI, the notion and belief that 'human error' is an adequate explanation as to why an incident or accident has happened has been frequently used. Human error entails that the cause of an unwanted consequence has been attributed to the human part of the system rather than to something else (Reason, 1997). *The fundamental attribution error* is the most documented bias in social perception which means to attribute someone else's behaviour to his or her dispositional qualities, such as personality or ability, instead of situational factors (Fiske and Taylor, 1991; Ross and Nisbett, 1991). This can also be why we accept human error as an explanation rather than something that needs explaining (Reason, 2013). This tendency for people to underestimate situational factors and overestimate dispositional factors (Ross and Nisbett, 1991), is a bias that both laypersons and more experienced people are prone to (see Tversky and Kahneman, 1982).

As we over the past 35 years or so have learned much more about the underlying causes of human failure, the effects of work related conditions and about the interaction between human, the work, organisational- and environmental factors, the explanations and thinking about what leads to failure and why has changed. Nonetheless, the types of human failures, as can be seen in figure 4, is still used to categorize failures on an individual level. In the *Swiss cheese model* these failures are referred to as active failures which are the errors

[16] See Hu et al. (2015) for more information.
[17] See Connor and Davidson (2003) for more information.

and violations committed by those in direct contact with the system (Reason, 1997, 2013). In any activity, there is a risk of human failure and most people do make errors, but are able to correct or detect them before they lead to any consequences or at least to any major consequences.

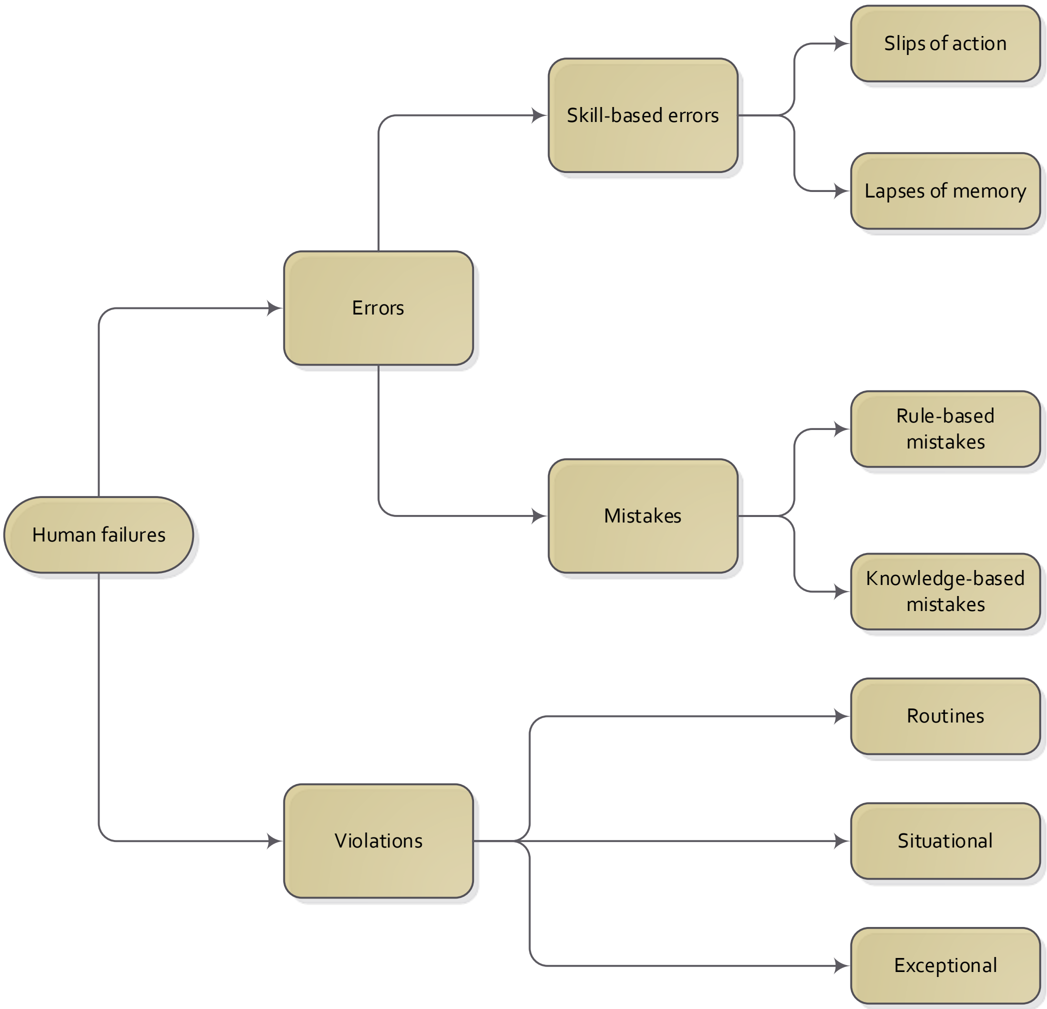

Figure 4 Types of human failure (taken from HSG48, 1999 p. 12).

The diagram in Figure 4 illustrates the diversity of erroneous actions. These may be divided into three main groups:

1. The group called "skill-based errors" refers to *unintended actions:* Your intentions may be fully appropriate, but what you actually do does not correspond to what you intend to do. A *slip of action* is can be understood as an attentional failure. It may, e.g., take the form of an intrusion (you perform an extra step which is irrelevant to the task), an omission (you omit a task step), you do the task steps in incorrect order, or your timing is incorrect. A *lapse of memory* can also take the form of an omission, or you can experience place-losing (not knowing where you are in a task sequence) or you can forget your intentions.
2. The group called "mistakes", refers to occurrences when your plan for performing the task proves inappropriate. *Rule-based mistakes* occur if we misapply a normally good rule because we fail to spot the contra-indications, when we apply a bad rule, or when we fail to apply a good rule.

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Knowledge-based mistakes can occur in situations where no appropriate rules exist, so that we have to improvise a solution.

3. The third main group, "violations", occur when a person deliberately deviates from a known procedure for performing a task. We speak of *routine violations* if a deviation is so common that it has established itself as an informal norm, i.e. something "everybody" does. Routine violations thus only occur in recurrent tasks – tasks that have been repeated so many times that deviating routines have had the time to build up. *Situational violations* may occur when it is perceived as impossible or highly impractical to do the job according to the book; there is a mismatch between the rules and the constraint of the situation. *Exceptional violations* occur in situations that are unfamiliar to the persons involved. A prominent example is the series of violations that the operators of the Chernobyl reactor carried out prior to the disaster, when the reactor was in a very special and dangerous condition.

An important implication of the diversity of erroneous actions is that there is no panacea or "wonder-drug" that counteracts all kinds of erroneous actions.[18] Action slips are very difficult to eliminate. The best you can do is probably to use a checklist and have one dedicated person to administrate the checklist and monitor the performance of each step. This can also help against some instances of memory lapses. Rule-based mistakes can sometimes be reduced by including counterindications as part of procedures and by training people to spot the relevant counterindications. Knowledge-based mistakes can sometimes be reduced by providing guidelines on how to handle situations that have previously been handled without guidelines, or by providing expert guidance.

The people who take part in routine violations are often not aware of violating rules, since the deviation has established itself as a competing informal rule. The first step towards reducing routine violations is therefore to compare procedures and practice to spot recurrent violations. The next step is to examine the reasons for the violations and the consequences. The "solution" may be to stick to the rules, but it may also be to improve the rules, or to take steps to make it easier to follow the rules. Situational violations call for a safe manner to adapt the rules to the constraints of the situation – i.e. a good procedure for changing procedures, and availability of personnel with the authority and competence to make and approve such changes.

Exceptional violations are difficult to prevent because they tend to occur in uncommon situations and sometimes in situations that have not been foreseen. The advice for decision-making in crisis situations given at the end of Paragraph 3.4.4 may help you prevent dangerous exceptional violations in crisis situations.

Paradoxically, exceptional violations can in a few cases shade into heroic recoveries. During an uncontrolled gas blow-out on the Snorre A platform in 2004, the main supply of electricity had shut down automatically due to large amounts of explosive gas on the platform (Rosness et al. 2010). However, to fight the blow-out, the crew needed to run the mud pumps at full capacity, and this was not possible without access to the main power supply. The platform manager decided to restart the main power supply, based on the fact that no gas had been detected on the platform during the last hour. An experienced electrician found a way to do this which minimised ignition risk. The crew then started the mud pumps in a final attempt to control the well. At 10:22 in the morning, when only 8-10 m^3 of emergency mud remained, a pressure of 0 bars was recorded. The attempt was successful. The decision to restart the main power supply can be seen as an exceptional violation, but this action may have prevented a much more serious disaster, involving a capsize of the whole platform and parallel blow-outs from several wells.

The above example is a story about an incident with a heroic resilient recovery by human beings in much the same way as can be found in *extreme environments* such as the Arctic. In environments where humans are

[18] You may think that taking the human out of the system and automating his or her tasks will remove human error. However, you may still be left with errors related to design, construction and maintenance, including software errors.

not naturally suited we need to focus on the psychological and physiological capabilities and limitations to understand the risks that pose a threat to both health and safety. This awareness and understanding is also a necessary key to adapt to the constraints of cold, dark/light, isolated and remote locations and find the necessary coping strategies for successful human performance.

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