

Impact case study (REF3)

Institution: University of Oxford		
Unit of Assessment: 12 – Engineering		
Title of case study: Oxevision - Vision-based patient monitoring and management in mental health settings		
Period when the underpinning research was undertaken: 2010 to 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof. Lionel Tarassenko	Professor of Electrical Engineering	1988 – present
Dr Mauricio Villarroel	Research Assistant Post-Doctoral Research Assistant	2010 – 2017 2017 – present
Period when the claimed impact occurred: Aug 2013 to Dec 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact		
<p>Research at the University of Oxford into methods and algorithms for the non-contact monitoring of vital signs led to the development of the Oxevision system, the main product of Oxehealth, a spin-out from Prof. Tarassenko's research group. Oxevision is the world's first CE-marked continuous medical-grade contact-free vital-sign monitoring system using low-cost digital video cameras. The Oxevision software turns video cameras into health monitors, allowing real-time estimation of heart rate and breathing rate with clinical-level accuracy. Computer vision algorithms enable the patient location (static monitoring) and motion (dynamic monitoring) to be determined and quantified. From this, indices relevant to the care of the patient, for example the likelihood of a fall for an elderly patient, are derived.</p> <p>Oxevision has been installed in 30% of mental health NHS Trusts in England and two separate sites in Scandinavia (1,277 patient rooms in November 2020, GBP2,080,000 Annual Recurring Revenue for Oxehealth). The resulting installation has resulted in better patient safety (e.g. 82% decrease in harmful falls for elderly patients), less intrusive observations (disturbance rate at night decreased by 98%) and improved patient privacy (e.g. 86% of patients on an acute psychiatric ward felt a greater sense of privacy).</p>		
2. Underpinning research		
<p>Current patient monitoring systems available to track changes in vital signs (heart rate/pulse rate, respiratory rate and blood oxygen saturation) require adhesive electrodes or sensors to be in direct contact with the subjects. Most patients outside of the Intensive Care Unit (ICU), where they are often sedated, find the probes difficult to wear over prolonged periods of time.</p> <p>From 2010 onwards, Prof. Tarassenko's team in the Institute of Biomedical Engineering developed new methods and algorithms for the non-contact monitoring of vital signs using a video camera positioned several metres away from the patient being monitored. Most of the prior work reported in the literature (from 2005 onwards) had been with human volunteers in controlled environments. [R2]</p> <p>Prof. Tarassenko and his group developed robust methods to estimate the heart rate/pulse rate and breathing rate of patients being nursed in <i>clinical</i> environments, by (a) cancelling out aliased frequency components caused by artificial light flicker, using auto-regressive modelling and pole cancellation; (b) identifying valid data using novel signal-quality algorithms; and (c) using smart machine learning algorithms. [R2, R4]</p>		

Heart rate and breathing rate estimation was shown to be sufficiently accurate and robust for the Tarassenko group technology to be clinically useful. It was evaluated in patients undergoing haemodialysis in the Oxford Kidney Unit [R4], in adult intensive care and in neonatal intensive care, in a clinical study involving the continuous monitoring of pre-term infants, for at least four consecutive days, in the high-dependency care area of a Neonatal Intensive Care Unit (NICU) [R3, R1]. Prof. Tarassenko's group was the first in the world to report (in 2014) the non-contact monitoring of changes in *oxygen saturation* (a third vital sign, important in respiratory disease) in patients using only ambient light and a single video camera. [R1]

3. References to the research

[R1]. Assessment of signal processing methods for measuring the respiratory rate in the neonatal intensive care unit. Jorge J, Villarroel M, Chaichulee S, Green G, McCormick K, Tarassenko L. *IEEE J Biomed Health Inform.* 2019 Apr 4. doi: 10.1109/JBHI.2019.2898273. PMID: 30951480 (Journal article)

[R2] Non-contact measurement of oxygen saturation with an RGB camera. Guazzi AR, Villarroel M, Jorge J, Daly J, Frise MC, Robbins PA, Tarassenko L. *Biomed Opt Express.* 2015 Aug 11;6(9):3320-38. doi: 10.1364/BOE.6.003320. PMID: 26417504 (Journal article)

[R3] Continuous non-contact vital sign monitoring in neonatal intensive care unit. Villarroel M, Guazzi A, Jorge J, Davis S, Watkinson P, Green G, Shenvi A, McCormick K, Tarassenko L. *Healthc Technol Lett.* 2014 Sep 23;1(3):87-91. doi: 10.1049/htl.2014.0077. PMID: 26609384 (Journal article, submitted to REF2021)

[R4] Non-contact video-based vital sign monitoring using ambient light and auto-regressive models. Tarassenko L, Villarroel M, Guazzi A, Jorge J, Clifton DA, Pugh C. *Physiol Meas.* 2014 May;35(5):807-31. doi: 10.1088/0967-3334/35/5/807. PMID: 24681430 (Journal article, submitted to REF2021)

4. Details of the impact

Oxehealth was set up as a spin-out company in 2012, and spent until 2015 evaluating the non-contact vital-sign monitoring technology and algorithms developed in Prof. Tarassenko's lab in applications such as baby monitors. From 2015 onwards the company decided to concentrate on patient monitoring in mental health settings, as there was a market-led demand, as well as a clinical need, for such a product. Baby monitors, on the other hand, were assessed by the Oxehealth Business Development team to be a niche application. The Oxevision product developed by the company based on the IP transferred from the University has previously been called the Digital Care Assistant. Prof. Tarassenko and Dr Villarroel (the senior post-doc researcher in his University lab on the camera research) have continued to act as technical consultants to the company.

Oxevision uses an "optical sensor" (video camera + infrared illumination in a secure housing mounted on a wall) to monitor a patient in a bedroom/seclusion room 24/7. No equipment is in contact with the patient, and staff interact with the system via a monitor in the nurses' station and portable tablet devices. [S1, S2] Clinicians can:

- take medical-grade cardio-respiratory measurements remotely (i.e. no need to enter the patient's room to obtain the pulse rate and breathing rate of a resting patient);
- access cardio-respiratory trends from the last 24 hours to understand if a resting patient's physical health may be deteriorating;
- receive real-time alerts to high-risk activity, prompting a safety check (for example, if a high-risk psychiatric patient spends a prolonged time in the bathroom or leaves the room, or if an elderly patient known to be at risk of a fall gets out of bed);
- view objective patient activity reports (daily, weekly) to support clinical decision-making.

Oxevision is a Class IIa Medical Device, and it has been validated with over 1,000,000 room-hours of live running on mental health wards in the NHS, including Broadmoor Hospital. It is currently installed in 30% (16) of England's NHS mental health trusts, including: West London, Kent and Medway, Oxford Health, Berkshire Healthcare, Nottinghamshire Healthcare, South West London

and St George's Mental Health, Coventry and Warwickshire Partnership, Hertfordshire Partnership University, Tees, Esk and Wear Valleys, Essex Partnership University, and Midlands Partnership [S3].

The economic and health impacts of Oxevision are now reviewed below.

Economic Impact – Exploitation of the video-based software through the spin-out company Oxehealth

- Oxehealth was set up in 2012 as a spin-out company, with GBP500,000 seed funding from IP Group, to exploit the video-based non-contact monitoring technology and software developed in Prof. Tarassenko's research group. The company has grown year on year from 4 employees (headcount: 4) in August 2013 and now has more than 60 employees (headcount: 60) on the Oxford Science Park [S4].
- The technology was transferred through the software code, know-how and exclusive licensing of patent applications [S5]. Prof. Tarassenko, as Founder Director, continues to be actively involved in the company, primarily as a member of the Board of Directors and technical consultant.
- Oxevision generates GBP2,080,000 Annual Recurring Revenue from UK and Scandinavia. It has been deployed in 16 NHS Trusts (30%). It is also deployed in two separate sites in Scandinavia (1,277 patient rooms in November 2020) [S4].

Health Impact 1 - Patients in mental health wards: elderly patients with conditions such as dementia

Elderly patients on dementia wards are at a high risk of falls, which increases at night. Conventionally, regular checks are carried out on the patients in their bedrooms, yet incidents of falls still occur. If the fall is not observed (the overwhelming majority of cases), the clinical teams must treat it as moderate, i.e. needing an A&E visit. Oxevision allows the staff to monitor the patients remotely, without the need to disturb them physically to check their status, giving the patient privacy and peace. Oxevision also allows the staff to replay the video of a fall, and follow an appropriate course of action upon that review.

Benefits for elderly patients (as documented by Coventry & Warwickshire Partnership NHS Trust findings in a 22-month clinical study – interim results after 8 months) [S3]:

- 48% decrease in falls at night
- 82% decrease in harmful falls
- 68% decrease in visits to A&E
- 49% decrease in emergency service call-outs
- 71% decrease in enhanced observations, equalling 7,800 clinical hours saved per year. (This represented a potential cost saving of GBP154,000 per year for their 24-bed dementia ward.) [S1].

"Falls have reduced massively on the ward because of the system. [Oxevision is] our sixth member of staff on the night shift".

Ward Manager, Coventry & Warwickshire Partnership NHS Trust [S3]

"I couldn't imagine not having the system now in place. It's something that makes us feel more secure and we feel it sets up safety for the patients."

Deputy Ward Manager, Coventry & Warwickshire Partnership NHS Trust [S3]

Health Impact 2 - Reducing safety incidents and improving patient well-being on Acute & Psychiatric Intensive Care Unit (PICU) wards

Patients on PICU and Acute mental health wards require close monitoring as they often pose a danger to themselves, or to staff monitoring them. However, the repeated checking (usually every

hour, but up to every 15 minutes at night) by staff can prove distressing and disruptive for the patient and their recovery. These disturbances can lead to aggression towards staff and the need for physical intervention to restrain the patient. Oxevision gives staff the ability to monitor patients safely and remotely and make judgement calls on treatment to avoid escalation when the patient is agitated, even when the patient is in seclusion. Where the patient has existing conditions that need monitoring or is administered medications with side-effects which need monitoring, the system can be used to conduct health checks without the need to distress the patient via in person visits, resulting in a better standard of care for patients and a safer working environment for staff. Ben's case below demonstrates the success of Oxevision in a PICU ward:

"When Ben [a pseudonym has been used to maintain patient anonymity] came to the ward, he was very low in mood. He had been trying to ligate and refused to use his Continuous Positive Airway Pressure (CPAP) machine [to help him sleep better]. He didn't feel that he could keep himself safe at that time, so we nursed him on close observations, but he found this really difficult and it really impacted his sleep. He was spending most of his time in bed because he was tired and feeling increasingly low in mood. We reduced observations as we knew they were causing Ben distress. Having the [Oxevision] system allowed us to check his pulse and breathing rate remotely and alerts us to certain activity if there is cause for concern. Ben's mood has steadily improved and we can see from the system's activity reports that he is spending much less time isolating himself in his room."

Deputy Ward Manager, PICU, Coventry & Warwickshire Partnership NHS Trust [S6]

Benefits for patients in mental health wards (as documented by Coventry & Warwickshire Partnership NHS Trust) [S7]:

- PICU – 26% reduction in bedroom assaults and 40% decrease in rapid tranquilisation, medication to calm or lightly sedate the patient (related to assaults)
- Acute – 22% decrease in bedroom self-harm; for female patients 66% and 15% decrease in bathroom and bedroom ligatures (respectively), and overall 15% decrease in bedroom assaults

Benefits for staff monitoring patients (as documented by Coventry & Warwickshire Partnership NHS Trust) [S3, S7]:

- 83% of staff identified incidents they would otherwise not have known about
- 91% feel they can make better care or clinical decisions
- 91% feel it improves safety between checks
- 68%, 61% and 55% reported that the system had enabled them to prevent (a) potential self-harm; (b) patient-patient incidents; and (c) contraband-use incidents, respectively.

"Over the 23 years I've been in nursing, this is the best nursing innovation I've seen. You don't have to go and wake up somebody or disturb their very important sleep to know that they are safe. You are reassured they are not in danger."

Deputy Ward Manager (PICU), Coventry & Warwickshire Partnership NHS Trust [S7]

"We had just completed our level 2 checks, but I had an instinct that a patient was going to self-harm. I used the Oxehealth system [Oxevision] to do a spot check and I could see her lying on the floor. I got the ligature cutters and the team went straight to her room. She had tied a ligature and it was pretty bad. We quickly cut it and transferred her to the local hospital to be treated. Had we waited any longer, she might not be here today. We often use the system to monitor patients' pulse and breathing rate, but in this instance, we saved a life."

Healthcare Assistant (Female Acute Ward), Swanswell Ward, Caludon Centre, Coventry & Warwickshire Partnership NHS Trust [S7]

Health Impact 3 - Younger patients admitted to acute psychiatric wards being monitored in seclusion rooms (where video cameras are already fitted)

Benefits for Group 3 (as documented by Oxford Health NHS Foundation Trust) [S3] and [S8]:

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- Only 1 out of 275 night-time observations required patient disturbance (3-week clinical study on a mental health ward). Without Oxevision, all 275 night-time patient observations would have required patient disturbance.
- Night-time observation rounds completed in half the usual time, and 100% of staff felt that they disturbed the patients less.
- 100% of patients surveyed felt safer at night and that they slept better, 86% feeling that their privacy at night had improved.

“I sleep better [in the room with Oxevision] than the other room where the lights are turned on and the shutters are opened a lot of the time.”

Patient testimonial, Oxford Health NHS Foundation Trust [S3]

“The way that nursing observations have taken place, with nurses checking patients in person, has not really changed for decades and can be incredibly disruptive to patient sleep. Working with Oxehealth is transforming the patient experience at night while providing reassurance to staff that the patient is safe.”

Deputy Chief Operating Officer, Oxford Health, NHS Foundation [S8]

Health Impact 4 – Keeping staff safe, and COVID-19 patients monitored

The Oxevision technology has been used to support inpatient services to manage positive and suspected cases of COVID-19 for those on mental health wards. The technology and algorithms were used (from April 2020 to December 2020, and beyond) to minimise avoidable clinician contact with those patients needing to be isolated, through monitoring the patient’s cardio-respiratory vital signs and their activities in their room. Oxevision kept the staff safe, the patient monitored, and the amount of direct in-person treatment to a minimum, thereby minimising the exposure of the staff to the SARS-CoV-2 virus [S1].

“We check Mary is safe and take her pulse and breathing rate measurements to avoid unnecessary contact. Having the system has been incredibly useful to help monitor Mary’s health, enabling us to respond in time if her physical health deteriorates while minimizing the team’s risk of exposure to COVID-19.”

Ward Manager, Older Adult ward, Coventry & Warwickshire Partnership NHS Trust [S3]

5. Sources to corroborate the impact

[S1] Briefing Paper: Oxehealth Digital Care Assistant (now Oxevision), evidencing how the product functions and the benefits to clinical staff using it. **Confidential** (2020)

[S2] Vision-based patient monitoring and management in mental health settings. Lloyd-Jukes, H., Gibson, OJ, Wrench, T., Odunlade, A., Tarassenko, L., et al., *Journal of Clinical Engineering*. 2021 Jan/Mar;46(1):36-43. doi: 10.1097/JCE.0000000000000447 (Journal article, accepted Dec 2020)

[S3] Oxehealth presentation on Oxevision corroborating the benefits to elderly patients and the staff monitoring them after 22-month study. **Confidential** (2020), and the study White Papers at 8 and 22 months. **Public** (2019 and 2020, respectively)

[S4] Corroborator 1: CEO of Oxehealth, who may be contacted to corroborate the deployment of Oxevision into NHS Trusts and sites in Scandinavia

[S5] Portfolio of patent applications from Prof. Tarassenko’s research group exclusively licensed to Oxehealth by Oxford University Innovation

[S6] Oxehealth “Stories from the Ward” PICU case study (Coventry and Warwickshire), featuring a testimonial from a Ward Manager on the benefits of providing care using the Oxevision system for patient well-being.

[S7] Clinical Study in Acute & Psychiatric Intensive Care Unit (PICU) wards (Coventry and Warwickshire) evidencing the reduction in incidents. **Confidential** (2020)

[S8] Vaughan Thomas Hospital Ward (Oxford Health) white paper evidencing how Oxevision improves patient rest and privacy at night (2019)