

# ***Final Report Executive Summary***



## ***HSC R&D Division Final Progress Report***

*Final Reports should be submitted via electronic copy to HSC R&D Division within 6 weeks of the request. The report should be completed on the attached form in clear typescript. Please extend boxes as required. Please adhere to any word limits. These reports may be subject to external peer review. Details from the Final Report may be placed on the HSC R&D Division website and shared with appropriate key stakeholders or members of the public.*

## HSC R&D Division Award Details

<b>HSC R&amp;D File Reference</b>	CDV/5078/14
<b>HSC R&amp;D Funding Scheme</b>	Career Development Fellowship
<b>Project Title</b>	Social Network enabled Interventions for Physical Activity Behaviour Change
<b>Award Holder Name (Employer)</b>	Dr Ruth Hunter
<b>Host Research Organisation</b>	Queen's University Belfast
<b>Award Duration</b>	3 years full time (equivalent)
<b>Award Start Date</b>	01.01.15
<b>Award End Date</b>	31.05.20
<b>Name of Lead Supervisor:</b> <i>(only applicable to training awards)</i>	Prof Frank Kee

## Signature

<b>Award Holder Signature:</b>	Ruth Hunter
	<b>Date: 30/09/2020</b>

# Evidence Brief

*(1 page: which may be used for dissemination by HSC R&D Division)*

Why did we start?

(The need for the research and/or Why the work was commissioned)

Research has shown that social networks (i.e. our friends, family, colleagues) have a significant impact on our health and behaviours. However, we know little about how these networks can help us to lead healthier lives. Social network interventions specifically use or alter the characteristics of social networks to generate, accelerate, or maintain health behaviours and positive health outcomes. This Fellowship addressed important knowledge gaps and built skills, capacity and evidence for behaviour change programmes that use social networks that we are embedded in, which has significant potential for improved public health.

What did we do?

(Methods)

The research undertaken to date has included reviewing previous studies in the area. The results have demonstrated that interventions utilising already existing social networks are particularly effective for encouraging health behaviour change and maintaining these changes longer term. Promisingly, these interventions were also particularly effective in reaching, and changing risky health behaviours, of hard-to-reach and most-in-need groups such as drug users, ethnic minorities, and those living in deprived areas. The review highlighted a dearth of research involving young people – this is an age group where peer influence and social networks are likely to be a key driver of health behaviours. Building on this work, we have conducted a number of computer simulations to help us better understand what types of network interventions might work best.

What answer did we get?

(Findings)

We conducted a systematic review and meta-analyses of 37 studies investigating the effectiveness of social network interventions for health behaviours and outcomes (or their surrogates). Our findings show a significant effect of social network interventions for a range of health behaviours and outcomes, in particular for sexual health outcomes, both in the short and longer term. Subgroup analyses were significant for the intervention approach and when trials were grouped on the basis of mean age and percentage of females.

For the simulation studies, interventions with seeds that were central to the network were generally relatively effective (i.e. Individuals network interventions), with faster or more complete adoption throughout the network. These results provide additional theoretical justification for utilising relevant network information in the design of public health behaviour interventions. There is clear benefit in designing interventions that utilise social network structures. Results demonstrated that interventions using network information to identify seeds were able to deliver substantial gains compared to random seeds. While the size of the potential benefit or loss varied across networks and for different simulation parameters, there were consistent patterns.

What should be done now?

(Practice/Policy Implications and/or Recommendations)

Evidence from this study suggests that social network interventions are associated with positive health behaviours and outcomes. Researchers and public health practitioners should consider how to use the social networks of their populations when delivering health behaviour interventions in order to maximise effectiveness. We recommend that the scientific community should move beyond individual-level approaches to design and test interventions that use the largely untapped potential of social networks to improve health behaviours and outcomes.

# Final Report

(no more than 20 pages)

**Please structure the report using the headings below**

- **Background**

Social networks of family, friends, neighbours, work colleagues, acquaintances, and others have significant impact on our health, health behaviours [1–4], and our ability to change behaviours. However, even though these networks are pervasive in the course of daily life, they have seldom been harnessed in studies of health behaviour interventions [5,6]. Most existing interventions continue to focus on individual-level behaviour and beliefs and fail to address the influential role of an individual's social systems and environments. In recent years, there has been a growing interest in understanding the effects of social networks on health behaviour, which has been accelerated by the emerging prominence of complexity or systems science in public health [7].

Significant developments in our understanding of the structure, characteristics, and function of social networks, and the impact they have on health, have provided opportunities for novel interventions to improve the health of individuals, communities, and populations. Social network interventions specifically use or alter the characteristics of social networks to generate, accelerate, or maintain health behaviours and positive health outcomes [8]. Such approaches have the potential to support various types of health promotion efforts (e.g., health communication, family, or organisational approaches) and to increase the reach or enhance the effectiveness of existing interventions. A landmark paper by Valente (2012) [8] set out a taxonomy of social network intervention approaches. Four approaches were detailed: (1) those that engage individuals who are selected on the basis of some network property and who may have greater roles in providing information or support within their network (see example by Campbell and colleagues [2008] [9]); (2) those that engage certain groups of people (an approach known as segmentation; see example by Buller and colleagues [1999] [10]); (3) those that encourage or enhance peer-to-peer interactions to cascade information and effects to other network members (a process known as induction; see example by Hoffman and colleagues [2013] [11]); and (4) those that involve changing the network (alteration) by adding or deleting members, adding or deleting specific social ties, or changing the entire network (see example by Litt and colleagues [2007] [12]). Such approaches can improve the efficiency and effectiveness of public health interventions because they leverage important mechanisms for behaviour change (e.g., the influence of social norms, social learning, and social support) [13] and potentially enhance behaviour change maintenance [14]. Although research in social networks dates back to the 1930s, social networks are not routinely considered in public health interventions. Extant research has largely focused on observational [1–4] and simulation studies [15–17]. Observational studies have identified features of social networks associated with health behaviours or outcomes that may be important targets for interventions, and simulation studies have begun to explore the potential impact of using social network characteristics for behaviour change [17]. However, real-world interventions that use social networks are less common.

Previous systematic reviews and meta-analyses have provided evidence to support the effectiveness of social network interventions for some specific health outcomes. A meta-analysis by Spencer-Bonilla and colleagues (2017) [18] involving 19 randomised controlled trials (RCTs) investigated the effectiveness of social network interventions on social support, glycaemic control, and quality of life in patients with type 2 diabetes. Results demonstrated that intervention improved social support (0.74 SD [95% CI 0.32–1.15]) and haemoglobin A1c (HbA1c) at 3 months (–0.25 percentage points [95% CI –0.40 to –0.11]) but not quality of life. However, the few trials identified had a high risk of bias. A systematic review by Wang and colleagues (2011) [19] focused solely on condom use. Among the nine included studies with control groups, eight showed significant improvements in at least one measure of condom use. Therefore, there is a need to further investigate the effectiveness of social network interventions for a range of other health behaviours and outcomes including drug use, diet, physical activity, screening, vaccinations, etc. There is also a need to explore the impact of different network intervention approaches, as this has not been done in other reviews and would further advance our understanding of how network interventions operate. Also, these previous reviews mostly included dyadic-level approaches involving spouses or pairs of other family members, emphasising the need for a review that focuses on network interventions that move beyond the dyad level.

The explicit use of social network data, which map the structure of social connections among multiple people, distinguishes social network interventions from the large body of general peer support and social support interventions that have been extensively studied and that typically focus on individuals' perceptions of social phenomena (e.g., social norms) or on dyads [20]. As such, the optimal way to apply the myriad of social network intervention approaches to various health interventions remains unknown. For example, it is not clear who in a social network should be engaged to catalyse the diffusion of behaviour change, nor which mechanisms can best be harnessed to maximise the effects of an intervention, though some have suggested using theory as a guide [6]. The present programme of work addresses this gap through a systematic review and meta-analysis of studies that aimed to harness social network interventions to improve health behaviours and outcomes (or their surrogates). We also examine whether different network interventions approaches—individual, segmentation, induction, or alteration—vary in their effectiveness. We then build on this work by using computer simulations to help us better understand mechanistic processes and possible network intervention approaches.

- **Personal and Public Involvement (PPI)**

Given the focus on adolescents we have undertaken PPI work as part of a Youth Advisory Panel. This panel met five times, involving 8-10 teenagers (aged 13-14 years) to discuss different intervention approaches for encouraging physical activity and how we might best utilise social networks within these programmes. The panel members received training in research methods, and analysing and interpreting data. This has led to the development of a new method involving network analysis techniques, called Participatory Theme Elicitation (PTE) (see Best et al 2017 in publications below (see StepSmart Papers)). Five further focus groups have been undertaken to explore: (i) plausibility and acceptability of network intervention approaches; (ii) views on the design and implementation of potential content for the intervention (Montgomery SC, Badham J, Donnelly M, Kee F, Dunne L, **Hunter RF**. A multi-method exploration into the social networks of young teenagers and their physical activity behaviour. BMC Public Health (under review).

- **Aim**

The overarching aim of the Fellowship programme of work was to develop the evidence base regarding the conceptual, methodological and effectiveness of social network interventions for health behaviour change.

Specific objectives of the programme of work included:

1. ***To conduct a systematic review and meta-analysis of social network interventions for health behaviour change.***
2. ***To use modelling and computer simulations to test how structural parameters and theoretical mechanisms of social network effects could affect the optimal design of a social network enabled intervention.***

- **Objectives, Methods and Key Findings**

The following section is structured by detailing the objectives, methods and key findings from each study undertaken as part of the programme of work.

***Objective 1: To conduct a systematic review and meta-analysis of social network interventions for health behaviour change.***

***Background***

There has been a growing interest in understanding the effects of social networks on health-related behaviour, with a particular backdrop being the emerging prominence of complexity or systems science in public health. Social network interventions specifically use or alter the characteristics of social networks to generate, accelerate, or maintain health behaviours. We conducted a systematic review and meta-analysis to investigate health behaviour outcomes of social network interventions.

***Methods and findings***

We searched eight databases and two trial registries from 1990 to May 28, 2019, for English-language reports of randomised controlled trials (RCTs) and before-and-after studies investigating social network interventions

for health behaviours and outcomes. Trials that did not specifically use social networks or that did not include a comparator group were excluded. We screened studies and extracted data from published reports independently. The primary outcome of health behaviours or outcomes at >6 months was assessed by random-effects meta-analysis. Secondary outcomes included those measures at >6–12 months and >12 months. This study is registered with the International Prospective Register of Systematic Reviews, PROSPERO: CRD42015023541. We identified 26,503 reports; after exclusion, 37 studies, conducted between 1996 and 2018 from 11 countries, were eligible for analysis, with a total of 53,891 participants (mean age 32.4 years [SD 12.7]; 45.5% females). A range of study designs were included: 27 used RCT/cluster RCT designs, and 10 used other study designs. Eligible studies addressed a variety of health outcomes, in particular sexual health and substance use. Social network interventions showed a significant intervention effect compared with comparator groups for sexual health outcomes. The pooled odds ratio (OR) was 1.46 (95% confidence interval [CI] 1.01–2.11; I<sup>2</sup> = 76%) for sexual health outcomes at >6 months and OR 1.51 (95% CI 1.27–1.81; I<sup>2</sup> = 40%) for sexual health outcomes at >6–12 months. Intervention effects for drug risk outcomes at each time point were not significant. There were also significant intervention effects for some other health outcomes including alcohol misuse, well-being, change in haemoglobin A1c (HbA1c), and smoking cessation. Because of clinical and measurement heterogeneity, it was not appropriate to pool data on these other behaviours in a meta-analysis. For sexual health outcomes, pre-specified subgroup analyses were significant for intervention approach ( $p < 0.001$ ), mean age of participants ( $p = 0.002$ ), and intervention length ( $p = 0.05$ ). Overall, 22 of the 37 studies demonstrated a high risk of bias, as measured by the Cochrane Risk of Bias tool. The main study limitations identified were the inclusion of studies of variable quality; difficulty in isolating the effects of specific social network intervention components on health outcomes, as interventions included other active components; and reliance on self-reported outcomes, which have inherent recall and desirability biases.

### **Conclusions**

Our findings suggest that social network interventions can be effective in the short term (<6 months) and longer term (>6 months) for sexual health outcomes. Intervention effects for drug risk outcomes at each time point were not significant. There were also significant intervention effects for some other health outcomes including alcohol misuse, well-being, change in HbA1c, and smoking cessation.

**Publication:** Hunter RF, de la Haye K, Murray JM, Badham J, Valente TW, Clarke M, et al. (2019) Social network interventions for health behaviours and outcomes: A systematic review and meta-analysis. *PLoS Med* 16(9): e1002890. <https://doi.org/10.1371/journal.pmed.1002890>

**Objective 2: To use modelling and computer simulations to test how structural parameters and theoretical mechanisms of social network effects could affect the optimal design of a social network enabled intervention.**

### **Background**

Building on the findings of the systematic review (objective 1), the purpose of this series of studies was to extend the work by Valente (2012), which detailed a taxonomy of different network interventions, to investigate the potential impact of these approaches on the effectiveness of public health behaviour, as measured by speed or reach of behaviour adoption, using computer simulation. Briefly, the different network approaches included; (i) Individuals - identify individuals who are selected on the basis of some network property and who may have greater roles in providing information or support; (ii) Segmentation - targeting the intervention towards certain groups of people; (iii) Induction – encourages peer-to-peer interactions to cascade information and effects to non-targeted participants; (iv) Alteration – changing the network by the addition of new members or breaking existing ties with those who facilitate unhealthy behaviours.

### **Simulation Study 1: Simulating network intervention strategies: Implications for adoption of behaviour**

This study uses simulation over real and artificial networks to compare the eventual adoption outcomes of network interventions, operationalised as idealised contagion processes with different sets of seeds. While the performance depends on the details of both the network and behaviour adoption mechanism, interventions with seeds that are central to the network are more effective than random selection in the majority of simulations, with faster or more complete adoption throughout the network. These results provide additional theoretical justification for utilising relevant network information in the design of public health behaviour interventions.

### **Methods and findings**

We compared the effect of interventions using agent-based simulation, with a model implemented in NetLogo. Fifteen network interventions were included; seven from the Individuals class, two Segmentation, four Induction, and two random selection methods for comparison. These interventions were used to select seed adopters in both real and generated networks. Required network properties were calculated using a combination of the NetLogo Network extension, NetLogo R extension to access R and the R packages 'igraph' and 'keyplayer', which implements group selection. The interventions were simulated over eight different networks: four real-world networks and four generated networks.

Interventions with seeds that were central to the network were generally relatively effective (i.e. Individuals network interventions), with faster or more complete adoption throughout the network. These results provide additional theoretical justification for utilising relevant network information in the design of public health behaviour interventions. There is clear benefit in designing interventions that utilise social network structures. Results demonstrated that interventions using network information to identify seeds were able to deliver substantial gains compared to random seeds. While the size of the potential benefit or loss varied across networks and for different simulation parameters, there were consistent patterns.

### **Conclusions**

These results have important implications for real world interventions. However, applying the results of this study to real-world interventions faces challenges beyond those arising from limitations in network information. For example, those people identified as the preferred seeds may not wish to participate in any trial intervention, may withdraw at any time throughout the study period, or may participate but not respond to the intervention.

**Publication:** Badham, J., Kee, F. & Hunter, R. F. Simulating network intervention strategies: Implications for adoption of behaviour. *Network Science* 2018. 6, 2, p. 265-280 16 p.

### **Simulation Study 2: Effectiveness variation in simulated school-based network interventions**

#### **Background**

Previous simulation studies have found that starting with high degree seeds leads to faster and more complete diffusion over networks. However, there are few studies and none have used networks that are relevant to a school setting.

#### **Methods and findings**

We construct 17 networks from friendship nominations in schools and simulate diffusion from a seed group of 15% of the students. That seed group is constructed with seven different approaches (referred to as interventions). The effectiveness of the intervention is measured by the proportion of simulated students reached and the time taken.

Seed groups comprising popular students are effective compared to other interventions across a range of measures and simulated contagions. As operationalised, selecting persuasive students is also effective for many simulation scenarios. However, this intervention is not strictly comparable with the others tested.

#### **Conclusions**

Consistent with previous simulation studies, using popular students as a seed group is a robust approach to optimising network interventions in schools. In addition, researchers should consider supplementing the seed group with influential students.

**Publication:** Badham, J., Kee, F. & Hunter, RF. Effectiveness variation in simulated school-based network interventions. *Applied Network Science* 2019.

### **Simulation Study 3: Network structure influence on simulated network interventions for behaviour change**

#### **Methods and findings**

We simulated diffusion of behaviour change over fifteen real-world networks with seven network interventions under both simple and complex contagion. We found that structural network properties affect both the diffusion outcome and the relative effectiveness of the different interventions, with confounding effects that were inconsistent with results expected from mathematical analysis. These results suggest that comprehensive studies are needed to identify the effects of structural properties on diffusion in real-world networks. Further, researchers attempting to identify the effect of individual properties must measure a range of properties to avoid incorrect attribution.

We found that structural network properties affect both the diffusion outcome and the relative effectiveness of the different interventions. The properties related to different aspects of degree showed the strongest effect, but were inconsistent with the effects expected from mathematical analysis of simplified networks. One likely explanation is that the much richer set of properties in real-world social networks confound each other, with some enhancing and others inhibiting diffusion. That is, the randomness assumptions in mathematical approaches and the unrealistic structure of synthetic networks compromise the capacity to apply the results. The results from this study with richer network structures suggest that comprehensive studies are needed to identify the effects of structural properties on diffusion in real-world networks if general advice is to be developed about what intervention approach is most appropriate for different networks. As a separate issue, studies that attempt to isolate the effect of specific structural properties must measure a range of properties to ensure any observed influences are not attributed to the wrong property.

**Publication:** Badham, J., Kee, F. & Hunter, R. F. Network structure influence on simulated network interventions for behaviour change. *Social Networks* 2020. 64, p. 55-62 8 p.

#### **Overall Programme of Work - Summary of Findings:**

Findings from this programme of work demonstrated strong evidence supporting the effectiveness of social network interventions for health behaviour change. More specifically, there was strong evidence for Individuals, Segmentation and Alteration network approaches, with all included studies primarily utilising these network approaches showing a positive intervention effect. In addition, there was promising evidence to support Induction network approaches (68% of studies demonstrated a positive intervention effect). Importantly, intervention effects were maintained in the majority of studies where outcomes were measured at least 6 months post-baseline. Perhaps most encouraging, these interventions have demonstrated effectiveness in recruiting and changing the behaviour of “hidden”, hard to reach, hard to engage and the most in need populations, including injection drug users, socially disadvantaged and minority ethnic groups.

#### **Overall Programme of Work - Implications of Findings:**

This programme of work highlights a number of areas that need addressing in order to take this promising research forward. These include: 1) *advancing theory* by developing, refining or integrating existing theories and models; 2) *understanding fundamental mechanisms* regarding how to induce behaviour change at the individual, network and environmental level; 3) appropriate methods and metrics for intervention, process and outcome evaluation; 4) novel and low cost methods of collecting network data to inform intervention development. Further, there was a lack of detail outlining the specific intervention approaches which made it difficult to understand active components. The development of a domains and reporting framework would help overcome this problem.

- **Pathway to Impact**

This body of work has formed a strong foundation for future grant proposals in the area, led to highly cited papers, built capacity in social network techniques and the application of social networks in health behaviour change interventions, and helped progress this promising area of research in public health. The range of outputs is evidenced in the section below.

Specifically, the work has:

- 1) developed a conceptual model to help understand the theoretical mechanisms underpinning social network interventions;
- 2) developed a methodological and reporting framework to guide the development and evaluation of social network interventions;
- 3) a review of measures of social networks;
- 4) a review of the associations of social networks and health behaviours in adolescents;



- 5) a successful grant application to explore mechanisms of social networks and social norms for health behaviour change in adolescents using novel game theory methodology;
- 6) development of a large consortium application to the UK Prevention Research Partnership (UKPRP) (lead for a programme of work on social networks);
- 7) built capacity in advanced social network analysis techniques such as Exponential Random Graph Techniques (ERGMs) and Simulation Investigation for Empirical Network Analysis (SIENA) modelling;
- 8) development of an interdisciplinary research group on Applied Network Science;
- 9) establishment of a national and international reputation re: applied social networks for health behaviour change.

The fellowship has been instrumental in helping to establish a range of collaborations with local, national and international collaborations, for example:

**Local:** School of Education, QUB; local secondary schools.

**National:** Universities of Bristol, Cambridge, Oxford, UCL, Stirling, Edinburgh, London School of Hygiene and Tropical Medicine, Glasgow, Leicester.

**International:** The WHO Europe, and universities of Yale (US), the Andes (Colombia), Deakin (Australia), Michigan (US), Harvard (US), Southern California (US) and the International Physical Activity and the Environment Network (IPEN) involving collaborations with universities in the US (Stanford, UCSD, Chapman), Belgium, China, Australia, Brazil.

#### **Leveraged Funding:**

The following section details the grant funding that I have either been successful in achieving or applied for directly related to my Fellowship (in addition to the 7 PhD studentship applications mentioned below). Those listed are either directly related to social networks or complexity science which have been leveraged as a direct impact of the NIHR Fellowship. See Table 1 below for breakdown of details.

**Table 1: Successful grants attained as either a Principal Investigator or Co-investigator in the area of social networks and complexity science**

Funder	Title	Role	Total Award
UKRI NHMRC	A vision of healthy urban design for NCD prevention	Principal Investigator	£800,000
MRC PHIND	Developing system-oriented interventions to reduce car dependency for improved population health in Belfast	Principal Investigator	£150,000
MRC PSMB	Using Game Theory to assess the effects of social norms and social networks on adolescent smoking in schools: a proof of concept study	Principal Investigator (joint with Prof Frank Kee)	£715,726
DfE GCRF	A complex systems approach to addressing refugee health issues in Turkey and Jordan	Principal Investigator	£35,000
Invest Northern Ireland	Derry/Londonderry as the nexus for food, education, trust and health; (recommended for funding)	Co-investigator; lead for social network component	£749,906
CSO Scotland	Sit less, move more: Improving sedentary behaviour and physical activity in community-dwelling older adults; Development and feasibility testing of a novel technology-supported intervention	QUB Principal Investigator; lead for social network component	£299,167
Newton Researcher Links for Travel Grants	Evaluation of instruments to assess social cohesion and social inclusion in programs that promote physical activity in public spaces (visit to build	Principal Investigator	£6500

(Jan2017-Feb 2018)	collaborations with Dr Olga Lucia Sarmiento, Los Andes University, Colombia)		
MRC PHIND (Jan 2015-Nov 2016)	Can Twitter sentiment help us design better mass communication interventions for public health? A feasibility study focussing on skin cancer prevention	Co-investigator	£149, 923
UKPRP	Opportunities for intervention and innovation in the UK School Food System: the GENIUS (Generating Excellent Nutrition In UK Schools) network  (Principal Investigator Prof Jayne Woodside)	Co-investigator and programme theme lead	£500,000
UKPRP	PHASE: The Population Health Agent based Simulation nEtwork  (Principal Investigator Prof Laurence Moore, Glasgow)	Co-investigator	£513,228
<b>Total</b>			<b>£3,884,485</b>

CSO: Chief Scientist Office; DfE: Department for the Economy; GCRF: Global Challenge Research Fund; MRC: Medical Research Council; NHMRC: National Health and Medical Research Council; NIHR: National Institute for Health Research; PHIND: Public Health Intervention Development Scheme; PI: Principal Investigator; PSMB: Population and Systems Medicine Board; UKRP: UK Prevention Research Partnership

The following related applications are under review or invited to submit a stage 2 bid:

Funder	Title	Role	Total Award
EU H2020	RESURGE4HEALTH: RESEARCHING URban Green space interventions for a healthier and more equitable Europe	Principal Investigator	5m Euro
UKPRP Consortium/Stage 2	GroundsWell: Community and Data Led Systems Transformation of Urban Green and Blue Space for Population Health	Principal Investigator	£6.5m Invited to submit a stage 2 bid (17 <sup>th</sup> Dec 2020)
UKRI ISCF Ageing Challenge	SPACE: Supportive environments for Physical and social Activity, healthy ageing and Cognitive health.	Principal Investigator	£2m Invited to submit a stage 2 bid (5 <sup>th</sup> Nov 2020)
<b>Total</b>			<b>~£12m</b>

EU H2020: European Union Horizon 2020; ISCF: Industrial Strategies Challenge Fund; UKPRP: UK Prevention Research Partnership; UKRI: UK Research and Innovation.

### **Collaboration Seed Funding:**

I was awarded Collaboration Seed Funding from the Faculty to build new collaborations. The fund is designed to help early career researchers who are probationary academic staff to establish new research links with world-leading programmes related to their research discipline. I visited the Human Nature Lab at the Yale Institute for Network Science, Yale University in October 2017. Their research focuses primarily on the relationship between social networks and health, including: 1) the social, mathematical, and biological rules governing how social networks form; 2) the biological and social implications of how they operate to influence behaviours; 3) network interventions for public health. Prof Nicolas Christakis is a social scientist and physician. He directs The Human Nature Lab and co-directs the Yale Institute for Network Science. He is a world-renowned leader in social networks and network interventions and health. He has published extensively in high impact journals such as Nature, The Lancet, New England Journal of Medicine, Proceedings of the

National Academy of Sciences, and named in the Time magazine's list of the 100 most influential people in the world in 2009.

**Published papers (n=23) from the Fellowship programme of work:**

**Systematic Reviews**

Webster D, Dunne L, **Hunter, RF**. Association Between Social Networks and Subjective Well-Being in Adolescents: A Systematic Review. Youth & Society 2020; <https://doi.org/10.1177/0044118X20919589>

Montgomery, S. C., Donnelly, M., Bhatnagar, P., Carlin, A., Kee, F. & **Hunter, R. F**. Peer social network processes and adolescent health behaviors: a systematic review. Preventive Medicine 2020. 130, 19 p., 105900.

**Hunter, RF.**, de la Haye, K., Murray, J., Badham, J., Valente, T., Clarke, M. & Kee, F. Social network interventions for health behaviours and outcomes: A systematic review and meta-analysis. PLoS Medicine 2019. 16, 9, 25 p., e1002890.

Kepper, M., Myers, C., Denstel, K., **Hunter, RF.**, Guan, W. & Broyles, S. The neighborhood social environment and physical activity: a systematic scoping review. International Journal of Behavioral Nutrition and Physical Activity 2019; 16, 14 p., 124.

Corepal, R., Tully, M. A., Kee, F., Miller, S. & **Hunter, R. F**. Behavioural incentive interventions for health behaviour change in young people (5-18 years old): A systematic review and meta-analysis. Preventive Medicine 2018. 110, p. 55-66 12 p.

Tate C, Kee F, Kumar R, **Hunter RF**. Mechanisms of Social Influence Shaping Smoking Behaviours Among Adolescents: A Review and Synthesis of Theoretical Perspectives. Soc Sci Med (under review).

**Simulation and Computational Modelling Studies**

Badham, J., Kee, F. & **Hunter, R. F**. Network structure influence on simulated network interventions for behaviour change. Social Networks 2020. 64, p. 55-62 8 p.

Badham, J., Kee, F. & **Hunter, RF**. Effectiveness variation in simulated school-based network interventions. Applied Network Science 2019.

Badham, J., Chattoe-Brown, E., Gilbert, N., Chalabi, Z., Kee, F. & **Hunter, RF**. Developing Agent-Based Models of Complex Health Behaviour. Health and Place 2018. 54, p. 170-177.

Badham, J., Kee, F. & **Hunter, R. F**. Simulating network intervention strategies: Implications for adoption of behaviour. Network Science 2018. 6, 2, p. 265-280 16 p.

**Hunter RF**, McAneney H, Davis M, Tully MA, Valente TW, Kee F. "Hidden" social networks in behavior change interventions. Am J Public Health. 2015;105(3):513-6. doi: 10.2105/AJPH.2014.302399.

**MECHANISMS Study**

**Hunter RF**, Montes, F., Murray, J., Sanchez-Franco, S. C., Montgomery, S., Jaramillo, J., Tate, C., Kumar, R., Dunne, L., Ramalingam, A., Kimbrough, E., Krupka, E., Zhou, H., Moore, L., Bauld, L., Llorente, B., Sarmiento, O. L. & Kee, F. MECHANISMS Study: Using Game Theory to assess the effects of social norms and social networks on adolescent smoking in schools – study protocol  
04 Aug 2020, In : Frontiers in public health. 8, 14 p., 377.

Murray, J. M., Kimbrough, E. O., Krupka, E. L., Ramalingam, A., Kumar, R., McHugh Power, J., Sanchez-Franco, S., Sarmiento, O. L., Kee, F. & **Hunter, R. F**. Confirmatory factor analysis comparing incentivized experiments with self-report methods to elicit adolescent smoking and vaping social norms  
07 Sep 2020, (Accepted) In : Scientific Reports.

Badham, J., McAneney, H., Dunne, L., Kee, F., Thurston, A. & **Hunter, R. F**. The importance of social environment in preventing smoking: an analysis of the Dead Cool intervention. BMC Public Health 2019. 19, 7 p., 1182.

### **StepSmart Study**

Corepal, R., Best, P., O'Neill, R., Kee, F., Badham, J., Dunne, L., Miller, S., Connolly, P., Cupples, M. E., Van Sluijs, E. M. F., Tully, M. A. & **Hunter, R. F.** A feasibility study of 'The StepSmart Challenge' to promote physical activity in adolescents. *Pilot and Feasibility Studies* 2019. 5, 1, 15 p., 132.

Corepal, R., Best, P., O'Neill, R., Tully, M. A., Edwards, M., Jago, R., Miller, S., Kee, F. & **Hunter, R. F.** Exploring the use of a gamified intervention for encouraging physical activity in adolescents: A qualitative longitudinal study in Northern Ireland. *BMJ Open* 2018.

Best, P., Badham, J., Corepal, R., O'Neill, R., Tully, M., Kee, F. & **Hunter, R.F.** Network methods to support user involvement in qualitative data analyses: An introduction to Participatory Theme Elicitation. *Trials* 2017. 18, 14 p., 559.

**Hunter, R. F.**, de Silva, D., Reynolds, V., Bird, W. & Fox, K. International inter-school competition to encourage children to walk to school: a mixed methods feasibility study. *BMC Research Notes* 2015. 8, 23 p.

### **Collaborations with UniAndes**

Guerra, A. M., Montes, F., Useche, A. F., Jaramillo, A. M., Gonzalez, S. A., Meisel, J. D., Obando, C., Cardozo, V., **Hunter, RF.** & Sarmiento, O. L. Effects of a physical activity program potentiated with ICTs on the formation and dissolution of friendship networks of children in a middle-income country. *International Journal of Environmental Research and Public Health* 2020.

Jaramillo, A. M., Montes, F., Sarmiento, O. L., Rios, A. P., Rosas, L. G., **Hunter, RF.**, Rodriquez, A. L. & King, A. C. Social cohesion emerging from a community-based physical activity program: A temporal network analysis. *Network Science* 2020. 14 p.

### **Editorials and Other Papers**

**Hunter, RF.** Wickramasinghe, K., Erguder, T., Bolat, A., Ari, H. O., Yilidirim, H. H., Ursu, P., Robinson, G., Breda, J., Mikkelsen, B., Connolly, P., Clarke, M. & Kee, F. National action plans to tackle NCDs: role of stakeholder network analysis. *BMJ* 2019. 365, 1871, 4 p.

**Hunter RF.** Gough A, O'Kane N, Fitzpatrick A, McKinley M, McKeown G, Walker T, Lee M, Kee F. Ethical issues in social media research for public health. *Am J Public Health.* 2018:e1-e6. doi: 10.2105/AJPH.2017.304249.

**Hunter RF.** Ball K, Sarmiento OL. Socially awkward: how can we better promote walking as a social behaviour? *Br J Sports Med.* 2018. pii: bjsports-2017-098564. doi: 10.1136/bjsports-2017-098564.

### **Workshops:**

- National workshop entitled "Ethics in Social Media" in collaboration with 12 researchers from across the UK from different disciplines (ethics, public health, computer science, social marketing, sociology, law) to develop ethical guidelines for the use of social media in public health at Queen's University Belfast, Nov 2016 (joint organiser and speaker).
- International workshop entitled "International Society for Physical Activity and Health (ISPAH) Early Career Network"; ISPAH Congress, Thailand, Nov 2016 (joint organiser).
- National workshop entitled "Friends with Benefits: Utilising Social Networks for Health and Wellbeing" at the UKCRC Centres of Excellence for Public Health Annual Conference in collaboration with DECIPHer, Cardiff University, Edinburgh, Nov 2015 (lead organiser and speaker).
- National workshop entitled "Introduction to Agent-based Modelling for Public Health" in collaboration with the UKCRC Centre of Excellence for Public Health (NI) and All-Ireland MRC Methodology Hub, Queen's University Belfast, Apr 2016 (joint organiser).
- National workshop entitled "Social networks for health behaviour change in complex interventions". UK Society for Behavioural Medicine, Cardiff, Dec 2016 (lead organiser and speaker).
- International workshop entitled "Social network interventions for physical activity and dietary behaviour change". International Society for Behavioural Nutrition and Physical Activity (ISBNPA), Canada, Jun 2017 (lead organiser and speaker).

- National workshop entitled “Social Network Interventions for Health Behaviour Change”. UK Society for Behavioural Medicine (UKSBM); Liverpool, Dec 2017 (lead organiser and presenter).
- National workshop entitled “Agent-based modelling in public health”; Queen’s University Belfast, 20-22 Nov 2017 (organiser).

### **Symposia:**

- Symposium entitled “Utilising social networks for physical activity and dietary behaviour change”; ISBNPA, Jun 2015. Collaborations with the University of Southern California (US), Kansas State University (US), Wake Forest University School of Medicine (US) and Deakin University (Australia) (lead organiser, chair and presenter).
- Symposium entitled “What works health and well-being in schools; What Works Global Summit”, London, Sept 2016 (organiser).
- Symposium entitled “Complex system modelling for behaviour interventions: Learning from Experience”; ISBNPA Jun 2017. Collaborations with Erasmus MC (The Netherlands) and the University of Melbourne (Australia) (joint organiser and chair).
- Symposium entitled “Maintenance of health behaviour change: Theories, trials and tribulations”; ISBNPA Jun 2017. Collaborations with the University of Victoria (Canada), McGill University (Canada) and University of Stirling (lead organiser and chair).
- Symposium entitled “Social psychology and social networks”; XXXVIII Sunbelt Conference, June 2018. Collaboration with the University of Southern California (joint organiser).

### **Other presentations:**

#### *Oral presentations:*

- Oral presentation: Social network interventions for health behaviour change: a systematic review (published abstract), ISBNPA conference, Jun 2015.
- Oral presentation: Utilising social networks for physical activity behaviour change: A conceptual model (published abstract), ISBNPA conference, Jun 2015.
- Oral presentation: “Hidden” social networks in behaviour change interventions. XXXV Sunbelt Conference of the International Network for Social Network Analysis (INSNA), Jun 2015.
- Oral presentation: “Hidden” social networks in behaviour change interventions. Public Health Annual Scientific conference, Jun 2015.
- Oral presentation: “Hidden” social networks in behaviour change interventions, HEPA Europe, Belfast, Sept 2016.
- Oral presentation: “Hidden” social networks in behaviour change interventions, UK Society for Behavioural Medicine, Dec 2016.
- Oral presentation: Investigating the mechanism of physical activity behaviour change using Agent-based Modelling, UK Society for Behavioural Medicine, Dec 2016.

#### *Keynote speaker/Invited speaker/seminars:*

- Invited speaker: Career pathway of early career academics. WE-CAN seminar series, Jan 2016.
- Invited speaker: Career pathway: NIHR Career Development Fellowship. Research and Enterprise Fellowship workshop, Queen’s University Belfast, Nov 2016.
- Invited seminar: Social networks and health behaviour change; at the University of Lancaster, Jul 2015.
- Invited seminar: Social network interventions for health behaviour change; University of Southern California; Oct 2015.
- Invited seminar: Agent-based Modelling (ABM) for designing physical activity interventions; Cambridge University; Jan 2016.
- Invited seminar: Social network interventions for health behaviour change; University of Stirling, Feb 2016.
- Invited seminar: Social network interventions for health behaviour change; Trinity College Dublin; Jun 2016.

- Invited seminar: Simulating network interventions for behaviour change; University of Manchester; Oct 2016.
- Invited speaker: ISPAH Early Career Network workshop; ISPAH Congress, London, Oct 2018.
- Invited seminar: Applied Network Science in Public Health; Yale University; 12th Oct 2017.
- Invited seminar: Applied Network Science in Public Health; University of Massachusetts; 25th Oct 2017.
- Keynote speaker: Multisectoral Response: Network analysis of stakeholders in Turkey. WHO/5<sup>th</sup> Turkish Medical World Congress; 27<sup>th</sup> Oct 2018.
- Invited seminar: Social networks and health behaviour change; Cambridge University; Nov 2018.
- Keynote Speaker: Social network interventions for health behaviour change. Latin American conference on complex networks, Cartagena, Colombia, 8<sup>th</sup> Aug 2019.
- Invited seminar: Social network interventions for health behaviour change. Radboud University, Nijmegen, 16<sup>th</sup> January 2020

### **Tools:**

- Developed Stakeholdernet.org: An online stakeholder network analysis tool.
- Developed a simulation platform for network interventions (see Simulation and Computational Modelling Studies papers for details).

### **WHO Reports/Workshops:**

- WHO NCD Office. Investigating National Coordination Mechanisms for Non Communicable Diseases. Lead author: Dr Ruth Hunter, Dec 2018.
- WHO NCD Office. Strengthening capacity for noncommunicable disease implementation research in the WHO European Region. Contributing author, May 2019.
- WHO NCD Office. Workshop to strengthen capacity for noncommunicable disease implementation research in the WHO European Region: 12- 15 February 2019. Invited speaker on network analysis and implementation research.

### **Mentoring**

Capacity building: formal supervisor for 7 related PhD students (4 have completed), 2 PDRF's mentored to fellowship application, 1 new lectureship leveraged (as well as my own).

Oct 2014 – Sept 2017 1<sup>st</sup> Supervisor - **Jennifer Murray**: Investigating the mediators and moderators of physical activity behaviour change (leveraged Department for the Economy (DfE) Studentship); Other supervisors: Prof Frank Kee, Prof Chris Patterson, Prof David French (University of Manchester). Status: Completed.

Oct 2014 – Sept 2017 1<sup>st</sup> Supervisor - **Rekesh Corepal**: A randomised controlled trial of a 'pedometer competition' to encourage physical activity in schools: A feasibility study (DfE Studentship). Other supervisors: Prof Frank Kee, Dr Mark Tully, Dr Sarah Miller (advisor; School of Education). Status: Completed.

Oct 2015-Sept 2018 1<sup>st</sup> Supervisor - **Niamh O'Kane**: Using social media to help us design better mass communication interventions for public health (DfE Priority Studentship); Other supervisors: Dr Michelle McKinley; Prof Weiru Liu (University of Bristol). Status: Completed.

Oct 2015-Sept 2018 1<sup>st</sup> Supervisor - **Shannon Montgomery**: Increasing physical activity in teenagers: A social network-enabled intervention (UKCRC Centre of Excellence for Public Health funded); Other supervisors: Dr Michael Donnelly; Prof Tom Valente (USC). Status: Completed.

Oct 2017 – Sept 2020 2<sup>nd</sup> Supervisor – **Deborah Webster**: Social networks and mental wellbeing in schools. Other supervisors: Dr Laura Dunne (Centre for Evidence and Social Innovation (CESI)).

Oct 2018 – Sept 2021 1<sup>st</sup> Supervisor – **Chris Tate**: Using Game Theory to assess the effects of social norms and social networks on adolescent smoking in schools: a proof of concept study (leveraged DfE Studentship); Other supervisors: Dr Rajnish Kumar (School of Management, QUB); Prof Frank Kee.

Jul 2020 – Jun 2023 2<sup>nd</sup> Supervisor – **Abdullah Alsarrani**. Association between friendship network and mental wellbeing in adolescents: longitudinal analysis and investigation of moderators and mediators (Ministry of Health, Saudi Arabia funded); Other supervisors: Dr Leandro Garcia, Dr Laura Dunne (CESI).

Formal and informal mentorship of PhD students, RA's and PDRF's fellowship applications.

### **Promotion:**

- Promoted from Lecturer to Reader in June 2019 (QUB);
- Took up a Lecturer position in Mar 2015 (QUB).

### **Funding Panels:**

- Appointed as a member to the NIHR Public Health Research panel, Oct 2019.

### **References**

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5. Hunter RF, McAneney H, Davis M, Tully MA, Valente TW, Kee F. "Hidden" social networks in behaviour change interventions. *Am J Public Health*. 2015; 105: 513–516. <https://doi.org/10.2105/AJPH.2014.302399> PMID: 25602895
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