Institution:
School of Natural Sciences & Psychology (Liverpool John Moores University)

Unit of Assessment:
UoA4 - Psychology, Neurosciences and Psychiatry

Title of case study:
Human Factors and Space Exploration

1. Summary of the impact (indicative maximum 100 words)

The Operator Functional State (OFS) describes the psychological capacity of an operator to deliver safe and effective performance. Expertise in OFS theory and methodology was developed at LJMU via studies of driving behaviour and aviation control. When the European Space Agency wished to prioritise issues surrounding OFS in the context of space exploration, they recruited an expert from LJMU. The resulting discussion led to the identification of key issues to maintain operational skill and reduce accident likelihood during long duration space missions. The expertise developed at LJMU has influenced the European programme for space exploration over the coming decade.

2. Underpinning research (indicative maximum 500 words)

Human factors research at LJMU is concerned with skill development and how complex performance may deteriorate under conditions of duress, such as high mental workload, boredom or sleep deprivation. Understanding the limits of skilled performance is especially important in the context of safety-critical behaviour where human error has the potential to cause fatalities. The Operator Functional Status (OFS) provides a framework within which to understand the capability of the human operator to perform effectively and safely during complex control tasks. The OFS approach is based upon a methodology where complex performance and accident risk is understood in terms of the relationship between workload, performance and operator skill.

Professor Andy Tattersall joined the unit in 1998 when his research concerned sleep patterns and workload in occupational groups (e.g. passenger ferry crews). Professor Stephen Fairclough took up his post at LJMU two years later with a background in the measurement of OFS in the context of driving behaviour. The unit completed a consultancy project funded by Volvo in 2001 to study sleep/wake patterns for HGV drivers. The knowledge gained through this project contributed to an article in the journal Ergonomics in 2003 that defined impairment of the driver due to alcohol, sleep/wake disturbances and mental workload in terms of quantifiable detriments of performance. Fairclough and Tattersall collaborated on a successful bid to EPSRC that ran from 2002-2004. This project investigated the relationship between skill acquisition and mental workload; the work also encompassed the detrimental influence of sustained performance on OFS and how system automation may be used to “protect” performance when the operator is tired or experiencing high task demand. The final project report was subject to review upon completion and received a rating of ‘4’ (Tending towards Outstanding).

In April 2002, Professor Tattersall was one of the group of international experts invited to an Advanced Research Workshop (ARW) at Il Ciocco (near Lucca, Italy) organised by the Research and Technology Organisation of NATO. The research meeting was entitled “Operator Functional Status and Impaired Performance in Complex Work Environments” and was part of the Human Factors and Medicine Panel (HFM) Task Group (HFM-056/TG-008). The ARW resulted in an edited collection that represented the state-of-the-art in OFS research (published in 2003 by IOS Press) and a NATO/RTO report describing how OFS could be defined and measured within the context of military systems.

The specific strand of OFS research conducted by LJMU focused on techniques to sustain effective performance under high mental workload (training, adaptive automation) and the risk of accident due to the influence of stressors on performance (monotony, disturbance of sleep/wake patterns). Our work has developed and refined multidimensional measures of OFS, from subjective self-report to psychophysiological techniques as evidenced in our outputs (see next section). This background in OFS concepts and methodology represents our expertise in this field and has contributed to the identification of human performance issues for long duration space exploration in the current impact case study as evidenced by our input to the ESA.

3. References to the research (indicative maximum of six references)

Brookhuis, K. A., Fairclough, S. H. & De Waard, D. (2003). Critical indicators of driver impairment. Ergonomics, 46(5), 433-445. *(citation count: 79)*

Fairclough, S. H., Venables, L. & Tattersall, A.J. (2005). The influence of task demand and learning on the psychophysiological response. International Journal of Psychophysiology, 56, 171-184. *(citation count: 62)*

Fairclough, S.H. & Venables, L. (2006). Prediction of subjective states from psychophysiology: a multivariate approach. Biological Psychology, 71(1), 100-110. *(citation count: 53)*

Mullen, R., Hardy, L., & Tattersall, A. J. (2005). The effect of anxiety on motor performance: A test of the conscious processing hypothesis. Journal of Sport and Exercise Psychology, 27, 212-225. *(citation count: 49)*

Tattersall, A. J., & Fairclough, S. H. (2003). Adaptive automation and modes of control. In G. R. J. Hockey, A. W. K. Gaillard & O. Burov (Eds.), Operator Functional State: The Assessment and Prediction of Human Performance Degradation in Complex Tasks. Amsterdam: IOS Press. (*citation count: 3)*

Tattersall, A. J., & Hockey, G. R. J. (2008). Demanding work, technology, and human performance. In N. Chmiel (Ed.), Introduction to Work and Organizational Psychology (2nd edition). Oxford: Blackwell. *(0 citations)*

Key Grants

EPSRC Grant GR/R81077/01: Biocybernetic Control of Adaptive Automation (2002-2004). PI: S. Fairclough, Co-I: A. Tattersall. (£60,000)

Volvo Research: Advanced Sleep Awareness Project (ASAP) (2000-2001).
PI: S. Fairclough (£35,000)

4. Details of the impact (indicative maximum 750 words)

The European Space Agency (ESA) require that human beings can survive and work in space for long durations of time in order to conduct a mission to Mars before 2020. However, a number of general risks to astronauts have been identified by the ESA that require further investigation before long duration space missions can be attempted. Some of these issues are medical (e.g. prevention of bone loss in zero gravity) whereas others are psychological in nature, e.g. boredom/monotony, human-system automation.

The ESA wish to protect the capacity of their astronauts to work effectively in order to maximise the safety of long duration missions into space. Therefore, they recruited a group of OFS experts to identify critical issues for space exploration. The research conducted by LJMU led to an invitation for Professor Tattersall to join a “Topical Team” from 2008-2011. The brief for this group of seven pan-European experts was to develop a detailed description of how long duration space missions could affect human performance and safety. Professor Tattersall also served the ESA as a nominated expert and reviewed applications related to human factors psychology factors on the research programme surrounding the Concordia facility (Concordia is an isolated Antarctic station used to approximate conditions of long duration space exploration).

Despite existing studies from NASA and reports obtained from the “Topical Teams” organised by the ESA, it was recognised that Europe had no roadmap for the exploration of space approved by the European scientific and industrial communities. The primary aim of the THESEUS project funded by the European Science Foundation (ESF) in April 2010 was to develop an integrated life sciences roadmap to enable a European space programme to take advantage of the expertise available in the community. This project organised activities into cluster groups and Professor Tattersall was invited to join Cluster 2 (Psychology and Human-Machine Interface). This group of

26 experts were divided into three themed groups (group/team processes, human-machine interface, skill maintenance) tasked with identifying knowledge gaps and defining/prioritising key issues for operational integrity during long duration space missions. The output from these discussions were documented over the two years of the project and presented at the THESEUS Roadmap launch event held in Paris on 15th March 2012. The key issues identified by the THESEUS Roadmap (see the Cluster reports cited in section 5) will feed directly into the European space programme to travel to Mars by 2020 and prioritise those human factors research topics to be addressed within the space exploration area of the Horizon 2020 programme.

Professor Tattersall chaired the group of eight experts concerned with OFS research issues surrounding skill maintenance. They identified four key issues for long duration missions into space:
(a) skill deterioration during long-duration missions and need for on-board training
(b) scheduling and delivery of task training
(c) threats to skill maintenance such as monotony/boredom, isolation, task demand
(d) scheduling of work/rest and sleep/wake patterns in space to prevent impaired performance.

There is continuity between original research at LJMU and those key issues identified in the Psychology/Human-Machine Interface area for space exploration. Our experimental paper (Fairclough et al, 2005) on the relationship between mental workload, performance and learning/skill development provided evidence of how training/skill development can alleviate high workload (issue 1). The paper on sustained complex performance (Fairclough and Venables, 2006) demonstrated how monotony can lead to errors and the book chapter (Hockey and Tattersall, 2008) described the effects of fatigue and workload on health and performance (issue 3). Our work on modeling sleep/wake cycles in order to predict impaired performance was conducted on a commercial-in-confidence basis for Volvo, but the knowledge obtained informed the identification of issue 4 resulting in the prioritisation of these themes in the THESEUS Roadmap for space exploration and represents a direct impact from our research as Professor Tattersall was leading discussion on the skill maintenance theme.

The OFS concept provides an explanatory framework for understanding and predicting how skilled performance may degrade under conditions of duress. The inclusion of OFS in the work of ESA and ESF is important because it permits the developing field of space exploration to exploit existing knowledge from other domains of skilled performance. This transfer of knowledge provides policy-makers with a preview of the risks, challenges and potential solutions during space exploration in order to inform their organisational protocols and priority areas for further investigation. Therefore, the expertise developed by Professor Tattersall at LJMU has been accessed to promote safety and inform operational procedures for space exploration over the coming decade.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Hockey, G. R. J., Åkerstedt, T., Gaillard, A. W. K., Manzey, D., Mulder, L. J. M., Pattyn, N., & Tattersall, A. J. (2011). Human Performance in Extended Space Operations. Report of the ESA Topical Team in Psychology. Paris: European Space Agency.

European Space Agency
Invited member of Topical Team on Operator Functional State (2008-2011)

Nominated ESA expert, Workshop/Closed Session on Human Behavior and Performance in Analogue Environments and Simulations, ESA/ESTEC, Noordwijk, The Netherlands, 7-9 December 2009.

External Consultant and Review Panel Member, AO-11-Concordia: Medical, Physiological and Psychological Research Using Concordia Antarctic Station as Human Exploration Analogue, March 2012.

Invited member of European Science Foundation programme THESEUS (Towards Human Exploration in Space: the European Union Strategy), January 2010 – March 2012.

Chair of THESEUS Skill Maintenance Expert Group (2010-2012).

THESEUS Website
http://www.theseus-eu.org/home.html

Link to Cluster 2 Report on Psychology and Human-Machine Systems (THESEUS)
http://www.theseus-eu.org/fileadmin/Docs/Eg_reports_roadmap/Cluster2_web.pdf

Link to Cluster 2 presentation as part of THESEUS RoadMap Launch Event
http://www.theseus-eu.org/fileadmin/Docs/Roadmap_conf/Cluster2.pdf