Health, Safety and Performance in High Altitude Observatories: A Sustainable Approach

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The research project "Optimising Performance, Health and Safety in High Altitude Observatories" was initiated by ESO to establish an approach to promote the well-being of staff working at its high altitude observatories, and in particular at the Antiplano de Chajnantor. A survey by a questionnaire given to both workers and visitors was employed to assess the effects of working conditions at high altitude. Earlier articles have outlined the project and reported early results. The final results and conclusions are presented, together with a concept for sustainable development to improve the performance, health and safety at high altitude employing Critical Incident Stress Management.

Innovative ground-based submillimetre astronomical observatories like the Atacama Large Millimeter/submillimeter Array (ALMA) and the Atacama Pathfinder EXperiment (APEX) take advantage of the very low natural levels of atmospheric water vapour at very high altitude sites to attain high sensitivity in the submillimetre wavelength range. As these and other similar ground-based facilities come into operation, more people will be exposed to high altitude conditions.

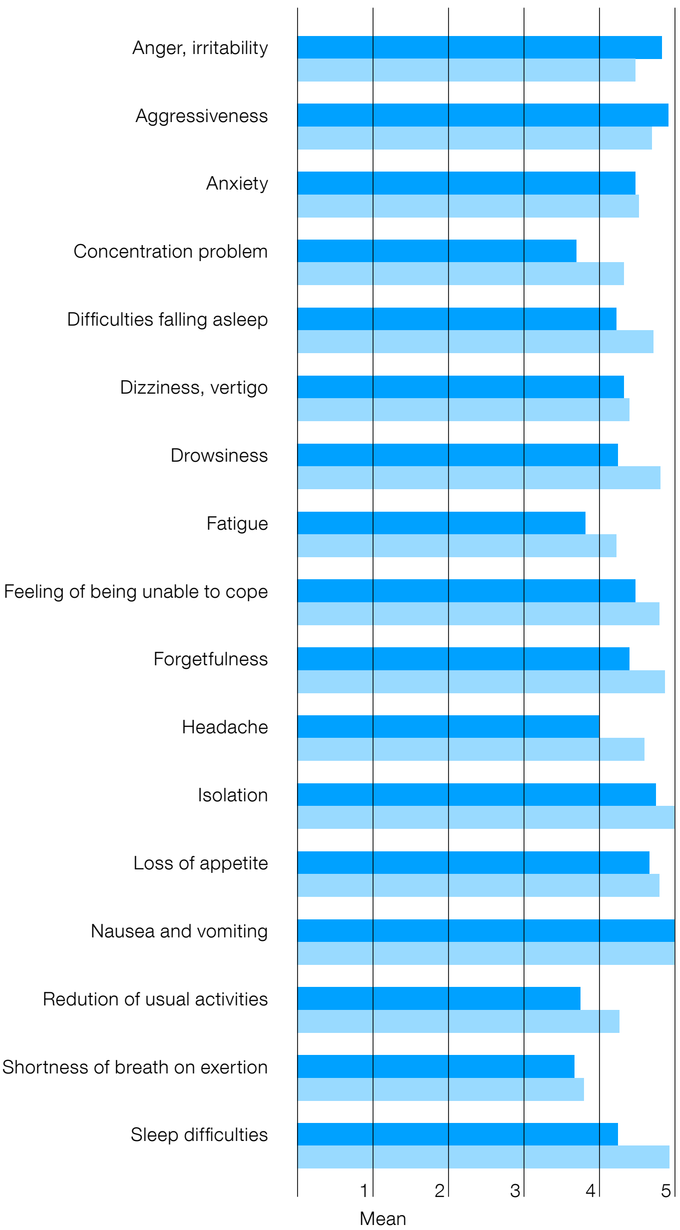
The research project "Optimising Performance, Health and Safety in High Altitude Observatories" was initiated by ESO from an organisational psychology perspective to establish a sustainable development programme for the well-being of its staff in special environments. The major objective is to consider the effects of high altitude on those people who will be required to work above 5050 m altitude at Llano de Chajnantor, the site of ALMA and APEX. The final goal of the project is to acquire and promote knowledge in the field of human activity at high altitude observatories, which then will be utilised to help in planning observatory operations.

In addition to the scientific challenge for the astronomical community presented by APEX and ALMA, there is the challenge for the executive organisations to take sufficient care of staff and equipment. This is especially true if sensitive work has to be performed at high altitude (above 3000 m). A good example is the operation of the ALMA transport vehicles: ALMA staff must move the antennas across the Chajnantor Altiplano over distances from 150 metres to 15 kilometres using these specialised transport vehicles (see Kraus et al., 2008). The weight of the antennas (about 100 tons), their delicacy and the hostile, high altitude environment impose severe constraints on the use and functionality of the transport vehicles and the technical equipment in general, as well as on the drivers and supporting staff. Amongst other manoeuvres, staff have to position the antennas to an accuracy of a few millimetres or move the antennas slowly for maintenance and repair from the Array Operations Site (AOS) at 5050 m altitude to the Operations Support Facilities (OSF) at 2900 m, via a 12-metre wide and 28 kilometre-long road — a 3 to 5 hour drive at 8 km/h.

While a great deal of knowledge has been acquired about the biomedical changes at high altitude and under low oxygen conditions, there is little knowledge available about the psychological changes. Furthermore, there are conflicting results on the effects of high altitude, adding emphasis to the importance of the project. So as to develop an adequate preventive health and safety process systematically, a questionnaire was developed and distributed to staff working for ALMA and APEX, or visiting the sites, and 28 questionnaires were returned by visitors and workers. As has already been summarised (Böcker et al., 2008), the results from the questionnaire indicated that working conditions at high altitude are better than expected. The visitors/workers reported neither major psychosomatic complaints nor impairments in abilities and work behaviour or performance (see Figure 1 for a diagrammatic summary of the questionnaire results). The participants reported moderate to slight limitations with respect to their tasks at low altitude workplaces. Planning and teamwork activities were slightly impaired, while manual and other tasks were moderately impaired. Teamwork could have a social activation function, in that it reduces fatigue and attention problems that might be induced by high altitude conditions and travel jet lag. Workers tended to report more limitations than visitors, especially for complex mental tasks, such as computer programming. Concentration problems, fatigue, reduction of their usual activities, shortness of breath on exertion (see Figure 1) were the complaints reported to occur on average slightly more often. Other complaints that have been reported by mountaineers, such as nausea, vomiting and severe sleep difficulties, were not experienced at all by the ESO site workers and visitors.

The regular workers generally report slightly more problems at high altitude, but received more benefit from preparatory documents/tools than visitors, although these results were not statistically significant. The experience of workers appears to be a good training for effective functioning at high altitude. However, cultural differences (optimism of local staff and workers as opposed to the critical outlook of the visiting scientist) and adaption to the difficult working conditions probably also play a role; for activities involving selective attention (concentration) and technical understanding of equipment, the differences were statistically significant. Two functions stood out from the questionnaire results as showing a tendency to be impaired at high altitude: perceptual speed and attention span (see Figure 2). Occupational Safety and Health (OSH) programmes could consider this result and try to address perception and attention problems. Workers reported slightly more impairment than visitors.

High altitude safety and health issues were generally considered seriously by visitors and also by the local and international staff working at the site. Serious incidents could result if individuals are unprepared for high altitude activities and in cases where the standard preparation procedures are not followed for whatever



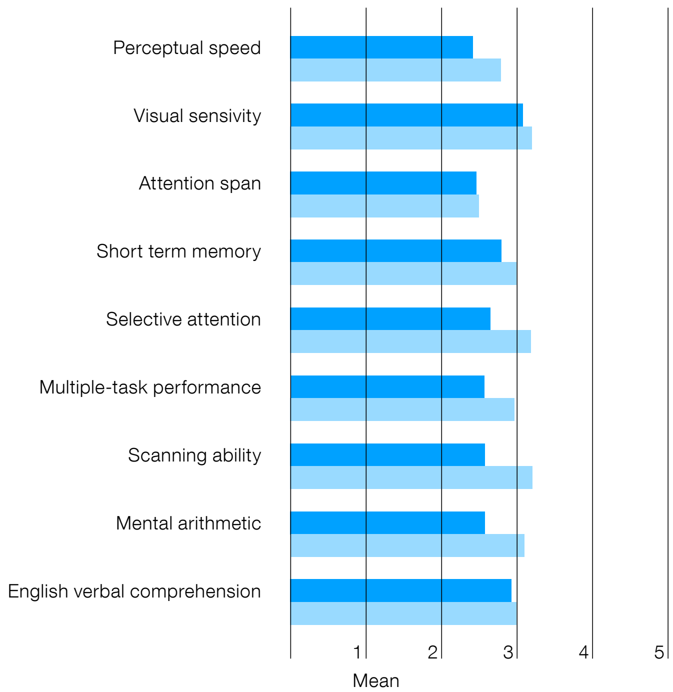


Figure 2. Ratings of abilities at high altitude from the questionnaire results (scale: 1 strongly impaired; 5 greatly improved).

Figure 1. Summary of questionnaire returns showing average scores for physical and psychological complaints (scale: 1 extreme; 5 absent).

reason. A decent amount of safety consciousness and consideration of the negative environmental conditions prevalent at high altitude sites are a necessity.

The questionnaire results indicated some areas worthy of further study and that could be given more support in OSH programmes, such as concentration/attention problems, under-arousal and reduced capacity. Measures to improve work conditions, organisation and human behaviour, safety and health consciousness at high altitude sites must be developed.

A sustainable development approach

From an organisational and personal development viewpoint, a comprehensive analysis should be carried out. This analysis should include psychological/team factors, because in other high altitude environments with established good team cultures, like APEX, fewer accidents seem to occur. In order to investigate psychological or team factors in the area of health awareness, a theory-based and empirically validated framework is needed to outline the process describing behavioural change. From nearly one hundred years of motivation and action research, it is known that behaviour modification is difficult and requires more than just information and insight. The overlap between what we think is right and what we actually act on is less than 30 % (Six, 1992).

The Health Action Process Approach (HAPA model; Schwarzer, 2008) is suggested as a basis for behavioural development. This model explicitly considers the volitional phase of action. But before such a person-centred framework is developed, a systemic approach to the personal, situational and organisational factors has to be taken into account to facilitate a broader view of optimising human and organisational performance. The adoption, initiation and maintenance of health behaviour are processes of motivation, volition and action (Schwarzer, 2008). Motivation means we must make people want to behave safely and in a healthy manner. Volition means we must increase their self-awareness of the consequences of unsafe actions and increase their belief in safe behaviour. Action is largely an individual's responsibility, but they should be properly

Malpractice	No. of workers recorded	Abuses %
Speeding	463	14
Drugs	38	4
Alcohol	35	13

Table 1. ALMA driving malpractice (driving too fast or after drinking alcohol or taking drugs) statistics recorded in a randomly chosen month.

supported in their self-management by tools, procedures and safety leadership.

An observatory site is a web of complex human relations under challenging conditions. The good intentions of staff with regard to safety do not guarantee the corresponding safe actions. Consideration of the accident statistics at ALMA demonstrates that, in spite of information campaigns, practical training, additional speed signs and increase of speed controls, vehicle speeding, for example, remains a problem. Although driving and drinking is proscribed at the observatory sites, it still remains a problem as the statistics in Table 1 demonstrate.

However, good intentions alone do not necessarily guarantee the corresponding right actions. Important factors are how hard a person will try to put an intention into practice and how long he or she will persist. Psychological distractions such as unforeseen circumstances may influence the maintenance of goals because of changing the self-efficacy (e.g., stressful incidents). Also work organisation practices can have a major influence. In future, ALMA will operate round the clock, so shift work will need to be considered in terms of matters of health, safety and performance of staff.

A major driver of the negative effects of shift work on employees is the desynchronisation of the circadian rhythm (body clock), both in biological and social respects. Due to the lack of adjustment of the body, the person has to work against its demands. Studies show that the error rate during night shift work is higher than for day shift and, as a consequence, productivity is lower, with a higher accident rate than during daytime. The most important social areas affected by shift work are partnership, family life and leisure time. Working shifts at a high altitude in the Atacama desert, far away from the social support of the family, with a reduced social life and possible jet lag due to overseas travel (for visiting scientists and engineers) can increase the risk of accidents.

Hence, at the prevention level, knowledge about critical behaviour and risk factors is essential. One efficient and certified programme for a sustainable development in organisations is Critical Incident Stress Management[1] (CISM), which facilitates a professional handling of accidents, near misses and critical incidents. Although CISM is conceived as an intervention after such negative occurrences, our experience demonstrates that CISM supports the prevention of problems and also facilitates innovation (Mosmann, 2009), as well as the development of a sustainable communication and safety culture. It is generally assumed that using CISM as a mutual basis for activities stabilises intercultural teams or networks. The physical (high altitude, etc.) and social stress factors (absence from family, etc.) at the high altitude Chajnantor site can promote maladaptive behaviour, such as the overestimation of abilities or drinking that can compromise safety. Prevention works on the basis of the culture that CISM fosters in communication and safety management. The professional intervention, prevention and implementation of CISM also imply positive business and economic benefits (Vogt & Pennig, 2006).

Conclusions

The recommendation for high altitude observatories is to integrate adequate occupational health and safety programmes early and to begin a process of personnel and organisational development quickly. Otherwise the physical and social stress factors at the high altitude observing site can facilitate maladaptive behaviour such as an overestimation of abilities, drinking or taking drugs, thus compromising safety. Adaptive coping by individuals must be promoted. In order to ensure this, a proper programme must be put in place, based on a scientific and standardised approach. One very efficient method is Critical Incident Stress Management.

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