Institution: Queen's University Belfast		
Unit of Assessment: 4		
Title of case study: Emotional and Empathic Artificial Intelligence Outside the Laboratory		
Period when the underpinning research was undertaken: 2010 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Dr Gary McKeown	**Role(s) (e.g. job title): Senior Lecturer**	**Period(s) employed by submitting HEI: 2002-2021**
Period when the claimed impact occurred: 2013 - 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Artificial Intelligence (AI) influences much of modern life; increasingly it is addressing the more personal aspects of life—emotionality and social interaction. Emotional and empathic AI recognises, understands and recreates human emotional communication. Emotion strongly motivates human behaviour, and consequently, this new AI creates both commercial opportunities and ethical dilemmas. Over 20 years of emotion research at QUB has produced commercially viable emotion AI. Partnerships and knowledge transfer with two SMEs—Sensum and Adoreboard—developed products and patents used by and sold to the advertising sector (Mindshare, Unilever, Havas), sports broadcasting (Red Bull Media House) and the automotive sector (Valeo, Volvo, Bentley, Honda, Ford, Jaguar). QUB emotions research has informed and developed ethical emotion AI standards together with the professional organisations IEEE and AAAC.

2. Underpinning research

Creating emotional and empathic AI that will work in real-world environments requires the generation of training data occurring in natural, ecologically valid settings with spontaneous and commonplace expressions and social signals. Work over 20 years at QUB has challenged the prevailing accounts of emotion expression in human communication that relied on discrete and static conceptions of emotion and has instead spearheaded a dynamic, continuous and contextualised understanding of emotion. Emotion relevant facial expressions and social signals have a socio-communicative function that depends on context and current social interactions. Intuitive human-computer and human-machine interfaces require emotional and empathic AI developed from natural human communication processes. These needs have created a research programme at the School of Psychology that seeks to understand human emotional communication in itself but with an added application of informing computational science and commercial partners how to take advantage of these discoveries. As part of this endeavour, it is essential to capture real interactive human behaviour; therefore, we have created many databases of emotional and social interactions. The most notable of these is the SEMAINE database **[R1]**, in addition to many others, notably BINED, ILHAIRE, and the Belfast Naturalistic Database. The goal is to place emotion AI on sound real-word foundations. The SEMAINE database was part of a large, ambitious EU project (The SEMAINE project) that sought to create an embodied conversational agent functioning as a human-computer interface **[R2].**

The knowledge gained in this research has led to theoretical work on human communication which presents ideas explaining the inherently social nature of human communication and how it differs from more general animal communication. **[R3]**. This has led to work on the importance of storytelling and how understanding emotional reactions to scenarios provides

the basis of good storytelling—important for advertising and broadcasting impact, and technological innovations in understanding expressions and reactions. The storytelling work was central to the impact with Red Bull Media House informing their multimedia storytelling of Red Bull extreme sports athletes.

Analysis of the dynamic and continuous nature of emotion expression in communication started by using trace techniques that provide continuous reports of felt and perceived emotion **[R4].** People are required to observe and provide responses to changes in emotion over time rather than selecting categories for a time period—permitting a more nuanced understanding of the dynamic unfolding of a complex emotional and communicative experience. To do this well required new statistical methods to be developed for use in the psychology of emotion **[R5].** These non-linear methods have also proved useful in the assessment of felt state using multiple physiological sensor signals and led to Knowledge Transfer Partnerships with commercial partners that have resulted in patent applications.

Through the course of three Knowledge Transfer Partnerships with the Company Sensum data collection and experimentation led to the joint production of eight publications to date. These were in the sports performance, sensor analysis, and automotive interface fields, an example publication is provided in **[R6]**.

3. References to the research

R1. **McKeown, G.,** Valstar, M., **Cowie, R.,** Pantic, M., & Schroder, M. (2012). The SEMAINE database: Annotated multimodal records of emotionally colored conversations between a person and a limited agent. *IEEE Transactions on Affective Computing*, *3*(1), 5-17. (566 citations Google Scholar; Journal Impact Factor 7.51). doi: 10.1109/T-AFFC.2011.20

R2. Schroder, M., Bevacqua, E., **Cowie, R.,** Eyben, F., Gunes, H., Heylen, D., ter Matt, M., **McKeown, G.,** Pammi, S, Pantic, M., Pelachaud, C., Schuller, B., de Sevin, E., Valstar, M. & Wollmer, M. (2012). Building autonomous sensitive artificial listeners. *IEEE Transactions on Affective Computing*, *3*(2), 165-183. (194 citations Google Scholar; Journal Impact Factor 7.51). doi: 10.1109/T-AFFC.2011.34.

R3. **McKeown, G. J.** (2013). The Analogical Peacock Hypothesis: The sexual selection of mind-reading and relational cognition in human communication. *Review of General Psychology*, *17*(3), 267. (32 citations Google Scholar; Journal Impact Factor 2.36). doi: 10.1037/a0032631

R4. **Cowie, R., McKeown, G., & Douglas-Cowie, E.** (2012). Tracing emotion: an overview. *International Journal of Synthetic Emotions (IJSE)*, *3*(1), 1-17. (84 citations Google Scholar). doi: 10.4018/jse.2012010101

R5. **McKeown, G. J., & Sneddon, I**. (2014). Modelling continuous self-report measures of perceived emotion using generalised additive mixed models. *Psychological Methods*, *19*(1), 155. (50 citations Google Scholar; Journal Impact Factor 8.188) doi: 10.1037/a0034282

R6. **Dupré, D., Andelic, N., Moore, D. S**., Morrison, G., & **McKeown, G. J.** (2020). Analysis of physiological changes related to emotions during a zipline activity. *Sports Engineering*, *23*(1), 1-11. doi: 10.1007/s12283-020-00328-9

4. Details of the impact

Impact has been economic and societal. These include commercial partnerships with companies, an active role in the international Affective Computing community, a role in setting Institute of Electrical and Electronics Engineers (IEEE) global standards for Empathic AI, and many points of public outreach.

Economic Impact

The company Adoreboard was founded in collaboration with Dr Gary McKeown in 2011 and it continues to perform strongly, having completed its ninth year of commercial operation with 20 full-time employees in 2020. A Knowledge Transfer Partnership project with Adoreboard and Dr McKeown was completed in 2014. Dr McKeown was awarded an Enterprise Fellowship by QUB for a year to work with the company.

In 2015 Dr McKeown started a long-term collaboration with Sensum - another affective computing company - formalised through 3 Knowledge Transfer Partnerships funded by the ESRC and Invest NI. The first two of these partnerships were given the highest rating of "Outstanding" by the KTP assessors, while the third is on-going **[C1]**. The relationship with the School of Psychology is central to Sensum's research strategy and features prominently on the "Learn More" section of the website **[C2]**. The first project implemented continuous, dynamic and multimodal data workflows and statistical processing in the company to give a competitive edge over rival companies (Affectiva, Realeyes, Emotient). Machine learning and time series statistical techniques drew multiple emotion relevant signals together to create emotional AI models [R5]. This functional AI model of emotion led to one of Sensum's principal products, the empathic AI engine Synsis™ and internal statistical mechanisms for dynamic sensor analysis. The project took place over two years and involved collaborative projects with many multinational corporations including Unilever in 2016 **[C3]** and Red Bull Media House in 2016 and 2017 **[C4].** Red Bull Media House wanted to understand the emotions of their "hero" extreme sports athletes using Sensum's synchronised sensor product SYNC **[C5],** to aid storytelling and provide data overlays of athletes' felt emotion as a visual aid during broadcasts. Together with Red Bull, we also developed a Virtual Reality Mountain Bike Experience **[C6].**

The second KTP project created a real-time model of emotion assessing emotional events as they unfold and incorporated acoustic information and facial expressions into the algorithms. A modular structure for rapid prototyping in different marketing contexts was also added. Real-time assessment is required in the automotive as onboard driver monitoring systems are required for the European New Car Assessment Program (Euro NCAP). Projects within the KTP included developing the Ford "buzz car" that responds to the emotions of the driver **[C7]**, and assessing emotions at the Goodwood Festival of Speed in 2018, attended by 200,000 visitors **[C8]**. Longer-term projects took place with Volvo, Valeo **[C9]**, and Bentley, using sensors to assess driver and passenger state as cars increasingly move towards autonomous driving.

The third, on-going, KTP involves the creation of an empathic interface for use in vehicles—automotive empathic AI. These emotion aware vehicles monitor drivers' states. This project featured in an episode of the Radio 4 series All in the Mind **[C12]**. Through these projects Dr McKeown has become an integral part of the scientific strategy of the company Sensum **[C10]**.

Societal Impact

Dr McKeown has a proactive role in the promotion of affective computing. He was elected to the executive committee of the Association for the Advancement of Affective Computing and is an associate editor of the field's flagship journal IEEE Transactions on Affective Computing. He plays an active role in the promotion of the ethical use of these technologies. Increasingly AI is a point of societal concern given the power it has to change how we live. Ethical use of AI in facial recognition technology, emotion AI and communicative understanding is currently or soon will be under the spotlight. Consequently, the industry is taking measures to create ethical global standards to ensure best practice. Sensum and Dr McKeown have taken a lead in this endeavour. The IEEE Standards Association asked Sensum to chair the IEEE P7014 Working Group to develop the P7014 global standard (Standard for Ethical considerations in Emulated Empathy in Autonomous and Intelligent Systems**) [C11]**. This group currently has regular meetings with the goal of developing these global standards.

Public Outreach

There is much public interest in emotion related psychology research and in emotional artificial intelligence and how the two interact. This interest has led to many radio and television appearances, written articles and interviews for newspapers. Collectively these appearances and articles have an audience reach of millions, including two appearances on BBC Radio 4 All in the Mind documentary, a separate Radio 4 documentary on Crying, and a BBC Television documentary on friendship and international radio and newspaper interviews **[C12].**

5. Sources to corroborate the impact

C1. KTP Certificates of Excellence.

C2. Sensum relationship with the School of Psychology at Queen's University webpage. (http://go.qub.ac.uk/SensumLearnMore).

C3. Unilever and Electric Run Festival in Malaysia (http://go.qub.ac.uk/C2SensumMalaysiaElecRun).

C4. Red Bull Media House and capturing extreme sports experience (http://go.qub.ac.uk/SensumRedBullMediaHouse).

C5. Sensum SYNC product (http://go.qub.ac.uk/SensumSYNC).

C6. Sensum and Red Bull Media House Virtual Reality Mountain Bike Experience. (http://go.qub.ac.uk/SensumHeroFeeling).

C7. Ford buzz Car Project (http://go.qub.ac.uk/SensumFordBuzzCar).

C8. Goodwood Festival of Speed Hill Climb Emotions (http://go.qub.ac.uk/SensumGoodwoodFestival).

C9. Valeo project with Sensum (https://www.valeo.com/en/from-smart-cocoon-to-empathic-mobility/)

C10. Testimonial letter from the CEO of Sensum.

C11. IEEE P7014 - Standard for Ethical considerations in Emulated Empathy in Autonomous and Intelligent Systems. (http://go.qub.ac.uk/IEEEEthicsStandardsGroup).

C12. Public Outreach and Media Appearances Document.