Institution: University of Southampton
Unit of Assessment: 04 Psychology, Psychiatry and Neurosciences
Title of case study: 04-03-Applying Psychology to Visual Searches for Security Threats in War Zones and High-risk Public Spaces

1. Summary of the impact

Researchers at the University of Southampton have informed aviation security policies and training procedures of soldiers in the USA and UK. The research has applied principles from vision science to the practical field of contemporary security, specifically the screening of airport baggage for weapons and explosives, and the search for Improvised Explosive Devices (IEDs) embedded in the environment in combat theatres such as Afghanistan. Findings have contributed to international airport security and to vital training for troops in combat situations. They have also been widely used to inform the public about the latest advances in security procedures.

2. Underpinning research

Academics at the Centre for Vision and Cognition (CVC) have applied principles from vision science and the human attention system to the practical field of contemporary security, specifically the screening of airport baggage for weapons and explosives, and the search for Improvised Explosive Devices (IEDs) embedded in the environment in combat theatres such as Afghanistan.

Research into the way airport security staff view X-ray images of passengers' baggage began shortly before the 9/11 attacks in the United States in 2001. With funding from the US Department of Homeland Security [3.G1], the UK Department of Transport, private defence firm QinetiQ and the EPSRC [3.G2], Professor Nick Donnelly (Head of Psychology), Professor Kyle Cave, (Reader in Psychology, 1999-2003) and Dr Tamaryn Menneer (Lecturer in Psychology) researched visual search for two different objects at the same time. This situation reflects a baggage screener's search for potential threats from metal weapons (guns or knives), which appear in blue on baggage scans, or IEDs, which appear largely orange.

Results [3.1] showed that conducting two single-target searches is more efficient than carrying out a dual-target search, concluding that the need for baggage screeners to search simultaneously for very different targets (guns, knives and IEDs) could result in inefficiencies. Building on these results, the CVC team confirmed [3.2, 3.3, 3.4] that a dual-target search for dissimilar targets reduces accuracy, suggesting that dividing search tasks for X-ray baggage screening would improve performance.

Further research [3.5, 3.6] revealed that conducting searches for two targets when one appears at a higher prevalence level than the other will result in the higher-prevalence target being detected often, at the expense of the lower-prevalence target. This finding exposed a potential weakness in current airport security screening policy, where screeners search for both bottles of liquid, which are frequently occurring, and threat items, which occur rarely.

The findings proved of interest to the Ministry of Defence's Counter Terrorism Centre (CTC), as it sought to improve efficacy of visual searches for IEDs by troops in Afghanistan, the main cause of casualties in combat. The Defence Science and Technology Laboratory (Dstl) and the CTC provided funding [3.G3] to explore how to improve detection of threats in physical real-world environments beyond X-ray environments [5.1-5.4]. Full details of these projects cannot be disclosed due to their security-sensitive nature but analyses of eye movement behaviour, attention allocation, and underlying decision processes displayed by soldiers, both experienced in finding IEDs and those new to the task, gave rise to recommendations for new improved training procedures.

The MOD is now applying the threat detection techniques developed for British troops in Afghanistan to security procedures closer to home, by funding the CVC team for on-going work to develop and test a training framework for searches of public spaces and buildings [3.G3-3.G5].

The CVC team has also been awarded funding by the Economic and Social Research Council (ESRC), under the RCUK Global Uncertainties programme, for on-going research on whether 3-D depiction of X-ray-image objects helps the search for possible security threats [3.G6].

3. References to the research

3.1 Menneer, Tammy, Phillips, Luke, Donnelly, Nick, Barrett, Doug J.K. and Cave, Kyle R. (2004) Search efficiency for multiple targets. Cognitive Technology, 9, (2), 22-25.

3.2 Menneer, Tamaryn, Barrett, Doug J.K., Phillips, Luke, Donnelly, Nick and Cave, Kyle R. (2007) Costs in searching for two targets: dividing search across target types could improve airport security screening. Applied Cognitive Psychology, 21, (7), 915-932. (doi:10.1002/acp.1305).

3.3 Menneer, T., Cave, K. R., & Donnelly, N. (2009). The cost of searching for multiple targets: Effects of practice and target similarity. *Journal of Experimental Psychology: Applied, 15,* 125-139.

3.4 Stroud, M. J., Menneer, T., Cave, K. R., & Donnelly, N. (2012). Using the dual-target cost to explore the nature of search target representations. *Journal of Experimental Psychology: Human Perception and Performance*, 38, (1), 113-122.

3.5 Godwin, H. J., Menneer, T., Cave, K. R., Way, R. L., Helman, S., & Donnelly, N. (2010). The impact of relative prevalence on dual-target search for threat items from airport X-ray screening. *Acta Psychologica*, *134*, 79-84.

3.6 Menneer, T., Donnelly, N., Godwin, H. J., & Cave, K. R. (2010). High or low target prevalence increases the dual-target cost in visual search. *Journal of Experimental Psychology: Applied, 16,* 133-144.

Selected grants:

3.G1 Donnelly, N. & Cave, K. R. July 2002 – June 2008. "Improving the efficiency of visual search: Single-target versus dual-target search". $490,324. Transportation Security Laboratory, U.S. Department of Homeland Security.

3.G2 Donnelly, N. October 2005 – September 2008. PhD studentship: "Visual search for threat items in airport security screening." £70,000. QinetiQ, Department of Transport and EPSRC.

3.G3 Donnelly, N. & Liversedge, S.P., June 2010 – current. "Threat detection in complex environments". £242,000, Defence Science and Technology Laboratory (Dstl) and the Counter Terrorism Science and Technology Centre (CTS & TC).

3.G4 Donnelly, N. & Garner, M.J., October 2013 – October 2016. PhD studentship "The role of cognitive neuroscience in understanding, managing and optimising human performance". £101,517, Defence Science and Technology Laboratory (Dstl).

3.G5 Garner, M.J., Godwin, H., & Hadwin, J.A., October 2013 – October 2016. PhD studentship "Understanding, managing and optimising human performance when engaged with complex visualisation displays". £85,502, Defence Science and Technology Laboratory (Dstl).

3.G6 Donnelly, N., Menneer, T. & Liversedge, S.P., November 2011 – November 2015. "Teaching the visual system to segment and interpret images of overlapping transparent objects". £550,000. ESRC.

4. Details of the impact

Research results actively disseminated by CVC academics have influenced current anti-terrorism and defence strategies employed by the Ministry of Defence (MOD), the US Department of Homeland Security (DHS), the Department for Transport and private defence company QinetiQ [5.1-5.8].

The work on detecting IEDs in combat zones is directly informing current training in Counter-IED procedures and is helping to build the capability of Britain's armed forces by tackling the main cause of casualties in the combat theatre. In 2009 USA Today reported that 75% of coalition casualties in Afghanistan were caused by IEDs, up by 50% on 2007. The CVC's findings [5.2-5.4] are being used to inform military personnel in combat zones and the MOD has forwarded the research to army commanders and private contractors in the field. The MOD's Counter Terrorism Centre acknowledged the value of the research as follows by email [5.1]:

"*The outputs from the studies conducted by the University of Southampton have been presented to a range of stakeholders, as well as informing the understanding of the mechanisms that underpin the visual search for targets in an operational environment. Presentations using the findings of these studies have been given to the following: [RESTRICTED TEXT REMOVED]*

Donnelly acted as one of the advisors to the Dstl's 'Tiger' IED detection team in 2010. In December that year, Dstl released a statement describing the "*success*" of the Tiger team in developing new technologies to detect IEDs in Afghanistan. The team, comprising the MOD, Defence Equipment and Support (DE&S), military and industry, demonstrated the "*viability of four exploitable solutions which are being transitioned to DE&S for final development and procurement.*" The statement also said that the success of the Tiger team would inform the MOD's research strategy. Over recent years (2010-2013) the number of deaths from IEDs for UK troops has reduced. There are multiple reasons for this reduction, including better detection of IEDs, which has been informed by the research from Southampton.

Further to this successful project, the MOD is drawing on the research of Southampton's CVC team to train security personnel in identifying threats in public spaces such as conference centres and private homes [3.G3]. The results of this on-going research [5.4] will be used to develop and inform training for high-level security procedures at, for example, public and VIP national and international events.

The findings on X-ray screening of airport baggage [5.5-5.8] led the DHS to test them in the field on US airport baggage screeners. The work is now informing airport security policy. Dr Josh Rubinstein of the DHS' Transportation Security Laboratory [5.5] says the CVC team "*has been instrumental in supporting the Department of Homeland Security's research program on aviation security. The research has greatly enhanced our understanding of the perceptual and cognitive processes involved in airport security x-ray visual search.*" He continues, "*your work is finally bubbling up to affect policy.*"

CVC researchers have also disseminated research findings to the international aviation security industry, presenting results at the Fourth International Aviation Security Technology Symposium and the International Transport Security Human Factors Technical Advisory Group (InterTag).

The research has informed a wider audience through publication in the press and broadcast media, including a film report by the Associated Press news agency for distribution to over 500 TV channels worldwide. The findings on dual-target search were conveyed to the general public at the Royal Society Summer Science Exhibition (London, July 2011) [5.9], attended by around 14,000 people. Interactive displays involved visitors having their eye movements tracked as they searched for guns and IEDs in baggage X-rays. Visitor questionnaires showed strong support for the statement, "*After visiting this stand I think that psychology research makes a valuable contribution to life in the UK.*" The BBC, The Guardian, China Radio International and various weblogs covered the involvement of the research in the exhibition [5.10]. Menneer was interviewed by radio station Radio Wave 105.

5. Sources to corroborate the impact

DSTL corroborator:

> 5.1 Ergonomist - Human Integration Team, Defence Science and Technology Laboratory.

Selected reports to DSTL:

> 5.2 Godwin, H. J., Kirkby, J., Liversedge, S. P. L., & Donnelly, N. (2010). Characterising expertise for IED detection in the visual environment. Research Report to Defence Sciences Technology Laboratory (Dstl).

> 5.3 Godwin, H. J., Liversedge, S. P. L., & Donnelly, N. (2011). Eye Movements and Visual Search for Threat in the Environment. Research Report to Defence Sciences Technology Laboratory (Dstl).

> 5.4 Donnelly, N., Mann, C. M., Godwin H. J., & Liversedge S. P. (2012). Eye Movement Behaviour during Building Search. Technical Report to Defence Sciences Technology Laboratory (Dstl).

Department of Homeland Security corroborator:

5.5 Chief, Army Research Laboratory, Human Research and Engineering Directorate.

Selected reports to DHS:

5.6 Donnelly, N., Menneer, T., Butler, C., Cave, K. R., Li, X., Stroud, M. J, and Rubenstein, J. June 2008. Search for multiple threat items is less effective than specialization. Research report to U.S. Department of Homeland Security, Transportation Security Administration.

5.7 Donnelly, N., Menneer, T. and Cave, K. R. March 2009. Dual-target search experiments. Summary of research (2002-2009) and Contribution to the Academic Research Database for Josh Rubenstein, U.S. Department of Homeland Security, Transportation Security Administration.

5.8 Menneer, T., Donnelly, N. and Cave, K. R. February 2010. Increasing the efficiency of airport security screening: A review of publications. Reported to Josh Rubenstein, U.S. Department of Homeland Security, Transportation Security Administration.

Royal Society Summer Science Exhibition corroborator and weblinks:

5.9 Events Officer, The Royal Society.

5.10 Links to example Exhibition material:

http://royalsociety.org/summer-science/2011/airport-security/

http://www.guardian.co.uk/science/blog/2011/jul/06/royal-society-summer-live-exhibition