Institution: University College London (UCL)

Unit of Assessment: 10 – Mathematical Sciences

Title of case study: 2011 London riots: Improving public understanding of mathematical modelling

1. Summary of the impact

While conducting research into the London riots of 2011, researchers in UCL's Department of Mathematics initiated two additional outreach projects: (1) a short film, made to explore the social impacts of the work and to engage with the communities affected by the events, and (2) a visualisation tool, developed to demonstrate to the public the potential of UCL's mathematical riot model.

The film involved a two-way discussion with youth charities, youth workers and ex-gang members across the capital, improving their attitudes towards the research and their understanding of the model, while the final version of the film raised awareness of the underlying social issues and stimulated a great deal of public debate online. The visualisation tool – in game form – has proved successful at events and festivals across the country in stimulating public interest in science.

These projects, along with the original paper, have received a good deal of media attention online, in press and on national television, serving to raise awareness, improve understanding and prompt public debate about the riots, the role of youth charities in London and the potential use of mathematical modelling to address questions about the UK's social systems.

2. Underpinning research

The Department of Mathematics at UCL has a strong background in exploring the relevance of mathematical concepts to problems of the real world, particularly those of interest to policy makers. For example, Steven Bishop (Professor 2004-present) examined in 2010 the potential of employing systems dynamics approaches to policy decisions [1], and conceptualised combining the methods of bottom-up system dynamics with statistical modeling in 2012 [2]. The techniques and ideas from this work formed the basis of the department's mathematical model of a recent real world problem: the 2011 London riots.

In summer 2011, London experienced the worst period of sustained rioting, violence, looting and arson seen in the UK for over 20 years. Following these events, Bishop and Hannah Fry (Research Associate 2010-2012) from the Department of Mathematics collaborated with researchers from UCL's Department of Security and Crime Science, UCL's Centre for Advanced Spatial Analysis (CASA) and the Metropolitan Police Service to undertake an interdisciplinary project, researching the causes of the London riots with the aim of informing policing strategies for similar events in the future.

The initial part of the collaborative London riots research project revolved around a dataset of all arrests made in connection with the riots, including the home and offence location of each suspect. The richness of the dataset allowed for a spatial and temporal statistical analysis of the riots, highlighting the important factors such as deprivation, transport and the role that retail centres played in the events. This statistical analysis then served as the basis for a second, more speculative research challenge: constructing a mathematical model of the riots capable of replicating the general patterns and dynamics identified, with the potential to investigate the effects of a range of alternative policing strategies. The model, built by Fry and Bishop in 2012 and published in Nature's Scientific Reports in February 2013 [3], aimed to exploit the analogies between the mechanisms highlighted in the earlier analysis, and existing well-studied models of the physical and natural world. In the three-stage process employed, models of epidemiology reflected the contagious nature of the 'idea to riot'; models of retail spending flows were exploited to describe how the rioters converged at certain areas throughout the city; and Lotka-Volterra dynamics allowed for simulated interaction between rioters and police.

Despite limited information on initial disturbances, the model captures many of the significant patterns seen in the data and accurately predicts which areas of the city were more susceptible than others, yielding insight into the mechanisms that drew people into the riots. The statistical

analysis served to demonstrate that rioters were predominantly in their late teens or early twenties and came from some of the poorest areas of London – areas with the worst schools, lowest incomes and highest unemployment levels. Alongside these findings, the model also provides a means with which to test various policing strategies and serves as a proof of concept for future collaborations with the police service.

Mathematical models based on real-world data to assist with predictive policing are a relatively new area of interest within the research community. This contribution by UCL offers some novel techniques and serves well as a proof-of-concept for future work.

3. References to the research

[1] Systems approaches for critical decisions, J.C.R. Hunt, S.R. Bishop and Y. Timoshkina, pp. 197-202, In: *Progress in Industrial Mathematics at ECMI 2008*, Mathematics in Industry 15 (2010), doi:10/d9csq6

[2] System dynamics applied to operations and policy decisions, J.C.R. Hunt, Y. Timoshkina, P.J. Baudains and S.R. Bishop, *European Review*, 20, 324-342 (2012) doi:10/ph8

[3] A mathematical model of the London riots and their policing, T.P. Davies, H. Fry, A.G. Wilson and S. Bishop, *Nature Scientific Reports*, 3, 1303 (2013) doi:10.1038/srep01303

Research grant: EPSRC ENFOLD-ing - Explaining, Modelling, and Forecasting Global Dynamics; Reference: EP/H02185X/1; Dates: 2010-2015; Value: circa £3 million across several UCL departments; PI: Professor Sir Alan Wilson, Centre for Advanced Spatial Analysis; Professor Steven Bishop, Department of Mathematics

4. Details of the impact

UCL research into the London riots of 2011 has stimulated a significant amount of public interest, debate and discussion about the issues surrounding the riots and about mathematical modelling. This has been achieved through a number of public engagement activities, including talks, a short film and a game.

While conducting the underpinning research, Fry felt it was important to initiate a discussion with members of the communities affected by the riots, particularly given the striking links between rioter involvement and deprivation in London that were uncovered in the statistical analysis of the data. To help prevent riots from happening again, and to understand why so many young people across London chose to riot, she wanted to learn more about the social issues within rioters' communities that led to their involvement; this was the initial motivation behind a series of meetings between Fry and various youth charities, youth workers and ex-gang members across the capital.

After several informal discussions, Fry took part in the inaugural EPSRC and UCL Focus on the Positive public event in May 2012. In these events, researchers present their ideas for tackling issues and the audience vote for a project that they think will make a real difference. Fry suggested a need to raise awareness of the difficulties affecting young people, of which the riots were just a single manifestation, and pledged to spend the £1,000 prize creating a short film to give a voice to young people in deprived areas of London: the very people blamed in the wake of the 2011 riots. Her aim was to improve public understanding of the issues uncovered in the paper as well as the difficulties around a lack of funding for youth services, an additional problem that had been highlighted in her conversations with affected communities. After debating the various issues that had been presented, the 58 members of the audience voted to fund Fry's project, demonstrating that the research stimulated public discourse and interest in the topic [A].

During the research for the film, Fry visited a number of affected communities, including Blackfriars Settlement, a young people's charity in Southwark; youth workers in Brixton; ex-gang members in Croydon; and teachers within Pupil Referral Units in Enfield (PRUs are centres for pupils unable to attend mainstream school, often due to emotional and/or behavioural difficulties). These meetings allowed for a two-way discussion, providing a context to the data for Fry, while changing the attitudes of the individuals and organisations involved towards mathematics, police intervention

and academia. One of these discussions, between Fry and Hackney resident Pauline Pearce (who gained exposure during the riots for confronting looters in her local area), was filmed as a case study for a secondary project, funded by the EPSRC, celebrating the impact of the Focus on the Positive events [B]. Pearce said of Fry's work "You have really opened my eyes – I don't know numbers […] but you have spoken a language that people can understand" [B].

Can Maths Predict a Riot?, the short film produced by Fry with her Focus on the Positive funding, was released in January 2013. It has been well received by a variety of audiences, with over 5,600 views on YouTube as of 31 July 2013, and has sparked discussion and debate amongst the public, as evidenced by the comment stream on YouTube [C]. Pearce, who has since joined the Liberal Democrats and stood for election within Hackney, offered her feedback on the film and pledged to promote it within her community, helping further to raise awareness of the work and its links to social issues within deprived areas of the city. She said: "You'll be amazed at how much your word will get around" [B]. The film also stimulated members of the public and the media to write about the work online; for example, influential visualisation blog flowingdata (300,000 visitors a month) [D] and science communication website popsci.com (1.2 million visitors a month) [E] both featured articles about Fry's work on their homepages (on 18 and 19 July 2013 respectively). These high-profile articles then led to many other websites (e.g. Professional Security Magazine, Phys.org and Laboratory Equipment), blogs (e.g. Urban Demographics, Paul de Gregorio and Snap VRS), Twitter and Google+ users writing about the research, including a tweet shared by Labour MP Tom Watson to his 130,000 followers [F].

Alongside the short film, the mathematical model potentially offered police an opportunity to examine various strategic scenarios, but was inaccessible in its original form. To address this issue and present the model in a way that is useful and intuitive for potential stakeholders, a proof of concept 'computer-game' style interface was created by Fry and a team of UCL computer scientists in April 2012. The game is presented on a touch table, with a map of London projected on to the screen. The player reacts to riots spreading across the map by arranging Lego police cars in a configuration to minimise the damage. As the simulation detects the placement of the cars using an Xbox Kinect, the model runs in the background, reacting accordingly.

By interacting with the riot table, members of the public are able to explore its mechanisms in a tactile and engaging manner. This helps them to gain an improved understanding of how this kind of mathematical modelling could be used in the future to benefit the police and society. Since its creation, the riot table has been taken to various conferences and festivals, including the Analogies conference at UCL on 20 April 2012 (with 400 visitors) and the Leeds Smart Cities Exhibition between 8 and 10 November 2012 (1,500 members of the public). At each event, participants' scores were tweeted to a live leader-board, which added a competitive element and stimulated public interest throughout the day. In total, the game was played 226 times in 2012, with each score recorded on the riot table Twitter account [G].

In terms of the research, the Nature Scientific Reports paper was also well received by the public. The open-access nature of the publication allowed the UCL researchers to distribute and publicise the work to a wider audience, informing people of the potential of mathematical modelling and improving their understanding of the methods employed. As of 31 July 2013, the paper had over 12,200 views on the Nature website [H]. It also had an altmetric score of 149, ranking in the top 1% of all articles of a similar age rated by the system. An altmetric score is based on the online attention that an article receives, and includes both social media and mainstream news media; the high score received by the UCL paper indicates that it stimulated a large volume of public interest in the research.

The paper also attracted a good deal of media coverage on publication, with articles in Wired magazine (audience of 3 million) and science blog ars-technica (website has more than 10 million unique readers per month). BBC London News also ran a feature on the model on 21 February 2013, including an interview with a UCL research student, and the work received national attention with a piece about the model by BBC's Newsnight on 12 March 2013. The associated publicity raised awareness of UCL's work, evidenced by increased online views of the paper on both occasions [H], and in turn led to a greater public understanding of this relatively new field of research. The online attention surrounding the *Can Maths Predict a Riot?* film in the latter part of

July 2013 also prompted a significant increase in views of the paper and reignited a general interest in the underlying research [H].

Alongside the paper, Fry was invited to speak about the research into the riots at the first TEDxUCL event in June 2012, to an audience of 100 members of the public. The footage of the talk was featured on the front page of TED.com for over three weeks in August 2012, and as of 31 July 2013 had over 500,000 views across all TED channels, ranking in the top 60 TEDx videos of all time (out of more than 30,940 videos). The stimulation of public interest and discourse on the research topic, and on complexity science in general, is further evidenced by the intense debate sparked amongst the public, with over 1,000 detailed comments and 'likes' on the TED website [I] and YouTube channel [J] by the end of the REF impact period. The talk also prompted several members of the public to contact Hannah Fry about the work, opening the opportunity for a two-way discussion. Examples of comments received online and via email include [K]:

"Very, very good, opened my eyes."

"I was very inspired by the fascinating TEDx talk."

"Your TEDx talk explained complexity in an accessible succinct manner, I'm planning my next semester and have your presentation on a list of supplemental materials."

5. Sources to corroborate the impact

[A] Corroboration that Fry won the Focus on the Positive event can be found online; for example, see the New York Times webpage: http://nyti.ms/GWDL93 (halfway down the page).

[B] Video exploring the impact of Focus on the Positive, available online at YouTube: http://youtu.be/G4XrhcQ5khs – corroborates the quotes from Pauline Pearce.

[C] Comment stream on the *Can maths predict a riot?* video, available online at YouTube: http://youtu.be/cY5iARq0nCc – corroborates that the research and the video sparked public discussion and debate.

[D] Blog post on flowingdata.com: http://flowingdata.com/2013/07/18/predicting-riots/ – corroborates that the film stimulated public interest in the research.

[E] Article on popsci.com: http://www.popsci.com/technology/article/2013-07/math-rioting-looks-lot-shopping – corroborates that the film stimulated media interest in the research.

[F] Tweet shared by Labour MP Tom Watson: https://twitter.com/TimPendry/status/361164461022781440 – corroborates that the film stimulated public interest in the research.

[G] Riot table Twitter account: https://twitter.com/RiotSim – corroborates the number of scores recorded on the riot table and hence the number of players.

[H] Article metrics for the Nature Scientific Reports paper: http://www.nature.com/srep/2013/130221/srep01303/metrics – corroborates the number of page views and corroborates that the paper has a high altmetric score, which indicates that it has stimulated a high amount of public interest.

[I] TEDx talk on TED.com: http://www.ted.com/talks/hannah_fry_is_life_really_that_complex.html – the detailed discussions in the comments corroborate that the research has stimulated public interest and discourse on the topic and on complexity science in general.

[J] TEDx talk on the TEDx YouTube channel: http://youtu.be/LnQYJa9-aR0 – the detailed discussions in the comments corroborate that the research has stimulated public interest and discourse on the topic and on complexity science in general.

[K] A compilation of feedback from three members of the public is available on request, and corroborates that the research stimulated public interest and informed understanding of mathematical modelling and applications of complexity theory to the real world.