ARE YOU SHARP WHILE ASCENDING?

Audun Hetland*, Gerit Pfuhl*, Maia Herding Solberg, Fred Inge Guttormsen, August Nordby, Martin Jensen Mækelæ and Andrea Mannberg.

UiT The Arctic University of Norway, Tromsø, Norway

ABSTRACT:
Objective: Avalanches pose a major threat to people negotiating avalanche terrain. The majority of the accidents occur as a result of one or several sub-optimal decisions. The present paper examines 1) if specific levels of heart rate (HR) affect the ability to process information, 2) if this can help explaining why skiers show impaired judgment when evaluating risks in avalanche terrain and 3) if being in good shape will facilitate rational thinking. *Method:* The paper present two empirical studies (N = 61). The participants walked on a treadmill with steep incline wearing a backpack and weights on their feet. While walking the participants completed several rounds of a cognitive test at different levels of HR. The test was inspired by the Deese-Roediger-McDermott (DRM) paradigm. The participants in study 2 also did a VO2max test one week prior to walking on the treadmill. In addition, they completed a deliberate reasoning test before and after walking. *Results:* The participants in study 1 (N=40) performed significantly worse on the DRM test when HR was high, and after being in physical activity for some time. In study 2 (N=21) the participants with high VO2 max had better rational thinking abilities. In both studies perceived physical but not mental effort correlated with cognitive performance changes *Conclusions:* High levels of physical arousal, particularly at long durations, may impair information processing in less physically fit individuals. In future studies we plan to increase the ecological validity of this finding.

KEYWORDS: Physical activity, exercise, decision-making, deliberate reasoning

1. INTRODUCTION

Fatal avalanche accidents take more than 100 lives every year in the European Alps, with another 60 in US and Canada (CAIC, 2018; Techel et al., 2016). In addition, Jamieson and Jones (2015) estimated that only one in ten non-fatal accidents are reported. 90% of the fatal avalanches are triggered by the victims or somebody in their party (Tremper, 2008).

In response, there is a growing body of literature on how human factors affect decision making in avalanche terrain. These studies cover topics like risk perception and attitudes (Hallandvik, Andresen, & Aadland, 2017), cognitive biases (Marengo, Monaci, & Miceli, 2017), group dynamics (Hendrikx & Johnson, 2014), forecasts and communication (Niedermeier et al., 2017), decision tools (Haegeli, Haider, Longland, & Beardmore, 2010), avalanche rescue equipment (Haegeli et al., 2014), and avalanche risk (Vanpoulle, Vignac, & Soulé, 2017). However, data sources are primarily obtained "after the fact" through interviews, surveys or analysis of accident data. This does not allow any causal conclusions, and suffer from hindsight bias.

In addition to cognitive biases or motivated reasoning, possible causes of aberrant decision-making could be high arousal states or mental fatigue. The latter two are common among trained and untrained back-country skiers, respectively. Raue, Streicher, Lermer, and Frey (2015) found that exercise reduced the experienced probability of risk and increased the willingness for risk. So, what about the ability to make decisions when out of breath?

Even though the effect of exercise on cognitive functions has not been studied in an avalanche context, the effect has been extensively studied in other fields, i.e. psychology. The literature describes two conflicting lines of evidence. In a recent meta-analysis acute exercise had a small but positive effect on cognitive performance (Chang, Labban, Gapin, & Etnier, 2012). But not only exercise duration and intensity but also participant fitness were significant moderators. The longer the activity lasts, the more intense it is performed and the less fit the person is the more likely it is that cognitive performance is severely reduced. Back-country skiing involves often long and strenuous uphill climbs, temporarily exhausting the skier. It is done by a range of people, some less fit than others. We therefore set out to measure cognitive performance during various intensities, and among less and more well-trained participants.

* *Corresponding authors addresses:*
Audun Hetland: audun.hetland@uit.no or
Gerit Pfuhl: gerit.pfuhl@uit.no
Department of Psychology
UiT The Arctic University of Norway

Making decisions in avalanche terrain often involves a conscious evaluation of a range of factors, i.e. snow cover, weather, terrain, personal skills and group dynamics, where in addition some change during the trip. We therefore test the effect of acute exercise on visual working memory, and rational decision making. In addition, we also measured reaction times and perceived performance.

Dual-process theories and cognitive effort

Dual-processing theories divide human thinking into two separate systems (Stanovich, 2009). System 1 or intuitive thinking, is autonomous, automatic, fast, parallel, unconscious and effortless. System 2 or deliberate reasoning, is slow, serial conscious and require effort. Since deliberate reasoning is costly, relying on intuitive processes to save mental effort is a universal phenomenon in humans (Hull, 1943) Accordingly, there is a trade-off between intuitive and deliberate reasoning. Relying on system 1 is in many cases sufficient and adaptive, but can also lead to irrational decisions. According to Stanovich (2009) the capacity to execute deliberate reasoning, is separated from the ability to know when and how to apply it. Several factors can impende or enhance deliberate reasoning. For example; social factors, emotional states and arousal,(Ariely & Loewenstein, 2006), or individual differences in intelligence or thinking dispositions. Fortunately, like any other skill, deliberate reasoning can be practiced and learned.

However, for any learning to occur we need feedback on our previous decision so that we can improve until next time (Ericsson, 2008). In avalanche terrain valid feedback is scares. In the majority of cases we have no idea as to how close we were to trigger an avalanche. Instead we are rewarded by the pleasant experience of skiing and thus system 1 learns that skiing is fun, not dangerous and system 2 has only theoretical input to simulate an avalanche accident. As such, slope-specific decisions may therefore be guided by reward expected pleasure and less so by possible fatal costs.

In addition, our attention changes as activity increases. At low intensity we can choose to focus outwards on our surroundings and inwards on bodily sensations. As activity increases our attention is more and more directed inwards leaving less attention to collect vital information from the environment (Balagué, Hristovski, Aragonés, & Tenenbaum, 2012). Finally, system 2 is slow and demands effort and is therefore less likely engaged during heavy exercise. Indeed, we prefer not to engage in cognitively demanding activities (Kool, McGuire, Rosen, & Botvinick, 2010; Mækelæ, Moritz, & Pfuhl, 2018).

Finally, high levels of activity may also impair ones metacognitive abilities – the ability to monitor and control our own thinking. This is challenging because without the ability to monitor our own cognitive processes we may not notice that we are not fully up to speed. This is thus a double burden - you may be unaware of your own inability to make good decisions (Kruger & Dunning, 1999).

As a first line of investigation we manipulated arousal and measured its effect on cognitive performance, deliberate reasoning and perceived performance. In study 1 we compared performance on a visual working memory task in acute exercise and a non-acute exercise setting. In study 2 we tested well-trained participants' deliberate reasoning skills. In both studies we also measured perceived physical and mental performance.

2. METHOD

2.1 Exercise set-up

This paper present data from two different studies. In study 1 (N = 40, 19 females), 23 participants were in the acute exercise group, i.e. walked on a treadmill with 8.3° inclination, wearing a backpack (15% of body weight) and weights (2x1,5 kilo) around their ankles to simulate backcountry skiing.

While walking on the treadmill they were subjected to a visual working-memory test (Pfuhl, 2018). This test was administered three times. First below the ventilatory threshold (at 70-75% of max heart-rate), then above (at 80-85%) and again, below at (70-75%). Max heart rate was established a few days ahead by running on a treadmill in a fitness studio. 17 participants performed the same visual working memory test (see below) but during sitting comfortable in front of the PC, i.e. they had resting heart rate.

In the second study (N = 22, 8 females) the participants first did at VO2max test. The following day they conducted a rational thinking test and one round of the visual working memory task at resting heart rate. Then they were asked to walk on the treadmill with the same setup as in study 1. Immediately after the treadmill test they were asked to do another rational thinking test.

2.2 Cognitive tasks

In both studies participants had to memorize 12 stimuli per round, shown for 2 sec each, and were presented with 5 test stimuli immediately afterwards. Stimuli were shapes (Hillier, Campbell, Keillor, Phillips, & Beversdorf, 2007) or faces (Lundqvist, Flykt, & Öhman, 1998); in study 3 we also used words (Roediger & McDermott, 1995) translated into Norwegian. Among the 5 test stimuli were two previously seen stimuli ("true positives"), two related but novel stimuli ("false positives") and one clearly unrelated stimulus ("true negative"). Participants indicated on a scale whether they think they were sure to have seen the stimulus, somewhat sure, somewhat sure to not have seen it, or sure not to have seen it. There were 6 to 8 rounds per heart- rate condition. Data was analysed by signal detection theory, where d' describes discrimination ability and c the bias to say "yes" (being liberal) or "no" (being conservative).

At the end participants rated how physically, mentally, temporally effortful the task was.

In study 2 participants took items from the Cognitive reflection test (Toplak, West, & Stanovich, 2011) before and after visual working memory testing during acute exercise.

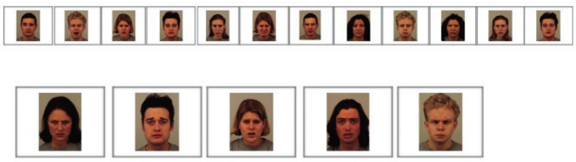

Figure 1: example set of 12 sample stimuli and 5 test stimuli of which 2 have been shown before (true positives), and 3 were novel (2 "false positives" and 1 "true negative")

3. RESULTS

3.1 *Study 1 – effect of acute exercise on discrimination ability and bias*

Comparing a non-exercising group with the acute exercise group yielded some benefit of exercise on cognitive performance, t(38) = 1.532, p = .134, Cohen's d = .49 as indicated by the medium effect size.

However, the higher the heart rate the worse the ability to distinguish "seen" from "not seen" stimuli; and performance did not recover after a few minutes of 80-85% max heart rate walking, F(2, 44) = 7.016, p = .002, $\eta^2 = .242$.

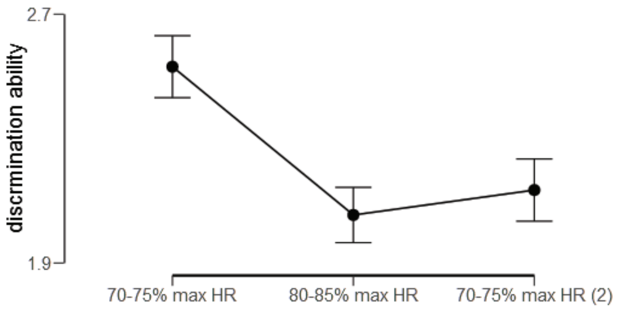

Figure 2: discriminability (d') during acute exercise (N=23) at two different heart rates. Error bars are standard error of the mean.

This agrees with Chang et al. (2012) finding that cognitive performance improves during exercise but is moderated by intensity and duration.

3.2 *Study 2 – effect of VO2max on deliberate reasoning*

In study 2 we recruited well-trained participants all having above average VO2 max (on average 20 ml, range 4 to 36 ml above tabulated reference values). These 21 participants had no change in their cognitive performance from resting rate, to moderate and then to 80-85% max HR treadmill walking. However, reaction time was significantly faster in the 80-85% max HR condition than the first 70-75% HR condition or during sitting, and was driven by a participant's VO2 peak. Notably, faster reaction times often indicated also a more liberal decision bias, i.e. saying "seen".

A participant's VO2 correlated positively with his / her deliberate reasoning score, r = .29. Better trained participants seemed inclined to use their system 2 more than system 1. Please note the small number of participants, warranting more data. However, it is in line with Chang et al. (2012) meta-analysis that exercising improves cognitive abilities.

3.3 *Perceived effort vs cognitive performance*

An important factor in avalanche decision making is knowing when one is good at making decisions, e.g. taking the time to recover one's breath after a strenuous passage. We measured metacognitive awareness or judging and monitoring how good one performs. We asked for perceived physical effort, cognitive effort and temporal effort directly after the 50-60 min treadmill walking.

In study 1 we found that the discrimination ability (d') correlated with perceived physical effort, r = .492 but not with perceived mental effort, r = -.19. Suggesting that the cognitive task did not feel difficult whereas how exhausting the treadmill walking felt, was more what participants should use as guide for their decision-making.

Similarly, in study 2 perceived mental effort was not related to the change in cognitive performance during 70-75% of HR to 80-85% of HR, r = .095 but was related to perceived physical effort, r = .47.

4. CONCLUSIONS AND OUTLOOK

In the two studies we wanted to test how strongly intensity, duration and physical fitness moderate the relationship between exercising and cognitive performance. In the first study we tested the effect of prolonged physical activity on visual working memory among well and less well-trained participants. In the second study we tested how rational thinking was affected by physical activity among above average physical fit participants.

In the first study we found that intense physical activity reduces accuracy in visual working memory, and importantly, the participants did not regain their cognitive abilities even though the intensity of activity decreased. Furthermore, the participants were unaware of their deteriorating cognitive abilities but how demanding the exercise was related well with the change in performance during intense and less intense treadmill walking.

In the second study we found that the more physically fit, as measured by VO2 max, the participant was, the better his / her deliberate reasoning abilities. Among these well-trained participants we found no change in cognitive performance during intense and less intense treadmill walking.

Crucially, in both studies participants' perceived mental demand was not related to their objective change in solving the task, but how physically demanding they judge the task correlated well with their ability to discriminate "seen" from "not seen" stimuli.

This has implications for deciding which slope to take. Physical exercise may reduce metacognitive awareness, but using how exhausted one feels may be a sufficient proxy for how well we perform cognitively. This warrants further research.

Physical activity is not just inevitable, but in most cases an important part of the experience of navigating avalanche terrain. However, as we gradually climb into steeper terrain where good decisions is a premise – our ability to make them can fail – either because of below average fitness or being unware how demanding the decision is. What is troubling for avalanche safety courses is that we think we can do it even when out of breath, when in fact only few can do it. Arousal, due to acute exercise, seems to facilitate using system 1. Being in good shape is a protective factor. A simple recommendation: get fit or go slow.

ACKNOWLEDGEMENT

We thank all our participants, C. Aranda-Rodriguez for kindly borrowing her treadmill. B Welde for VO2max testing, and T Nermo for technical assistance.

REFERENCES

Ariely, D., & Loewenstein, G. F. (2006). The heat of the moment: The effect of sexual arousal on sexual decision making. *Journal of Behavioral Decision Making, 19*(2), 87-98.

Balagué, N., Hristovski, R., Aragonés, D., & Tenenbaum, G. (2012). Nonlinear model of attention focus during accumulated effort. *Psychology of Sport and Exercise, 13*(5), 591-597.

CAIC (Colorado Avalanhe Information Center). (2018). Avalanche Accidents and Statistics. Retrieved from http://avalanche.state.co.us/accidents/statistics---and---reporting/

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research, 1453*, 87-101. doi:https://doi.org/10.1016/j.brainres.2012.02.068

Ericsson, K. A. (2008). Deliberate practice and acquisition of expert performance: a general overview. *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine, 15*(11), 988-994. doi:10.1111/j.1553-2712.2008.00227.x

Haegeli, P., Falk, M., Procter, E., Zweifel, B., Jarry, F., Logan, S., . . . Brugger, H. (2014). The effectiveness of avalanche airbags. *Resuscitation, 85*(9), 1197-1203.

Haegeli, P., Haider, W., Longland, M., & Beardmore, B. (2010). Amateur decision-making in avalanche terrain with and without a decision aid: a stated choice survey. *Natural Hazards, 52*(1), 185.

Hallandvik, L., Andresen, M. S., & Aadland, E. (2017). Decision-making in avalanche terrain–How does assessment of terrain, reading of avalanche forecast and environmental observations differ by skiers' skill level? *Journal of Outdoor Recreation and Tourism, 20*, 45-51.

Hendrikx, J., & Johnson, J. (2014). *Using global crowd-sourced data to understand travel behavior in avalanche terrain.* Paper presented at the Proceedings of the International Snow Science Workshop, Banff, Alberta, Canada.

Hillier, A., Campbell, H., Keillor, J., Phillips, N., & Beversdorf, D. Q. (2007). Decreased false memory for visually presented shapes and symbols among adults on the autism spectrum. *Journal of Clinical and Experimental Neuropsychology, 29*(6), 610-616.

Hull, C. (1943). Principles of behavior.

Jamieson, B., & Jones, A. (2015). *The effect of under-reporting of non-fatal involvements in snow avalanches on vulnerability.* Paper presented at the Proceedings 12th International Conference on Applications of Statistics and Probability in Civil Engineering, ICASP12, Vancouver, Canada.

Kool, W., McGuire, J. T., Rosen, Z. B., & Botvinick, M. M. (2010). Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology: General, 139*(4), 665.

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology, 77*(6), 1121.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska directed emotional faces (KDEF). *CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet, 91*, 630.

Mækelæ, M. J., Moritz, S., & Pfuhl, G. (2018). Are Psychotic Experiences Related to Poorer Reflective Reasoning? *Frontiers in Psychology, 9*, 122.

Marengo, D., Monaci, M. G., & Miceli, R. (2017). Winter recreationists' self-reported likelihood of skiing backcountry slopes: Investigating the role of situational factors, personal experiences with avalanches and sensation-seeking. *Journal of Environmental Psychology, 49*, 78-85.

Niedermeier, M., Weisleitner, A., Lamm, C., Ledochowski, L., Frühauf, A., Wille, M., . . . Kopp, M. (2017). Is decision making in hypoxia affected by pre-acclimatisation? A randomized controlled trial. *Physiology & behavior, 173*, 236-242.

Raue, M., Streicher, B., Lermer, E., & Frey, D. (2015). Being active when judging risks: bodily states interfere with accurate risk analysis. *Journal of Risk Research*, 1-18.

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of experimental psychology: Learning, Memory, and Cognition, 21*(4), 803.

Stanovich, K. E. (2009). Distinguishing the reflective, algorithmic, and autonomous minds: Is it time for a tri-process theory. *In two minds: Dual processes and beyond*, 55-88.

Techel, F., Jarry, F., Kronthaler, G., Mitterer, S., Nairz, P., Pavšek, M., . . . Darms, G. (2016). Avalanche fatalities in the European Alps: long-term trends and statistics. *Geographica Helvetica, 71*(2), 147-159.

Toplak, M. E., West, R. F., & Stanovich, K. E. (2011). The Cognitive Reflection Test as a predictor of performance on heuristics-and-biases tasks. *Memory & Cognition, 39*(7), 1275.

Tremper, B. (2008). *Staying alive in avalanche terrain*. Seattle: The Mountaineers Book.

Vanpoulle, M., Vignac, E., & Soulé, B. (2017). Accidentology of mountain sports: an insight provided by the systemic modelling of accident and near-miss sequences. *Safety science, 99*, 36-44.