Exploring Novel Technologies to Enhance Food Safety Training and Research Opportunities

Joseph E. B. Baldwin[1*] and Ellen W. Evans[2]

[1]Perceptual Experience Laboratory, Cardiff School of Art and Design, Cardiff Metropolitan University, Western Avenue, Llandaff, Cardiff, Wales CF5 2YB; [2]ZERO2FIVE Food Industry Centre, Cardiff Metropolitan University, Western Avenue, Llandaff, Cardiff, Wales CF5 2YB

[*] Author for correspondence.
Telephone: +44 (0) 2920 5836; Fax: +44 (0) 2920 416982.
E-mail: jbaldwin@cardiffmet.ac.uk

INTRODUCTION

In food safety research, be it focused on consumers in the domestic setting, or food handlers in the industry; technology capabilities have enhanced in recent years that have improved the rigour of research findings, reduce research biases, simplified data collection methods or enhanced the delivery of food safety education and training. For example, utilisation of online surveys can save time compared to paper-based surveys where the task of data entry is eliminated and approach to data analysis is simplified *(43)*. The cost, availability and portability of surveillance equipment has enabled an increase in covert observational research of consumer food safety practices in domestic environments *(33, 34, 81)* or of food handlers in industry based settings *(19, 35, 36)*.

The 21st century has become the era of new technologies which afford many new opportunities to interact with target audiences. These evolving technologies are changing the way in which screens are used and could be the next big thing that the food industry and researchers can take advantage of; creating new and stimulating experiences that benefit areas such as food safety behaviour, cognition and training.

Given advancements in technology, a food safety researcher and a user centred design researcher, have joined forces to explore novel technologies that can be utilised to enhance food safety training and research opportunities. The aim of this general interest article is to explore alternative technologies such as biometric and realities technologies that can be utilised by food safety researchers to enhance understanding of food safety practices, increase industry insight on food safety behaviours and present opportunities to optimise food safety education prospects. Additionally, this article gives an overview of several physiological and psychological technologies which are utilized alongside simulated environments, within applied user testing, product development and behavioural analysis research.

OVERVIEW

The terms virtual reality and augmented reality are often mistaken, we describe the main characteristics and differences of these technologies along with simulated task environments, and eye-tracking; along with biometric technologies to consider how we can utilise such technologies to benefit food safety research, training and education in the future.

Virtual reality technology.

Virtual Reality (VR) technology is generally used to immerse a user in a computer generated environment so that they can feel present in new virtual worlds away from their body's physical location. Simulated environments are largely experience through head-mounted display which use stereoscopic binocular technology to project independent images onto each eye, producing a sense of depth perception based on human binocular disparity (two eye view) *(40)*.

The earliest known example of VR technology "the Sensorama", was developed in the late 1950s *(51)*. It was a mechanical system provided an immersive video experience to train individuals without subjecting them to possible hazards of particular situations *(50)*. Significant advancements have been made to VR technology and head-mounted displays, such as; representing the sensation of peripheral vision and the viewer's changed orientation within an environment *(100)*; an ability to navigate simulations with stereoscopic vision and access embedded information in the form of anchored hypermedia links *(15, 16, 85)*.

During the application of VR environments, presence and immersion are recognised as being highly dependent for user satisfaction *(21)*. Immersion is determined by the technical provision of the VR technology, and presence is the psychological response to the VR environment, regarded as "being there", as a result of the external sensory information *(4, 63, 95)*. For a VR experience to feel realistic, user presence is optimised by providing a first-person point of view which is recognised as a way in which we judge our sense of depth and experience being engaged in the world *(47)*. In video games, attempts to improve their immersive depth has included the representation of the person playing the game from a first-person perspective.

VR application for food safety training.

VR technology has been developed and utilised within military, commercial, healthcare and research due to the desire and need to simulate the sensations of an actual experience to an individual for real-life training *(51)*. For example, VR flight simulators have been utilised to improve decision making and performance of combat pilots *(28, 55)*. Head-mounted display technology has enabled architects to immerse clients in their designs from a first-person point of view, gaining improved spatial impressions and customer experience *(14)*.

The popularity of VR headsets for entertainment and gaming has reduced their cost; which could bring about novel opportunities to enhance food protection. Although this technology may not be suitable for the provision of wide scale domestic food safety education interventions for consumers, as ownership of VR headsets are still not commonplace. Nevertheless, given the affordability and portability of VR headsets, this technology could be used as an educational tool to facilitate training in the food manufacturing industry. The technology can replicate a real environment, which is beneficial when the representative environment is not easily accessible, or where delivery of training could be an inconvenience for people working in that area. For example, one-to-one training regarding procedures in high-risk or high-care food manufacturing environments could be delivered using this technology. Because variables are controlled, this ensures the reliability and repeatability of the training and can allow for comparison of awareness between subjects or change in awareness of subjects over time. VR technology has been utilised to present trainees with scenarios designed to teach important lessons with the goal of meeting Food Safety Modernization Act standards. The technology provides data to plan future training according to identified areas of difficulty among trainees *(86)*.

VR-based training could be superior to classroom based training, due to the immersion and the feeling of "presence" which can trigger an emotional response *(8, 84)*, which aids memory and learning *(101)*. The use of VR environments in health and safety training, has been found to be better than for PowerPoint-based training in changing attitudes and awareness *(59)*. “The Corrupt Kitchen” VR environment was designed to explore attitudes to workplace corruption. However, the design, development and creation of the VR environment is very detailed and lengthy *(103-106)*. There is a need to explore the potential usability, impact, effectiveness and acceptability of VR-based food safety training in food industry environments.

Augmented reality.

Augmented Reality (AR) often gets mistaken for VR because both technologies are computer generated. Unlike VR technology (an interactive computer-generated experience taking place within a simulated environment), AR technology superimposes a computer generated image on the user's view of the real world *(26)*. It allows people to add digital information into their physical world without having to immerse themselves into a virtual replacement of an actual environment. This enables users of AR technology to interact in real-time with computer-generated objects within their real physical environment *(2)*. AR technology is widely used in smart phone applications. For example, computer-generated filters and effects can be applied over real-life images on social media platforms (Instagram, Snapchat, Facebook, etc.), enabling users to give visual expression *(78)*.

AR application for food safety education and training.

Popular smart phone based AR games such as Pokémon Go (a GPS location-based AR game), are unique as they combine the physical and virtual world in one interface which results in increased exercise, socialisation, and outdoor activity *(89)*. AR is often used to give an interactive experience in museums *(53, 72)*. In addition to using smart phones, AR technology can be experienced utilising AR wearables such as 'smart glasses' *(80)*, which have been utilised in construction and high-end manufacturing *(66)*.

AR technology can enhance digital shopping experience and sales *(31, 32)*. For example, consumers can download AR smart phone applications that enable the pre-purchase visualisation of products by placing virtual content (e.g. new furniture) in a real environment (e.g. image of the consumer's home) *(83)*. This has a positive impact on consumers and e-commerce vendors *(11, 48)*. AR technologies have also been applied in healthcare environments *(98)*, examples include cognitive aids for people in the early stages of dementia *(49)*; and tools to improve competencies, learning or critical thinking in healthcare education by providing an authentic, engaging experience *(17, 126)*. Application of AR technology in education has the potential to: engage, stimulate, and motivate students; help teach subjects where real-world first-hand experience is not feasible, and create an authentic learning environment suitable to various learning styles *(125)*. However, to enable successful design, development, and application of AR educational technology, there is a need to utilised a framework driven by learning theory *(127)*.

As games and activities are commonly used in consumer food safety educational campaigns, particularly those targeted at children *(39, 73, 88)*; given the widespread ownership of smart phones, consumer food safety campaigns using AR technology may be an alternative approach to be considered in the future by food safety educators. Beck et al. *(5)*, discussed the potential application of AR in the food industry to enhance the training of new employees. They suggest AR could be effective in enabling employees to locate supplies, identify objects, and to provide a technological alternative to a mentor *(5)*. Ryznar suggest that AR technology has the potential to transform food service and food production facilities by improving speed, quality, efficiency, consistency, traceability and training in any operation *(87)*. In food manufacturing, AR technology could be used to visualise and understand the importance of cleaning in food manufacturing environments, to understand how pathogens grow in such environments and how niches are established.

Simulated task environment.

Unlike the AR and VR technology described earlier – which use a head-mounted display, smart phone, tablet or computer to view the virtual or augmented scenes of an environment – simulated task environment (STE) technology utilises a video theatre design. The video theatre is made up from high-resolution flat panel displays (capable of higher resolution than typical consumer-grade televisions) or rear projected media panels, to recreate a computer-synthesised depiction of an environment where the viewer occupies the space within the video theatre *(25, 61)* (see Figure 1). Sensors communicate user movement and interaction within the video theatre which maintain appropriate real-time rendering of environment scales during exploration. STE set-up often include allied props and multisensory cues to increase presence and context *(64)*. As the real environment can be too complex to provide experimental control, variables in a STE can be controlled, potentially making it easier to study behaviour in a STE than in the actual task environment *(44)*. Consequently, researchers can study behaviour in a task environment that is appropriate to the research question of interest *(44, 74)*.

STE application for food safety training.

Increasingly, global companies utilise STE and VR technology to better understand consumer purchasing behaviour *(52)*, this can be utilised to improve the design of products and packaging and strengthen brand competitiveness. The use of STEs to test packaging designs concurs with Young's opinion that product testing is more valid when participants are in an appropriate shopping context with realistic product surroundings *(123)*. Inclusion of multisensory cues in STE (e.g. olfactory, temperature control, air movement, auditory effects and props) facilitates high levels of presence and engagement *(64)*, this has successfully provided real-life context for product testing across several research areas *(41, 42, 57, 58)*. Given the technical setup and running costs for STE facilities, such technology is used exclusively for in-house testing by companies with large research, development and marketing budgets. Consequently, dissemination of commercial research activity and such valuable insights are not made available in the public domain and small and medium sized businesses may not have access to such valuable technology.

STEs could be utilised to expand upon the training and education capabilities of AR and VR discussed earlier by delivering interactive group training relating to areas that are not easily accessible which enables peer-to-peer learning. It is known that knowledge-based training alone may not improve food safety performance, whereas behaviour-based training approaches are believed to be effective in improving food safety performance and frequency *(124)*, the use of simulated tasks in an STE facility may provide a knowledge and behavioural-based training approach to enhance food safety.

Eye-tracking.

Eye-tracking technologies project near infrared light beams onto an individual's eyes, producing reflections that are captured by sensors and then processed by algorithms that infer gaze point data (determine where the user is looking) allowing metric calculations of eye movement data *(108)*. Eye-tracking data can be captured using either wearable eye-tracking technology (e.g. eye-tracking glasses *(115)*) or unobtrusive screen-based eye-tracking technology (e.g. eye-tracking bar placed on a laptop *(114)* or using a laptop webcam *(113)*).

Eye-tracking provides non-invasive and rich indices of brain function and cognition *(29)*. The importance of eye-tracking technology is that it allows the assessment of individual's visual attention and behaviour whilst they perform tasks within a desired setting. Eye-tracking data is initially observed using attention-based heat maps and gaze path visualisations. Further, detailed investigation rely on demarcating areas of interest for quantitative analysis *(111)*. These unique insights have resulted in eye-tracking technology becoming embedded throughout the research, development and marketing stages of new and existing products from global manufacturing companies *(107)*.

The ability to capture an unbiased visual record of a participant's subconscious during tasks (implicit research) robustly supports behavioural and attention insights and removes uncertainty of response data (candour) collected in traditional research methods such as questionnaires whereby responses can be subject to biases *(110, 112)*. Eye-tracking technology has significantly improved in its usability, accuracy, and speed while decreasing in cost *(27)*, resulting in increased availability and use in research *(82, 107)*. Research exploring visual reaction to stimuli has been conducted in psychology, neuroscience, education, health, medicine, linguistics, reading, ophthalmology, visual perception, software development, and user experience research *(82, 109)*.

Eye-tracking application in food safety research.

Within food and drink settings, fixations and saccades (rapid movements) are analysed to examine shopper engagement with packaging which can be used to improve in-store merchandising *(116, 120-122)*. Pieter and Warlop determined product preference correlated with shopper attention

(76). Although, eye-tracking technology is widely used to explore consumer behaviour, it could be applied to explore the interaction of a target audience with food safety educational interventions such as videos or leaflets. This technology could be particularly beneficial in the evaluation of interventions to determine engagement or specific points of disengagement and to determine if all critical elements are 'seen'. The data captured with such technology could inform purposeful placement of key messages in interventions. Eye-tracking technology can be used alongside STE and head-mounted display technology to explore visualisations in an immersive environment. Lawrence *et al.* is a recent example of commercial STE and eye-tracking research conducted for food packaging design assessment providing real-life context for product testing in a laboratory setting *(57, 58)*. Research combining VR and eye-tracking technology can investigate decision making in real-life scenarios *(68)*, particularly in hazardous situations *(91, 102)*.

Biometric technologies.

There are numerous biometric technologies available, these technologies provide physiological measurements via sensors that monitor specific bodily activity (e.g., pulse rate, brain activity, sweat glands, visible expressions and pupil diameter) to help indicate human responses/reactions to experiences.

- ***Emotion state software:*** Facial expression coding software recognises facial muscle activity to provide measurements of emotions through visible expressions *(60)*. Emotion state technology is a non-contact, automated system founded on the basic emotion states defined by Ekman and Friesen (happiness, sadness, anger, surprise, disgust, fear) *(30)*. The technology is applied by researchers and marketers interested in understanding the effect of stimuli on emotions and human behaviour from the effects of emotions on mood. The non-verbal communication of emotions provides objective insights into human interaction between people, machines and products *(97)*. In food-mood related research, this biometric technique detect change in emotion states evoked by different food tastes. Traditionally, consumer acceptance of new food products are tested explicitly (e.g. liking ratings). Implicit tests such as this technique can provide additional information on consumer acceptance and enjoyment of foods *(24)*.

- ***Galvanic skin response technology:*** This technology assesses conductivity of skin (electrodermal activity), via sensors attached to the fingers that measure changes in the skin conductance response *(9, 10, 13)*. The differences in the electrical conduciveness of the skin is caused by the change in moisture levels (sweat) *(22)* which is associated with mental activity. The technology determines physiological arousal which is used as an indicator of emotional arousal to stimuli *(9, 54)*. The technology is regarded as one of the most robust measurements of arousal *(37)*. Galvanic skin response data has been used to measure the interaction of participants psychological state in wide ranging research scenarios that encompass emotionally evocative stimuli *(54)*; anticipations of risks *(20)* and consumer attitude and purchase behaviour *(18, 45, 46, 71, 119)*.
- ***Heart rate variability technology:*** An electrocardiogram is used to measure the electrical activity of the heart. This biometric method reveals the variation in heartbeat during the cardiac cycle *(79, 90, 94)*. Advances in portable sport and health devices, such as “Fitbit” in recent years has increased the accessibility of heart rate data and level of physiological arousal away from the laboratory *(6)*. During events of stress an increased heart rate is brought about due to processes in the autonomic nervous system being altered *(1, 23, 75, 96)*. It is also used to measure immediate changes in arousal, physical effort, cognitive effort and attention *(7, 77, 99)*. In research, prolonged cardiac deceleration has been associated with enhanced attention and processing of stimuli *(12, 56)*. The effectiveness of advertising stimuli has been found to be highly dependent on arousal and attention capabilities *(7, 56)*. Furthermore, this biometric measurement has been applied in STE based tourism research to assess reactions to a tourism-related setting and explore tourisms’ potential to alleviate stress and enhance hedonic wellbeing *(3, 62, 92, 93)*

Biometric technology application in food safety research.

Consumer research has combined these biometric measurements (heart rate, galvanic skin response, and emotion state) to investigate responses towards popular and unpopular brand logos *(65)*. Although each technology has its individual merit, combining such technologies is beneficial in obtaining a robust interpretation of physiological arousal and emotional intensity towards stimuli. The multimodal approach of combining biometric techniques has been shown to strengthen behaviour predictors *(118)*. Indeed, such combined biometric techniques could be utilised to measure a variety of emotional responses to food safety training or education interventions. Emotion is an important element in education as it drives attention, learning and memory *(101)*. In terms of food safety training, education or messaging, targeting the emotional side of foodhandlers in training or education may be more persuasive than formal training *(67)*. Triggering an emotional response in food safety risk communication may shape risk perceptions and motivate people to facilitate behaviour change. Understanding emotions in food safety risk communication is said to be an important tool to motivate people to change their behaviour *(38)*, as an emotional response could be instrumental in shaping an individual's food safety risk perception as well as motivating their adoption of preventive practices *(69)*. Consequently, it may be of benefit to explore what emotions are triggered by food safety training or educational interventions. In the future, we may consider the physiological and psychological impact alongside the cognitive and behavioural impact of food safety interventions.

Conclusions.

This general interest article has explored some of the novel technologies that have become increasingly available and accessible to researchers in recent years, such technologies have not been fully utilised in the area of food protection. Opportunities for exciting transdisciplinary research have been proposed, which, could open research fields that cannot be fully subsumed within a single specialisation and may offer the most relevant approach to developing solutions to problems in the real world *(38)*. Indeed, it is believed that technologies such as VR and AR will become valuable allies in the quest for improved product, worker and customer safety in the food industry *(70)*. We have researched and have considered how technologies such as VR, AR, STE, along with eye-tracker, emotion state, galvanic skin response, and heart rate variability techniques can be utilised to provide exiting and innovative opportunities to explore and enhance food safety training, education interventions and research opportunities. These technologies could be combined to give in-depth understanding and evaluations relating to the engagement and interaction of consumers or foodhandlers with food safety related training or education interventions. Furthermore, the novel technologies described could be triangulated with existing cognitive and behavioural food safety research methods to give a truly in-depth holistic approach and unique understanding. Such important discoveries could be utilised to transform current approaches utilised to design, develop, implement and evaluate food safety interventions, which in turn could improve our research, training and education capabilities to ensure enhanced food protection in the future.

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FIGURE LEGENDS

Figure 1. Example of STE technology at Cardiff Metropolitan University's perceptual experience laboratory (the research facility comprises of a 2.5 metre-tall, high-resolution cylindrical rear projection screen which wraps 200° around the participant. It can be configured to represent virtually any environment in terms of sight, sound, smell, temperature, air movement and physical objects *(117)*).

Figure 1