**Mapping Microbial Stories: Creative microbial aesthetic and cross-disciplinary intervention in understanding nurses’ infection prevention practices.**

Consistent implementation of hand-washing within the hospital environment remains a challenge in infection prevention (IP) procedures. IP is one of a number of measures to tackle antimicrobial resistance (AMR). A cross-disciplinary team was assembled to experiment with different ways of visualising the microbial. The paper details a comparative experimental design where nurses (n=2) performed a series of routine care procedures in a mock-ward setting where traces of coloured ultra-violet glow-powders had been purposely placed, firstly with routine hand-washing and secondly without routine hand-washing. The results presented as a series of photos, video-clips, ethnographic observations and nurse interviews explore nurse-microbial relations and the potential for affective and embodied encounters with microbial worlds to generate new insight in IP. We argue for creating unfamiliar aesthetics that engage the sensate as an intervention in established IP education. The aesthetic rendered invisible microbes visible through techno-artistic practice. The performance term ‘devising’ was used to analyse the cross-disciplinary methodological process. Finally, we consider the potential for nurses to act as microbial citizens as they extend their care for the human to entail the need to care for the microbial, perhaps not to kill but to relocate the risky pathogen, as part of a commitment to multispecies living in a world with AMR.

**Key Words**: Aesthetics, cross-disciplinary, embodied knowledges, experiment, hand-hygiene, infection prevention, microbial worlds, practice.

“Contact-transfer of pathogenic organisms on the hand is an important means by which patients acquire infection in hospitals, and numerous tests have been used to evaluate the efficacy of procedures designed to interrupt spread by this route.” (Marples and Towers 1979: 237)

**1. Introduction**

Marples and Towers (1979) and others from subsequent eras (Gould, 1991; Kelsall et al 2006), have evidenced the importance of hand-washing within infection prevention (IP) procedures. Ensuring consistent implementation of hand-washing within the hospital environment however remains a substantial challenge. Is it a failure of education, of care, forgetfulness, or an ongoing risk when events overcome routine? In 1998, Courtenay argued that the literature examining the teaching and learning of infection control principles is limited in scope with a number of factors working against effective performance of hand-washing. More recent research in healthcare recognises the multifaceted structural challenges to changing the hygiene behaviours of healthcare professionals, and visitors, in order to reduce infection risks to patients (Pittet *et al*., 2000; Whitby *et al*., 2007). By contrast, Prieto writes:

“principles of infection prevention are notoriously difficult for healthcare workers to grasp and to apply consistently [...], the interpretation of these principles within policies and practice guidelines is not always clear or presented in ways to enable ready application to practice” (2016: 5).

Whether education or a structural failing, the risks of infection spread when hand-washing does not take-place have been proven (Kelsall et al 2006).

Situated within the large cross-disciplinary research investment (see MRC, 2018 *Tackling AMR - A Cross Council Initiative*) to address the global challenge of antimicrobial resistance, this research project focuses on IP practice. IP is one of a number of measures being named to reduce antibiotic usage (Allegranzi and Pittet, 2009; Moody *et al*., 2012), and there is consensus that tackling antimicrobial resistance (AMR), caused by high-levels of antibiotics in the environment (O’Neill, 2015), in part, requires urgent attention to hygiene practices. Within a cleaner environment, where humans (and animals) contract disease less often, this would lead to a reduction in antibiotic dosing. If one can remove the need to use antimicrobials, the opportunity for a resistant strain to adapt through gene-transfer in the microbial landscape following repeated exposure to antimicrobials, is reduced (Costello *et al.,* 2010).

This paper reports on the research activities of an interdisciplinary team of scholars. The authors brought their different methodological and disciplinary perspectives to this challenge that spanned social, health, biological, engineering sciences and the humanities. We ask, firstly, can we make new *non*-medo-scientific knowledges about the IP practice of hand-washing in the hospital environment? And secondly, how can different disciplinary knowledges, aesthetics, and technologies collaborate and unite to bring original approaches to the study of shared objects of research interest?

Human geographers have argued for the need to study lay embodied knowledges of biological (including microbial) organisms (Roe and Greenhough, 2006). Additionally, Kirksey and Helmreich (2010) have introduced the concept of multispecies ethnography to study the hosts of organisms of varying scales whose lives and deaths are linked to human social worlds. Spanning health and cultural geographies, a literature has developed studying nursing practices. Andrews and Moon describe the value of a qualitative geographical approach to understand the micro-scale spatial features of disease, in terms of social interactions ‘among patients’, ‘between staff and patients’ (58) and how ‘the complex features of health settings may facilitate or contain the disease in terms of work cultures (norms, rituals), organisational and management cultures’ (2005: 58-59). Thus, whilst the term micro-scale geographies is referred to, it is not a material geography of mobile, microbial lives they described. Our work extends this literature by attending to the agency and performative qualities of the non-human within the micro-scale spatiality of disease played out between not only bodies of staff, patients and work cultures, but also, the affective, presence of lively microbial organisms.

 Following Law (2004), research methodology makes the world we study, rather than solely describing the world we are in. In a wet-skills lab – where water, pseudo-pathogens as UV powders, mannequin bodies, hospital equipment and (training) nurses can entangle and make mess – creativity and interdisciplinarity came together. We illustrate how nurses ‘know’ the microbial, and reflect on what a multispecies ethical commitment to care, not only for the human but also the non-human microbial world, would offer. In this way, the findings develop the field of human microbiome research by adding to debates about knowledge-deficit or structural reasons which explain how hand-washing can fail to happen. It also discusses how working creatively with ‘pedagogic materials’, commonly used to teach IP globally, unfamiliar non-cognitive embodied experiences can be made through presenting novel visualisations, that usefully intervene in the routinised.

**2. Literature Review**

***Microbial Life***

The last three decades have seen cultural geographers begin to unsettle the ‘human’ within human geography, putting ‘the onus on ‘livingness’ as a modality of connection between bodies (including human bodies) and (geo-physical) worlds’ (Whatmore, 2006: 603). The scaling of these enquiries has nearly always been bigger than the microbe. This special issue of *Geo* is evidence of a shift in scalar focus towards the microbe and how it works as an agent to shape human encounters with ‘other’ humans, animals, soils because of the activity of microbial life (see Bastian *et al*., 2017; Haraway, 2003; Hird, 2010). Such research follows Hird’s assertion that micro-organisms, whether bacteria, archaea, fungi, protozoa, algae, or viruses, are *actants* who, time after time, form “symbiotic companions with life on earth” (2009: 133). Microbes aren’t just on us but actively ‘make us up’, participating in our digestion and eating, and supporting fermentation processes (Ingram, 2011). What unites these studies is that each seeks to advance thinking on more-than-human worlds and public understanding of it. However, humanistic agendas still dominate ‘expert’ approaches to studying human engagement with microbial worlds, with emphasis being given to the threat they pose to human physical and financial wellbeing; for example, the IP paradigm in the health sciences. This study supported cross-disciplinary knowledge-exchange in terms of letting cultural geographers into the workspaces of nursing and, introducing health scientists to cultural geographic insights on the social life of pathogenic microbes and how they shape the embodied, tacit and everyday geographies of labouring nursing bodies.

Shared health risks at the human, non-human and environmental interface (see Haraway, 2003; Hinchliffe, 2015) have seen cultural geographers engage with the geographies of health and disease through examining non-humans in the form of harmful and benign organisms, disease vectors, host species, and antibiotics and antibacterials. Cliff *et al.,* (2009: 221) argue that antimicrobial agents have formed the ‘cornerstone of therapeutic responses to infectious diseases for almost 70 years’ (see Blaser, 2014). At the heart of this public health approach sat an emphasis on antimicrobial worlds where fewer microbes equated with healthier places (Lorimer, 2017), thus fostering an untargeted destruction of microbial life. Interestingly, the rise of AMR has prompted a shift toward *displacing* harmful microbes rather than complete eradication. This could be through encouraging the growth of good microbes or, the spatial displacement of harmful microbes in water solution through cleaning practices. Significantly, cultural geographies of microbes are valuable empirically and methodologically by asking different questions about human-microbial-technology life relations.

***Nursing and infection prevention***

There is a growth of interest in the intersection between nursing, healthcare work and spacetimes (Andrews, 2003; Liaschenko, 2001) alongside calls for nursing pedagogy to engage productively with knowledges developed outside of its disciplinary borders (Holmes and Gastaldo, 2004; Holmes, Gastaldo and Perron, 2007). For Andrews and Evans (2008), the post-1990s geographies of nursing literature has offered insight into the socio-spatial complexity, diversity, and day-to-day operation of working life in healthcare. Gavin Andrews (2003) argues that the emergence of this interdisciplinary field can be accredited to two principal structural changes over recent times; first is a shift in healthcare provisions (i.e. community-based care), and the second relates to changes in nursing roles and responsibilities (prioritising physical closeness). Sandelowski describes nurse presence as a “felt perception on the part of embodied and vulnerable patients that they are cared for” (2002: 64). This emphasis on embodied empathy signals critical awareness of the emotional dimensions of labour (Hochschild, 1983), but also simultaneously, a move away from viewing body work as ‘dirty work’ to the ‘cleaner’ work of technology (i.e. viewing the patient in terms of their condition).

In their daily work, healthcare staff take measures to protect themselves and patients from infection, through the use of personal protective equipment and hand hygiene (Beam *et al*., 2011; c.f. Lapum *et al.,* 2012 on the liminal space between technology and nursing practice; also see Sandelowski, 1999). IP practices actively work to tackle the risks associated with sick human bodies sharing space and sharing professional attendant practitioners, or in other words nurses, doctors and other healthcare staff. However, it is known that the application of IP principles in practice remain inconsistent (D’Alessandro, 2015), with studies showing that healthcare workers’ adherence to recommended hand hygiene procedures is highly variable (between 5% and 89%), and varies by health profession (WHO, 2009: 66; see Pittet *et al*., 2000). D’Alessandro (2015) examines the discrepancy between practices and standards of medical hygiene in preventing hospital-acquired infections in Niger. The author argues on the one hand how a lack of disposable materials and equipment makes it impossible to implement appropriate infection-prevention practices that rely on specific tools (sterile gloves, disinfectant, soap, compresses). Yet on the other, D’Alessandro accounts for the ‘shared geographies’ and the absence of formal spatial segmentation for different activities, in contributing to the spread of (anti)microbial life: “the cleaners put the mop to dry on the railing. Later (…) a nurse took out [...] injectable drugs, syringes, needle, etc. [...] put them on the railing, and started to prepare an injection” (2016: 66). This fieldwork illustration emphasises the need to understand the movement of pathogenic agents as the output of a complex interplay with objects and human touch. How might creative methodologies create new knowledges with non-human microbial life as part of a reinvigorated move to appreciate what is at stake, and what our ethical responsibilities to multispecies living could be in the spaces of nursing work?

***Creative Methodologies***

A body of work that supports researching *with* non-human life is that from feminist science scholars like Haraway (2008: 2016) and Barad (2012). They have encouraged greater attention to both how we could understand the practices we study, as well as to those we perform ourselves as researchers in the course of doing research, as interactive change-bringing interventions in the material world (for an application see Roe and Greenhough, 2014). Both encourage us to respond to the choreography of intra-action between materialities and practices – particularly pertinent for research involving non-humans – with care for what worlds we make together. Non-representational theories (Thrift, 2008) and growing interest in performance and practice (Butler, 1990), are also useful for thinking through “the composition and working of assemblages through which health arises and is performed” (Andrews, 2018: xii; see Andrews, 2017). The philosophy of nursing literature itself has not been immune to methodological and interpretative frameworks that draw on post-structuralism, phenomenology, affective and performative theories and methodologies (see for example Ducey, 2007, 2010; Holmes 2010; Lapum, 2008). Likewise, these theories have contributed to cultural geographic scholarship around nursing that prompts consideration of our haptic-sensory encounters with the socio-materiality of the nonhuman, although the focus of this work has been on agentive technologies rather than agentive biological matter. Not only can the visceral materiality and agency of our networked configurations with the non-human world be considered, but also the imaginative, emotional and aesthetic geographies that shape our responses to managing, mitigating, living with, and or avoiding contact with the non-human world; whether stag beetles (Lorimer, 2007), bees and butterflies (Bingham, 2006), or slugs (Ginn, 2014).

Microbes, touch, and various visualisation techniques have featured in creative and participatory methodologies within cultural geography and beyond. MacDuff *et al.,* (2014) have explored how healthcare workers and patient representatives conceptualise pathogens through different forms of risk-identification activities, and accounted for the envisioned geographies of pathogens (as “monster”, “creature”, “nasty”). Not dissimilarly, in their ‘Kitchen Safari’, Hodgetts and Lorimer adopted an “upstream citizen science” approach to “provide important insights into peoples’ hygiene practices and understandings in a world characterized by both ‘good’ and ‘bad’ microbes” (2017: 27). In an example of activism meets performance, Mukherjee (2016) illustrates how food installation art might animate concerns over environmental toxicity by front-staging non-humans, and local resident’s forced intimacy with them. Interest in microbials worlds has equally spread to art practitioners. Artist Mellisa Fisher (2013, 2017) and microbiologists Clements and Betts have, for example, collaborated on a series of living sculptures including ‘Microbial Me’ and ‘Microbial Michael’. These works, created from human body casts made from agar and cultivating bacteria from the artist’s own skin, make visible the growth of bacteria, partially through the use of UV light.

***Interdisciplinary methodologies***

Not only is there a strong case for working creatively to address adherence to IP guidelines and its connection to the social life of microbes that generate what Dame Sally Davies (2017) from Public Health England calls the “wicked issue” of AMR, but also a need to foster interdisciplinary ways of working on this issue. We follow Hinchliffe *et al.,* in asserting that emerging diseases, and their subsequent resistance, are “more than a matter of microbes alone” (2016: xiii). To create an understanding of the relations between microbes, hosts and their social and physical environments, and a cultural geography of microbial life, requires for us, the development of new methodological approaches and connections beyond the constraints of disciplinary borders. In the context of human and non-human worlds, Buller has described interdisciplinarity as an “(inter)active practice of convergence involving the relational construction of distinct areas and objects of interaction, intermediacy and translation that lie beyond disciplinary frontiers” (2008: 396). What Buller offers our approach is a framework for thinking about interdisciplinarity as creative and as process, which is, by its very nature “explorative rather than definitive” (402).

There is a long history of interdisciplinarity between science and art, with organisations such as Arts Catalyst (2016) and Wellcome Trust (2018) producing and funding creative outputs in association with scientific research. Likewise, much cultural geographical scholarship, particularly post non-representational ‘theory’, has been characterised by engaging with creative methodologies (McCormack, 2013; Veal, 2016) and / or lively collaborations with a host of art practitioners and practices (Dixon, 2009; Hawkins, 2013) as a way of accessing the precognitive, embodied, sensual knowledge that ‘makes us human’. Yet what seems missing is how cultural geographical knowledge might advance interdisciplinary studies within the health sciences.

**3. Methodology: The staging of the experiment**

*Mapping Microbes* (2016) was an interdisciplinary pilot project, involving two engineers, two academic nurses, a microbiologist, a performance artist, and two cultural geographers. The project was funded through an EPSRC Bridging the Gap Research Grant; a scheme committed to the notion that “a multidisciplinary approach is needed to tackle these challenges and make a step change in addressing antimicrobial resistance” (2014: 2). *Mapping Microbes* focused specifically on theme three; “examining behaviour within and beyond the healthcare setting” (*ibid*). As cultural geographers, we reflect on our experiences of academic boundary crossing, and of our encounters with the falling away of presumed disciplinary-specific methodological toolkits. Indeed, while our ontological vantage points differed across disciplinary training and learning, whether understanding microbes as isolated, mobile vectors for disease spread, or ‘situated matters’ as disease (Hinchliffe *et al.,* 2016), we collectively came together to examine how rendering the non-human sense-able might shape knowledge-practices.

The methodological process was anchored at the outset by the following questions:

* To what extent might we demonstrate the agency of non-humans?
* Can creative methods contribute to understanding the perception of risk associated with transmission models of contagion?
* How can we creatively map the movements of simulated microbes through the routine touch-practices of nurses?
* Can creative methods produce pedagogic materials for healthcare workers?

Two stages of the research process are discussed in this paper as findings; the process of designing the experiment itself which we report on as findings, and the ‘data outputs’ from running the pilot experiment with two registered nurses as photos, video-clips, ethnographic observations and qualitative interview extracts with the nurses.

Unable for health, ethical and safety reasons to conduct our research in a ‘live’ hospital ward with real patients or to use actual pathogens, we turned our focus to working with pedagogic materials in a Wet Skills Lab – a training environment for practicing nursing labour – and to explore it as a site in which our experimentations could be trialled and tested (see Soffer, 2016). The research apparatus included pedagogic materials from a wet-skills lab -three plastic mannequins; three coloured ultraviolet (UV) sensitive Glo-Germ powders (used on their own and suspended in glycerine as a gel) that are invisible under natural light. These pseudo-substances (ultraviolet powder), used internationally in hand hygiene education in hospitals (Biswal *et al*., 2014; Vanyolos *et al*., 2015) and schools (Randle *et al*., 2013; Snow *et al*., 2008; Witt and Spencer, 2004), were literally brushed and scattered in various sites as pretend pathogens. We were able to recruit to our experiment two registered nurses, one with specific training in infection prevention. The pseudo-substances were moved around unbeknown by the registered nurses during routine hospital tasks, and then made visible when the room was illuminated by UV lighting. Such materials are frequently used to illustrate poor hand-washing techniques (Wiles *et al*., 2015) by providing healthcare workers with instant visual evidence of areas of “missed hand-hygiene” (Lehotsky *et al*., 2015: 83). In our research, we extended the use of these gels from not only hands but also patient bodies, equipment, protective clothing, bed linen etc.

 With no breathing patients nor dangerous pathogens this placed the investigative team as creatives more akin to artist Luke Jerram (2018), who sculpts pathogenic microbes from glass than forms of BioArt employing live cells and tissues (Catts and Zurr, 2002; Dixon, 2009). These common UV substances have received little attention from artists. Pedagogic materials and clinical equipment were supplemented with creative apparatus - specialised UV lights, a camera and tripod. We began to experiment with ways of making the microbial realm sensible, and to map human-non-human mobilities. Never entirely certain that our methodology might succeed, health scientists and cultural geographers constructed and staged a pilot experiment of nursing / UV powders / mannequin improvisation (Figure 1). To test the significance of handwashing, the clinical tasks were carried out on the UV powder doused mannequins, both with and without regular handwashing from the nurses. The actions of the nurses were filmed live using the ward CCTV and UV photos taken after each task. See VIDEO ONE[[1]](#footnote-1) – Bed change without gloves

We pretend that our three patients have three different infectious conditions. Our ‘patients’ – Mr Blue, Green and Red – and associated props (sheets, bed rails, catheter) are then doused with three differently-coloured UV powders that are pseudo-pathogens purposely chosen by our nursing colleagues; meticillin-resistant Staphylococcus aureus (MRSA), Clostridium difficile (C. diff) and Escherichia coli (E. coli). Corresponding with these conditions, a series of routine nursing practices were identified as potential causes of microbial transmission; changing bed sheets, emptying a catheter, facilitating use of a bed pan, and conducting observations. Two registered nurses in costume (scrubs) are called onto set, task sheets in hand, and asked to complete four routine nursing tasks first without, and then with, recommended hand hygiene guidelines (gloves, hand washing, antimicrobial gels). (Veal, 17th May 2016)

There were obvious challenges to mapping microbiomes through the use of pseudo-substances. We were never studying the actual agency of mobile pathogens, but decoys located on bodies and equipment through existing microbiological knowledge of how our three pathogens behave. Nor were we studying nurse-patient interactions around microbial well-being in real-life. In fact, the nurses clearly knew they were handling mannequins and pseudo-substances. In this world of pretence, the practices from the laboratory and the theatre stage (not the surgical theatre), to experiment and to improvise, overlapped. Our scientific experiment improvised into a performance, and our laboratory into a theatre for performing and spectating on microbial worlds. Here we use the term experiment to describe the twice-repeated tasks we asked the nurses to perform once using hand hygiene and once not using hand hygiene. And the experimental process involved refining a solution that stuck to surfaces of metal, cotton, plastic, and glass, along the continuum between UV gel through to powder form. Some team members experimented with different ways of tracking repetitive movement using overhead CCTV cameras (installed for examining nursing training) and facial recognition software programs re-coded (with limited success) for hands touching surfaces. The term improvisation refers to what the interdisciplinary experimenters enacted as they explored new ways of studying the non-human microbe. The artist Hurley improvised with aesthetic techniques of photographing simulated pathogens, and the engineering researchers explained the possibility for using UV lights and different optical filters that would make our UV powders light-up. Veal improvised with ways of notating haptic encounters within her ethnography that documented the mundane, practiced, haptic geographies of our nurses. The term performance describes the product of the improvisatory and experimental labours; the non-human microbes performing an aesthetic, all colourfully aglow, to narrate a human-non-human story.

Following the experiment (the performance by nurses of a series of routine tasks), semi-structured interviews were conducted with both nurses to discuss their experience in the experiment.

**4. Nursing Practices: Responding to Human–Non-Human Configuration**

*To what extent might we demonstrate the agency of non-humans?* For those working in areas of infection-prevention, making sense of the invisible microbial world necessitates knowing something of the haptic mundane, repeated, rehearsed daily routines of practicing nurses (see Andrews, 2018; Butler, 1990), and their facilitating and/or inhibiting role in the spatial configuration of microbial landscapes in and on the human. As Patterson (1998) notes, a holistic approach recognises the need for looking inward and down to the microscopic, as well as outward to the macroscopic level. It also requires a critical consideration of nursing practice as response to vulnerability and a potentially dangerous non-human. The significance of studying mundane nursing tasks, is underlined by Nurse One’s detailed reflection on her inability to recount the complexities of this tacit practice; “sometimes you just do things on autopilot”. Nurse Two emphasised the iterative “engrained” nature of specific activities and a disjoint in memory between those tacit tasks that did and did not engage his conscious brain. Indeed, in one memorable case, Nurse Two recounted the difficulty of moving between patients, when the team’s curiosity to capture an aspect of the experimental event, disrupted routine hand-washing opportunities. This led him to reflect on his “overriding” urge to hand-wash and draws attention to the habitualization of hand-washing within nursing practice; a reminder that nurses can carry a microbial threat, via routine nursing practices, that could harm the next vulnerable body. Indeed, Campkin and Cox’s (2012) edited collection powerfully uncovers how cleanliness is produced within particular historical, cultural and moral contexts, and play on individual anxieties over eradicating the invisible and unknown. Thus, whilst nursing is a form of practice – in care-giving, emotional support, and medical administration (Bolton, 2000; Henderson, 2001) – it is also organised to ‘make clean’; whether of self, equipment, or other body, through displacing dirt.

***Dirt and Caring***

An embodied response to “feeling” dirty (“it’s the psychological thing because you know you need to wash your hands”; Nurse One) was identified by both nurses as driving hand hygiene practice. For both nurses, the context of the experiment gave a heightened experience of feeling dirt to that common in their work on hospital wards. By dirt, or ‘matter out of place’ (Douglas, 1966), Nurse One referred to “flaky skin” and mobile “bodily fluids” (see Dixon and Straughan, 2010; Longhurst, 2001), to which one could add sickness, vomit, and sweat – all potential vectors of pathogens, even in trace quantities. Whilst labelled by the nurses as psychological, we interpret this thinking as emergent in response to being a vulnerable, porous body; through physically reaching out and onto (touching) or being materially affected by another body, it can render either body at risk. The agent of risk here, of course, isn’t the human body, but the microbial ones that accompany it. Similarly, for the nurses, handling patients with specific medical conditions resulted in a corporeal sense of the non-human as leakage, as repugnant, as contaminating, as soilage, and as seepage. Following this logic, when performing their tasks without hand hygiene measures, both nurses therefore recounted their anxieties of being proximal to potentially harmful (albeit simulated) pathogens. Nurse One, whilst in conversation about Mr Blue’s documented skin condition, discussed the uncomfortable mobility of human-microbial matter.

“You have patients who have excessive skin loss, so they have quite flaky skin because they are either dehydrated or have various skin conditions and you can see … and feel sort of the skin on your hands. So that would make me go and wash my hands.”

Interestingly, Nurse One recognised that it was “controversial” to mention greater or lesser amounts of human-microbial matter shed from bodies. When discussing Mr Red, suffering from *C. diff*, Nurse Two also identified microbes’ risky materiality, and a sense of potential vulnerability from contaminating microorganisms hosted in sickness and diarrhoea:

“you are much more aware of where your hands are. I am more aware, for example if I touch the handrail … I would definitely notice that … I would think to myself, oh sugar, he’s got this condition, I’ve touched the handrail, I am going to need to remember to scrub a bit more.”

***Making Clean as Care***

Whether it is changing bed sheets, conducting observations, emptying catheters or bedpans, or administering intravenous medication, nurses touch or are touched, and consequently ‘making clean’ is the closure of an activity. This ‘making clean’ of themselves, equipment, or patient’s body may be acknowledged consciously or disappear from memory under the guise of routine, habit, or mundane daily *iterations* with microbial life. Part of the challenge of this act of making clean – alongside other creative ‘making’ acts from making beds to making patients comfortable – is that one works with bodies whose imagined borders are permeable and leak ‘stuff’, dirtying surrounding environments. Furthermore, the practices and places that surround the very *materiality* of the stuff that leaks, including sickness and diarrhoea, accelerates the imaginative threat posed, both in time and, crucially, space. In light of significant medical and public knowledge of the cross-contamination risks of *E. coli* and *C. diff*, Nurse Two explained;

“Definitely with the patient who we put on a commode. Even though it was a simulation, at the end of it, you just think to yourself, I’ve just touched the commode … I’ve wiped them. I need to go and wash my hands.” (Figure 2)

[see also VIDEO TWO - Bed pan with gloves]

Yet rather than suggesting that some conditions deterred tacit encounters, both nurses identified how patients with severe symptoms, including diarrhoea, would induce higher levels of nursing concern, which “instinctive[ly]” leads to greater acts of touch; “[I would] just feel their forehead. Just make sure they haven’t got a raised temperature” (Nurse Two). Bodily fluids like sweat are read in particular ways, in certain contexts, to tell a story of a body exposed, threatened by microorganisms whether as a consequence of infection, hormone, temperature or humidity levels.

Alongside bodies, and the fluids and materials that leak and seep from them, the wider hospital landscape, including handrails, curtains, blood pressure cuff, and task sheets (Figure 3), were imagined by our nurses, as potential sites or agents supporting cross-species contamination. As Nurse Two recounts, potential contamination was not only a story of his hands, but also,

“the story of the equipment I am using. So for example, I know that this cuff it’s going to be on this patient (Mr Blue), plus that patient (Mr Red), plus that patient (Mr Green). It’s touching *them* and that’s still a touch story.”

[VIDEO THREE– observations with no gloves]

This reflection suggests our simulated pathogens enhanced attention to the nurses’ movement of objects, like the task sheet, from one patient to another. The ability of microbes to reside in everyday nursing objects was made all the more apparent by our pseudo-substance’s materiality;

“I definitely thought more about my handover sheet, I’m not going to lie about that, because obviously I could feel the grains [UV powders]. Every time I was touching it, I was thinking to myself … if I could not feel these grains, I would probably be touching it more.” (Nurse Two)

***Enhancing senses of microbes***

Our efforts to contextualise the performative and practiced characteristics of simulated microbes, thus led to a critical engagement with the senses and illustrates the possibilities for technology to support, rather than hinder, caring practices (Ducey, 2010). For our two registered nurses rehearsing the experiment without gloves, the microbes took on a performative materialism, as grainy and slimy, sticky and moist substances. In comparison to their textbook teachings – concerned with the communication of microbiology and clinical routines – here microbes occupied the realms of presence as living subjects with vitality; they existed within three-dimensional space as shared configurators of the laboratory.

Our nurses’ express disgust as fingers touch the cold slimy powders spread on Mr Blue’s bed-rail. They laugh uncomfortably, not knowing what they have touched, and not wanting to touch again. Each examines the grainy qualities of the substance between their fingertips, but invisible to their eyes. Quickly however, their focus returns to the task at hand, and they adopt their perfunctory practice of changing bedsheets with efficiency. A sense of curiosity about the stories their hands might tell nevertheless increases (Veal, 17th May 2016).

Inadvertently, this moment offered a sense of how a heightened tactile experience of invisible agents could play out as education tool, as opposed to the common emphasis on the visual realm. One of the challenges of exploring AMR / IP relations is its nature as microscopic, and yet within nursing practice microscopes are never used. However, the microscopic worlds that lay beyond the known (visible/tactile) frontiers of human materialities (sick, urine, diarrhoea, dry skin) are ‘making worlds’ (Salazar, 2017) of IP that shape nursing practices day-in-day-out. Collectively, these examples illustrate various geographies of microorganisms at play in nursing practice on a ward; they can become repulsive to look at, uncomfortable to touch, but equally, of little concern as the care priority requires reaching through the microbial ‘film’ to touch a body that needs care. Microbes are awkward, but necessary, companions to be around because context situates how they become known (Hinchliffe *et al.,* 2016). The status of microbial flora on the hospital ward shifts, depending on whether bodies with particular vulnerabilities to certain bacteria are near. Or, threats can be ignored when caring trumps IP, until the task is completed. Care and clean, care and clean, care and clean.

***Creative jamboree of nurses, microbes and researchers***

Experimenting with, and encountering the non-human realm, equally provoked enquiries into the transdisciplinary team’s own practice. Here we conceptualise our research practices as an explorative style of researching and thinking about non-human scholarship; where pathways of human-microbial relations could be wrenched free of the microscope and brought into the visible everyday space of the laboratory. *Can creative methods contribute to understanding the perception of risk associated with transmission models of contagion?* Guthman and Mansfield (2013) have specifically recognised that the mobility of bodies and matter necessitates new methodologies to trace and analyse molecular flows empirically. Echoing methodological approaches within creative geography, our research was an experiment in practicing collaboration (Askins and Pain, 2011; Callard and Fitzgerald, 2015) when mapping the microbial (see also Lorimer and Hodgetts’ (2017) *Good Germs, Bad Germs* a participatory approach on kitchen surface microbiomes), as mobilised through touch. Taking a participatory research stance with microbial worlds, approaching non-human–human entanglement seriously and, by questioning how science is ‘done’, shifts knowledge-making away from a paradigm of human exceptionalism (Bastian *et al.,* 2017). Indeed, the rise of AMR makes us more aware that the go-to-method for controlling nature (and killing it; i.e. biocides), can ultimately foster environments for resistant-genes to generate and thus practices of IP should focus more upon the spatial displacement of ‘risky’ bacterial organisms and not ultimate destruction. This point emphasises the significance of participatory research *with* more-than-human worlds. It also insists preventing infection by nurses may require the need to embed care for microbial lives alongside care for human lives.

At its most simplistic, our creative encounters with microbiome were staged. Prior to the ‘research phase’, our experiments were repeated, rehearsed, reworked and iterated to make them ‘perform’. Our roles as researchers thus morphed in the pre-experimental phase as we played at being nurses (*cf.* nurses playing as patients Soffer 2016). Supported by our colleagues in nursing and microbiology, we experimented in learning how to make hospital beds and empty catheters (Figure 4), and practiced with the camera to achieve effective angles and lighting. Alongside our engineering counterparts we held coloured light filters, wheeled professional UV lights into position, and repeatedly sought to ‘excite’ our powders in our garages, studios, offices and laboratories. So too, during the ‘final performance’, our nursing activities were staged. Like a game of musical chairs, we called ‘action’ and ‘cut’, collecting ‘evidence’ at intervals of *our* (and our nurses’) choosing. We learnt more and more about the positionality – what knowledges mattered and why – of our interdisciplinary colleagues as we were requested to perform and improvise different roles, handle different technologies and materials, and required to find a shared language so we could communicate beyond our disciplinary specialisms.

Our practice in transdisciplinarity was thus often conceptualised, to follow Buller (2008), as “explorations” in failure. For those of us interested in creating, improvising, experimenting, and devising, there is important space to provide a critical conceptualisation of failure (see Veal and Hawkins, forthcoming) or perhaps rather as Thomas A. Edison quotes “I have not failed. I've just found 10,000 ways that won't work.” More so, in the world of performance, failure is integral to the creative process (O’Gorman and Werry, 2012). To exemplify, we became frustrated when our gels wouldn’t light up, when our gloves couldn’t be distinguished by the facial recognition software programs re-coded for hands, the poor quality of our overhead surveillance cameras, and when our powders wouldn’t stick during haptic encounters. Yet those practical failures invigorated conversations and promoted the exchange of shared experiences and knowledge. Presented with elements that would not work led to new methodologies being presented, equipment being refashioned, new powder-glycerine substances concocted, and nursing stations reshaped. In such contexts, working out what works and what doesn’t, and even what it means ‘to work’ was integral to our experimental doings. This is not only significant in thinking about the very practical nature of transdisciplinary, but also of conceiving of risk-taking activities as improvisations in learning and doing.

**5. Enhancing the multi-species experience**

***Unfamiliar Aesthetics of the microbial***

In this section, we consider what work microbial worlds produced through experimentations in light, captured in images, can add to the debates that surround IP practices. We ask, *how can we creatively map the movements of simulated microbes through the routine touch-practices of nurses*? And, can the political-aesthetics surrounding IP shift away from an untargeted elimination of microbial life and toward fostering care for multispecies living in microbiotic worlds through an emphasis on displacement instead? In our considerations, we draw on Dixon’s work on how the political-aesthetics of the non-human have been presented through BioArt:

“The ‘matter’ of BioArt is of concern to a wide range of geographers, physical as well as human, insofar as it is the product of artists and scientists working together to engage public interest in the vital scientific, political and ethical issues of our day, making visible the policies, practices, artefacts and lifeforms that emerge from a technoscientific biology, certainly, but also environmental degradation and climate change” (2009: 423)

Hand-washing, UV light and glow powders is not the typical context for BioArt. It tends to focus on biotechnologies, for example bodily tissue storage, rather than public and professional education to support habitual hand-washing. However, here we were in a wet-lab, albeit with pseudo-‘wet-ware’ of pathogens and human bodies, but with the biological and technological fused into the pedagogic materials; UV light, UV sensitive powder and human hands/bodies entangled. This is an arena where the biological and the artist can work together to make visible different hygiene practices. Uniquely, this produced microbial worlds through experimenting with different spectrums of light rather than scale or ‘scopic regimes’, by employing the revealing qualities of UV. Here we follow, Bastian *et al.,* who building on Law (2004), argue that “methods don’t just describe worlds, but make worlds. That is they make some things more visible and others more difficult to take into account” (2017: 2). These fieldnotes explain the photographic performances we engaged in:

Over 200 long exposure, large aperture (1/10s, f3.5) photographs mapped the vital materiality of the two hour scene spatially, rendering visible microbial worlds. Later, a linear account of simulated non-human encounters with nurses, and their progression in time – whether on hands, gloves, beds, stethoscope, bed pans, or catheters – are digitised in an interactive timeline (Veal, 15th June 2016)*.*

Images like those below, we argue, gave a new apprehension of the microbial to our nurses. We go on to explore the politico-aesthetic of world-making around IP traditions that the production of our aesthetic artefacts sought to intervene in. One form of intervention is their use in a short film entitled *These are the hands* (Turp and Hurley, 2016) [See VIDEO 4][[2]](#footnote-2), which recognises how *practices* of visualising contribute to the *production* of geographical worlds (Crang, 1997). Building upon cultural geographers’ interest in touch and tacit knowledge (Paterson and Dodge, 2012), and intimate and affective spaces of the micro (Dixon and Jones 2014), we argue that rather than approaching the body as isolated (molecular life as either ‘out there’ or ‘in me’), we emphasise pathways via the vector of touch. Through touch the orifices of the body - mouth, wounds, urethra - become vulnerable to microbial others.

***Staging what becomes visible and invisibl*e**

 ‘Bad bugs’ in the world have been given visibility in cartoon form on countless occasions. One recent addition to this canon is ‘Meet the Microbes’ (Osborne and Smith, 2014), with anthropomorphic characters like ‘Steph Le Coccus’. In contrast, we let the simulated microbes perform visual stories (see DeSilvey, 2007) of potential pathogenic mobility between patients, objects, medical equipment and clothing, disrupting their common ‘absent-presence’ under normal working conditions, and thus anthropocentric ‘ways of seeing’ (Berger, 1972). We think here about the value of producing alternative knowledges about medo-scientific landscapes, including the cultural and ethical complexities of nursing in response to the more-than-human, and making worlds that configure the microscale and molarscale in various ways. Both nurses reflected upon how seeing simulated pathogens under UV lights – on their bodies, clothes and nursing equipment – confirmed the necessities of hand hygiene practices, and reinforced their IP training. Like Macdonald and Macduff (2018) and Macdonald *et al* (2017), the *Mapping Microbes* team created visualisations of non-humans (as simulated pathogen) by fusing aesthetics, nursing care, and scientific knowledge (see Macduff *et al.,* 2014); yet the politico-aesthetic conjured aimed to engage microbial citizenship practices, drawing on Haraway’s (2016) manifesto for multi-species living. Findings from interviews indicate we had some success. Nurse Two explained, “I appreciated what hand washing does (…) but you do not appreciate how much it has transferred, and then seeing it there it was like, oh goodness”. Discussing the images, Nurse One also noted that it was a “fantastic way of showing that if I went from bed one to bed four that movement would occur”.

Through images, evocative of starscapes, TV forensics, or acid house raves, the aesthetic encounters with the non-human world estranged nurses from the mundanity of clinical objects and tasks in hand. The multiplicity of coloured powders illustrated in the images (Figure 5) demonstrated both opportunities for cross-contamination, but were also informative in envisaging microbes as negotiating their own complex positionalities within dynamic multispecies communities, habitats and microbial ‘cities’ (Watnick and Kolter, 2000). In this respect, it advocated for the agency of microbes as mobile, labouring, performing actants, active in the shaping of dynamic shared landscapes. This was not only via optical techniques of depth of field and zoom, but also changes of light, employed in the creation of affective atmospheres. As Edensor notes, “illumination uniquely blurs the boundaries between affects generated by representational and nonrepresentational qualities” (2012: 1112). This blurring also suggests a consideration of magic at work in the creative aesthetic we were using:

‘Magic works by transforming the visible (or what is available to the spectators’ senses), playing on an economy of visibility/invisibility. Magic does not only or mostly obscure; magic works as much through what is shown as what is hidden’ (Rolfe, 2014: 1605).

The transformative process of the UV and camera image operated across scalar-distances to create a stage and audience where a political aesthetic worked differently than would a microscope. Sontag (1977) conceives of photographing as an act of appropriation, cultivated as a result of positioning oneself in relation to the world. By contrast, our photographs gave opportunities to explore contrived visual relationships that purposefully brought attention to non-human agency; as present, active, material, and mobile. Furthermore, using photography to emphasise mobility, and by experimenting aesthetically and technologically with relative size, the non-human gained visible recognition. Hence, these surrogate micro-beings gained currency as requiring ‘care-ful’ relationships (see Ginn, Beisel and Barua, 2014); care for and care of. The implication was both to ‘scale up’ the micro beyond the microbial realm (to that read-able by the human eye), but equally, to splice through the restrictive binaries of visible/invisible, micro/macro. As such the camera became a technology for making simulated things visual and magical - and imbuing them with the real (“yukky”) agency of that which they substituted.

***Creative aesthetics and knowledge intervention***

Yet more than this, the creative outputs also combined practices and narratives of the nurses with data from artistic, rather than scientific, perspectives of the simulated microbes. *Can creative methods produce pedagogic materials for healthcare workers?* The effect was to produce a creative knowledge intervention that tells a story of infection (between patients, nurses, objects; figures 6 and 7), in a way that would not have been possible from a single-perspective microbiological or IP study. Thus, following Auslander’s (2006) work in performance studies, the images produced were both *documentary* and *theatrical*. That is to say, they recorded an event (with the potential for its reenactment) as well as manipulated the aesthetic to create a new artefact. This aestheticisation of medo-scientific knowledge, through artistic (though not abstract) imagery of a real experiment in real space, created an affective/emotive understanding of microbial infection and its agency, that is, we argue, invaluable in the fight against AMR.

Was the political-aesthetic of these images cultivating a new sensibility to the microbial; a microbial citizenship? Following Roe and Buser (2016) who argue participatory performance art can engage people with the politics of ecologies, through staging embodied intra-actions with non-humans, here the political aesthetic provokes wonder at what microbial citizenship could be. As health policies tackle the challenge of AMR, political aesthetics work to give new visions on the microbial, generated through embodied activities. Such visions may prepare people for the complexity that surrounds caring for the microbiome as entangled with the health of bodies of any species bigger than the micro. This complexity of caring was illustrated by Nurse Two when discussing the nasal cannula;

“out of instinct, I would move it out of the way, even though I know there may be [microbes]. There should be a better way to do it. I would do it because (…) it’s still on the patient, although maybe I should be more *careful*”

The making visible of microbial actants within the experiment led nurses and researchers towards a ‘thinking with’ (Haraway, 2016) rather than a thinking *about* non-humans in *geographies* of infection. This was not only in terms of the simulated pathogenic materialities, but also the non-human technologies such as the commode, blood pressure cuff and task sheet. Interpreting visualisations of microbial life through ecological-thinking, prompted us, as cultural geographers, to approach care from multiple directions and to engage productively in debates around pro- and pre-biotics and the microbiota.

 **6. Conclusion**

Given the ongoing challenges of ensuring healthcare workers grasp infection prevention, and apply them in practice (Prieto, 2016), and growing interest in how people and things are co-configured in practice (Soffer, 2016), the move our research makes to create an embodied experience that offers a different way to communicate the principles through the medium of the sensate have been proven as effective in this pilot study (n=2). In answer to our first research question, yes, we can make new *non*-medo-scientific knowledges about the IP practice of hand-washing in the hospital environment. The experience presented simulated pathogenic microbes in colour or as ‘yucky’ to the touch to perform on a stage that interrupted the familiar aesthetic of the ward environment - contrasting the light with the dark, the palette of healthcare with the palette of neon glowing, the feel of metal, skin, fabric with a sticky coating. The world we created was an unfamiliar aesthetic, but not in terms of the architecture of patient and healthcare equipment and the request to get-on with highly-practiced care routines. Further research to scale this study up would arguably be beneficial to take the findings further and consider how they can be embedded into IP training approaches.

The study illustrated the value of creative methodological play within microbial worlds to foster potential new ways of knowing, ways of imagining the vital, liveliness of a diversity of microbes whether their capacity to move or the environments that support their life. Importantly we learnt audiences may not need the specific microbiological detail, but instead can still respond generally to actors (UV powders) performing for risky pathogenic matter; this abstraction is powerful when carefully staged to key into other aspects of the familiar. For example, the photographs employed the aesthetic, the emotive, and the performative to re-orientate the gaze and centre-stage the microbe. The assemblage of images rendered these hidden geographies present, producing visible haptic spacetime scores in which mobility is seen, not from human-centric detached, aerial or microscopic gazes, but alongside and in conjunction *with* human practice. Incorporating elements of the aesthetic into the production of the experiment presented a fundamentally novel and multifaceted piecing together, and imagistic testimonial, of human-non-human happenings within the familiarity of the ward.

In responding to calls for nursing scholarship to move beyond hegemonic paradigms and stagnant methodologies to understand the complexity and messiness of human social life (Holmes and Gastaldo, 2004; Holmes Gastaldo ,and Perron, 2007), we argue, in answer to our second research question, yes, cross-disciplinary approaches are vital to generate new knowledges of the microbial because one discipline alone could never have achieved the synthesis of approaches, technologies and expertise that is evident in the making of the experiment and its findings. Using the performance language of ‘devising’ enabled us to think of interdisciplinarity as framework, theories, methods and language originating from collaborative, often improvisatory, sharings and doings. The value of the concept of ‘devising’ is thus in foregrounding a process of sharing knowledge, improvising with that knowledge, failing in some of the steps, and having another go with new insight. Our study is a rich illustration of one such cross-disciplinary process tackling working on microbial life. Our experience accords with Borgdorff’s characterisation of transdisciplinary research as involving “a partial interpenetration of practice, theory, and method, in response to research questions arising from highly specific, local contexts” (2012: 92); in our case the local challenge of hand-washing to prevent infection spread by nurses. And, there is much potential in bringing physical, biological, social, health and creative arts altogether to collectively tackle the microbial world because of the pertinence of the various expertises to address a world too often invisible yet world-shaping in how it is known.

Finally, our work sought to respond to the challenge, identified by Haraway (2016), to bear witness to how practices affect the lives of multiple species and to give scrutiny to where and for whom the ethical import to care lies. Nurses became interesting subjects to witness because of the iterative care practice of making-clean world’s often made dirty by the microbial. Further work is needed to understand how microbial citizenship could foster understanding for valuing the lives of microbes alive, but perhaps moved away from the vulnerable in water solution, rather than killed by cleaning with antimicrobials agents. Our project has offered a different political-aesthetic of microbial worlds, to the cartoon depictions of feared/imagined bugs, that does give visibility to multispecies living with microbes. This is a start.

**Acknowledgements**

We are very grateful for the opportunity to develop this cross-disciplinary research project with University of Southampton colleagues Dr Jacqui Prieto and Professor Lisette Schoonhoven (nursing), Dr Sandra Wilks (microbiology), Professor Xunli Zhang and Dr Robert Zmijan (bioengineering). Thank you also to the two nurse practitioners who outside of their working hours spent time taking part in our experiment. Much appreciation also to Professor Tim Leighton for his enthusiastic support and guidance as principal investigator of EPSRC award EP/M027260/1 Network for Anti-Microbial Research Action (NAMRA) that funded this research. Thank you also to the members of Network for Anti-Microbial Research and Infection Prevention (NAMRIP) at the University of Southampton and beyond.

 **References**

Allegranzi, B., and Pittet, D. (2009). Role of hand hygiene in healthcare-associated infection prevention. *Journal of Hospital Infection*, *73*(4), 305-315.

Andrews, G. (2003). Locating a geography of nursing: space, place and the progress of geographical thought. *Nursing Philosophy,* *4(*3), 231-248.

Andrews, G. (2017). Geographical thinking in nursing inquiry, part two: performance, possibility, and non‐representational theory. *Nursing Philosophy*, *18*(2), e12137.

Andrews, G. (2018). *Non-Representation Theory and Health: The Health in Life in Space-Time Revealing*. London: Routledge.

Andrews, G., and Evans, J. (2008). Understanding the reproduction of health care: towards geographies in health care work. *Progress in Human Geography*, *32*(6), 759-780.

Andrews, G., and Moon, G. (2005). Space, place, and the evidence base: Part I—an introduction to health geography. *Worldviews on Evidence‐Based Nursing*, *2*(2), 55-62.

Arts Catalyst (2016). *About arts catalyst*. Available at: [www.artscatalyst.org/content/about-arts-catalyst](https://www.artscatalyst.org/content/about-arts-catalyst). (Accessed 3rd May 2018).

Askins, K., and Pain, R. (2011). Contact zones: participation, materiality, and the messiness of interaction. *Environment and Planning D: Society and Space,* 29(5), 803-821.

Auslander, P. (2006). The performativity of performance documentation. *PAJ: A Journal of Performance and Art*, *28*(3), 1-10.

Barad, K. (2012). On touching—The inhuman that therefore I am. *Differences: A Journal of Feminist Cultural Studies,* *23*(3), 206-223.

Bastian, M., Jones, O., Moore, N., and Roe, E. (Eds.) (2017). *Participatory Research in More-than- Human Worlds*. London: Routledge.

Beam, E., Gibbs, S., Boulter, K., Beckerdite, M., and Smith, P. (2011). A method for evaluating health care workers’ personal protective equipment technique. *American Journal of Infection Control*, *39*(5), 415-420.

Berger, J. (1972). *Ways of Seeing*. Available at: [www.youtube.com/watch?v=0pDE4VX\_9Kk](https://www.youtube.com/watch?v=0pDE4VX_9Kk). (Accessed 20th April 2018).

Bingham, N. (2006). Bees, butterflies, and bacteria: biotechnology and the politics of non-human friendship. *Environment and Planning A,* *38*, 483-498.

Biswal, M., Rajpoot, S., Dhaliwal, N., Appananavar, S., Taneja, N., and Gupta, A. (2014). Evaluation of the short-term and long-term effect of a short series of hand hygiene campaigns on improving adherence in a tertiary care hospital in India. *American Journal of Infection Control*, *42*(9), 1009-1010.

Blaser, M. (2014). *Missing microbes: how killing bacteria creates modern plagues*. London: Oneworld.

Bolton, S. (2000). Who cares? Offering emotion work as a ‘gift’ in the nursing labour process. *Journal of Advanced Nursing,* 32(3), 580-586.

Borgdorff, H. (2012). The mode of knowledge production in artistic research. In Gehm, S. Husemann, P. and von Wilcke, K. (Eds.). *Knowledge in motion: Perspectives of artistic and scientific research in dance* (p.73-80). London: Transaction Publishers.

Buller, H. (2008). The lively process of interdisciplinarity. *Area*, *41*(4), 395-403.

Butler, J. (1990). *Gender Trouble: Feminism and the Subversion of Identity.* Oxon: Routledge.

Callard, F., and Fitzgerald, D. (2015). *Rethinking Interdisciplinarity across the Social Sciences and Neurosciences*. London: Palgrave Macmillan.

Campkin, B., and Cox, R. (Eds.) (2012). *Dirt: New geographies of cleanliness and contamination*. London: IB Tauris.

Casewell, M., and Phillips, I. (1977). Hands as route of transmission for Klebsiella species. *BMJ*, *2(*6098), 1315-1317.

Catts, O., and Zurr, I. (2006). The tissue culture and art project: The semi-living as agents of irony. In Broadhurst, S., and Mchon, J. (Eds.) *Performance and Technology* (p153-168). London. Palgrave Macmillan.

Cliff, A., Smallman-Raynor, M., Haggett, P., Stroup, D. and Thacker, S. (2009). *Emergence and re-emergence. Infectious diseases: a geographical analysis*. Oxford: Oxford University Press.

Costelloe, C., Metcalfe, C., Lovering, A., Mant, D. and Hay, A. (2010). Effect of antibiotic prescribing in primary care on antimicrobial resistance in individual patients: systematic review and meta-analysis. *BMJ*, *340*, 1-11.

Courtenay, M. (1998). The teaching, learning and use of infection control knowledge in nursing. *NT Research*, *3*(2), 118-130.

Crang, P. (1997). Picturing practices: research through the tourist gaze. *Progress in Human Geography,* 21(3), 359-373.

d'Alessandro, E. (2015). Human activities and microbial geographies. An anthropological approach to the risk of infections in West African hospitals. *Social Science and Medicine,* 136, 64-72.

Davies, S. (2017). *Antimicrobial resistance: a cause for collaboration*. Available at: [www.gatescambridge.org/news/antimicrobial-resistance-cause-collaboration](https://www.gatescambridge.org/news/antimicrobial-resistance-cause-collaboration). (Accessed 4th May 2018).

DeSilvey, C. (2007). Art and archive: memory-work on a Montana homestead. *Journal of Historical Geography*, *33*(4), 878-900.

Dixon, D. (2009). Creating the semi-living: on politics, aesthetics and the more‐than‐human. *Transactions of the Institute of British Geographers*, *34*(4), 411-425.

Dixon, D., and Jones, J. (2015). The tactile topologies of Contagion. *Transactions of the Institute of British Geographers,* 40(2), 223-234.

Dixon, D., and Straughan, E. (2010). Geographies of touch/touched by geography. *Geography Compass,* 4(5), 449-459.

Douglas, M. (1966). *Purity and danger: An analysis of concepts of pollution and taboo*. London: Routledge and Kegal Paul.

Ducey, A. (2010). Technologies of caring labour from objects to affect. In Borris, E. (Ed.). Intimate labors: Cultures, technologies, and the politics of care (p18-32). Stanford: Stanford University Press.

Edensor, T. (2012). Illuminated atmospheres: anticipating and reproducing the flow of affective experience in Blackpool. *Environment and Planning D: Society and Space*, *30*, 1103-1122.

EPSRC. (2014). *Bridging the Gaps between the Engineering and Physical Sciences and Antimicrobial Resistance*. Available at: [www.epsrc.ac.uk/files/funding/calls/2014/btgamrcall/](https://www.epsrc.ac.uk/files/funding/calls/2014/btgamrcall/). (Accessed 12th February 2018).

Fisher, M. (2013). *Microbial Me*. Available at: [www.mellissafisher.com/microbial-me](http://www.mellissafisher.com/microbial-me). (Accessed 8th February 2018).

Fisher M. (2017). *Current Work*. Available at: [www.mellissafisher.com/current-work-1](http://www.mellissafisher.com/current-work-1). (Accessed 8th February 2018).

Ginn, F. (2014). Sticky lives: slugs, detachment and more‐than‐human ethics in the garden. *Transactions of the Institute of British Geographers,* 39(4), 532-544.

Ginn, F., Beisel, U., and Barua, M. (2014). Flourishing with awkward creatures: Togetherness, vulnerability, killing. *Environmental Humanities,* 4(1), 113-123.

Gould, D. (1991). Nurses' hands as vectors of hospital‐acquired infection: a review. *Journal of Advanced Nursing*, *16*(10), 1216-1225.

Guthman, J., and Mansfield, B. (2013). The implications of environmental epigenetics: A new direction for geographic inquiry on health, space, and nature-society relations. *Progress in Human Geography,* 37(4), 486-504.

Haraway, D. (2003). *The Companion Species Manifesto: Dogs, people, and significant otherness*. Chicago: Prickly Paradigm Press.

Haraway, D. (2008). *When species meet.* Minneapolis: University of Minnesota Press.

Haraway, D. (2016). *Staying with the Trouble: Making Kin in the Chthulucene*. Durham: Duke University Press.

Hawkins, H. (2013). *For Creative Geographies: Geography, Visual Arts and the Making of Worlds.* New York: Routledge.

Henderson, A. (2001). Emotional labor and nursing: an under‐appreciated aspect of caring work. *Nursing Inquiry,* *8*(2), 130-138.

Hird, M. (2009). *The origins of sociable life: Evolution after science studies*. Basingstoke: Palgrave Macmillan.

Hird, M. (2010). Meeting with the microcosmos. *Environment and Planning D: Society and Space,* *28*(1), 36-39.

Hinchliffe, S. (2015). More than one world, more than one health: Re-configuring interspecies health. *Social Science & Medicine,* *129*, 28-35.

Hinchliffe, S., Bingham, N., Allen, J., and Carter, S. (2016). *Pathological Lives: Disease, Space and Biopolitics*. Chichester: John Wiley & Sons.

Hochschild, A. R. (1983). *The Managed Heart: Commercialization of Human Feeling*. Berkeley: University of California Press.

Hodgetts, T., and Lorimer, J. (2015). Methodologies for animals’ geographies: cultures, communication and genomics. *Cultural Geographies*, *22*(2), 285-295.

Holmes, D., and Gastaldo, D. (2004). Rhizomatic thought in nursing: an alternative path for the development of the discipline. *Nursing Philosophy*, *5*(3), 258-267.

Holmes, D., Gastaldo, D., and Perron, A. (2007). Paranoid investments in nursing: a schizoanalysis of the evidence‐based discourse. *Nursing Philosophy*, *8*(2), 85-91.

Ingram, M. (2011). Fermentation, rot, and other human-microbial performances. In Goldman M. Nadasdy, P. and Turner, M. (Eds.). *Knowing Nature: Conversations at the Intersection of Political Ecology and Science Studies* (p99-112). Chicago: University of Chicago Press.

Jerram, L. (2018). *Glass Microbiology*. Available at: [www.lukejerram.com/glass/about](http://www.lukejerram.com/glass/about). (Accessed 11th May 2018).

Kelsall N., Griggs, R., Bowker, K., and Bannister, G. (2006). Should finger rings be removed prior to scrubbing for theatre? *Journal of Hospital Infection* *62*(4) 450-452.

Kirksey, S., and Helmreich, S. (2010). The emergence of multispecies ethnography. *Cultural Anthropology*, *25*(4), 545-576.

Lapum, J. (2008). The performative manifestation of a research identity: Storying the journey through poetry. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, *9*(2), 1-33.

Lapum, J., Fredericks, S., Beanlands, H., McCay, E., Schwind, J., and Romaniuk, D. (2012). A cyborg ontology in health care: traversing into the liminal space between technology and person‐centred practice. *Nursing Philosophy*, *13*(4), 276-288.

Law, J. (2004). *After method: Mess in social science research*. London: Routledge.

Lehotsky, Á., Szilágyi, L., Ferenci, T., Kovács, L., Pethes, R., Wéber, G., and Haidegger, T. (2015). Quantitative impact of direct, personal feedback on hand hygiene technique. *Journal of Hospital Infection*, *91*(1), 81-84.

Liaschenko, J. (2001). Nursing work, housekeeping issues, and the moral geography of home care. In Weisstub, D., Gauthier, S., Thomasma, D. and Tomossy, G. (Eds.) *Aging: Caring for our elders* (p123-137). Dordrecht: Springer.

Longhurst, R. (2001). *Bodies: Exploring Fluid Boundaries*. London: Routledge.

Lorimer, J. (2007). Nonhuman charisma. *Environment and Planning D: Society and Space,* 25, 911-932.

Lorimer, J. (2017). Parasites, ghosts and mutalists: a relational geography of microbes for global health.  *Transactions of the Institute of British Geographers*, *42*(4), 544-558.

Lorimer, J., and Hodgetts, T. (2017). Good germs, bad germs, citizen science and microbiology. *The Biochemist: Magazine of the Biochemical Society,* 39(3), 35-37.

Macdonald, A., and MacDuff, C. (2018). *HAIVAIRN: Report on the HAIVAIRN (Healthcare Associated Infection Visualisation and Ideation Research Network) network grant funded by the Arts and Humanities Research Council.* Available at: [radar.gsa.ac.uk/5642/1/HAIVAIRN\_Final\_online.pdf](http://radar.gsa.ac.uk/5642/1/HAIVAIRN_Final_online.pdf). (Accessed 3rd May 2018).

Macdonald A.S., Macduff C., Loudon D., and Wan, S. (2017) Evaluation of a visual tool co-developed for training hospital staff on the prevention and control of the spread of healthcare associated infections.  *Infection, disease & health.*  22.3 105-116

Macduff, C., Wood, F., Hackett, C., McGhee, J., Loudon, D., Macdonald, A., Dancer, S., and Karcher, A. (2014). Visualizing the invisible: applying an arts-based methodology to explore how healthcare workers and patient representatives envisage pathogens in the context of healthcare associated infections. *Arts & Health,* 6(2), 117-131.

Mapping Microbes. (2016). *Mapping Microbes: Preventing the spread of infection in hospital care settings: Health professionals, the agency of microbes and image tracking technology.* Available at: [mappingmicrobes.wordpress.com/](https://mappingmicrobes.wordpress.com/). (Accessed 13th February 2018).

Marples, R., and Towers, A. (1979). A laboratory model for the investigation of contact transfer of micro-organisms. *Epidemiology & Infection*, *82*(2), 237-248.

McCormack, D. (2013). *Refrains for moving bodies: Experience and experiment in affective spaces*. London: Duke University Press.

Moody, J., Cosgrove, S., Olmsted, R., Septimus, E., Aureden, K., Oriola, S., Patel, G., and Trivedi, K. (2012). Antimicrobial stewardship: a collaborative partnership between infection preventionists and healthcare epidemiologists. *Infection Control & Hospital Epidemiology*, *33*(4), 328-330.

MRC. (2018). *Tackling AMR - A Cross Council Initiative*. Available at [mrc.ukri.org/research/initiatives/antimicrobial-resistance/tackling-amr-a-cross-council-initiative/](https://mrc.ukri.org/research/initiatives/antimicrobial-resistance/tackling-amr-a-cross-council-initiative/). (Accesseed 25th April 2018).

Mukherjee, R. (2016). Toxic Lunch in Bhopal and Chemical Publics. *Science, Technology, & Human Values,* 41(5), 849-875.

O'Gorman, R., and Werry, M. (2012). On failure (on pedagogy): Editorial introduction. *Performance Research*, 17, 1-8.

Osborne N., and Smith, I. (2014) *Meet the microbes* ebook. [www.meetthemicrobes.co.uk](http://www.meetthemicrobes.co.uk). (Accessed 11th May 2018).

O’Neill, J. (2015). *UK Review on Antimicrobial Resistance. Securing New Drugs for Future Generations–the Pipeline of Antibiotics*, May 2015.

Patterson, E. (1998). The philosophy and physics of holistic health care: spiritual healing as a workable interpretation. *Journal of advanced nursing*, *27*(2), 287-293.

Paterson, M., and Dodge, M. (Eds.) (2012). *Touching space, placing touch*. Aldershot: Ashgate.

Pittet, D., Hugonnet, S., Harbarth, S., Mourouga, P., Sauvan, V., Touveneau, S., and Perneger, T. (2000). Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *The Lancet*, *356*(9238), 1307-1312.

Prieto, J. (2016). Guest editorial. *Journal of Research in Medicine,* *21*(1), 5-7.

Randle, J., Metcalfe, J., Webb, H., Luckett, J.., Nerlich, B., Vaughan, N., Segal, J., and Hardie, K. (2013). Impact of an educational intervention upon the hand hygiene compliance of children. *Journal of Hospital Infection*, *85*(3), 220-225.

Roe, E., and Buser, M. (2016). Becoming ecological citizens: connecting people through performance art, food matter and practices. *Cultural Geographies,* *23*(4), 581-598.

Roe, E., and Greenhough, B. (2006). Towards a geography of bodily technologies. *Environment and Planning A*, *38*(3), 416-422.

Roe, E., and Greenhough, B. (2014). Experimental partnering: interpreting improvisatory habits in the research field. *International Journal of Social Research Methodology,* *17*(1), 45-57.

Rolfe, C. (2014). A conceptual outline of contemporary magic practice. *Environment and Planning A,* 46, 1601-1619.

Salazar, J. (2017). Microbial Geographies at the Extremes of Life. *Environmental Humanities*, *9*(2), 398-417.

Sandelwoski, M. (1999). Troubling distinctions: a semiotics of the nursing/technology relationship. *Nursing Enquiry*, *6*, 198-207.

Sandelowski, M. (2002). Visible humans, vanishing bodies, and virtual nursing: Complications of life, presence, place, and identity. *Advances in Nursing Science*, *24*(3), 58-70,

Soffer, A. (2016). Situating beyond the social: understanding the role of materiality in Danish nursing education. *Advances in Health Sciences Education*, *21*, 819-832.

Snow, M., White, G., and Kim, H. (2008). Inexpensive and time efficient hand hygiene interventions increase elementary school children's hand hygiene rates. *The Journal of School Health*, *78*(4), 230-234.

Sontag, S. (1977). *On Photography*. New York: Farrar, Straus, and Giroux.

Thrift, N. (2008). *Non-representational theory: Space, politics, affect*. London: Routledge.

Turp, J. and Hurley, P. (2017). *In Our Hands with Michael Rosen*. Available at: [www.youtube.com/watch?v=W7xnaXSJab0&t=1s](https://www.youtube.com/watch?v=W7xnaXSJab0&t=1s). (Accessed 13th February 2018).

Vanyolos, E., Peto, K., Viszlai, A., Miko, I., Furka, I., Nemeth, N., and Orosi, P. (2015). Usage of ultraviolet test method for monitoring the efficacy of surgical hand rub technique among medical students. *Journal of Surgical Education*, *72*(3), 530-535.

Veal, C. (2016). A choreographic notebook: methodological developments in qualitative geographical research. *Cultural Geographies,* *23*(2), 221-245.

Veal, C. and Hawkins, H. (forthcoming). Creativity as method: Doing creativity Geographies, exploring challenges, fulfilling promises? In Kong, L. and de Dois, A. (Eds.) *Geographies of Creativity*. Elgar.

Watnick, P., and Kolter, R. (2000). Biofilm, city of microbes. *Journal of Bacteriology,* 182(10), 2675-2679.

Wellcome Trust. (2018). *The Arts*. Available at: [wellcome.ac.uk/what-we-do/our-work/arts](https://wellcome.ac.uk/what-we-do/our-work/arts). (Accessed 11th May 2018).

Whatmore, S. (2006). Materialist returns: practising cultural geographies in and for a more-than-human world. *Cultural Geographies*, *13*(4), 600-610.

Whitby, M., Pessoa-Silva, C., McLaws, M., Allegranzi, B., Sax, H., Larson, E., Seto, W., Donaldson, L., and Pittet, D. (2007). Behavioural considerations for hand hygiene practices: the basic building blocks. *Journal of Hospital Infection*, *65*(1), 1-8.

Witt, S., and Spencer, H. (2004). Using educational interventions to improve the handwashing habits of Preschool Children. *Early Child Development and Care*, *174*(5), 461-471.

WHO. (2009). *WHO Guidelines on Hand Hygiene in Health Care: First Global Patient Safety Challenge Clean Care is Safer Care*. Available at: [apps.who.int/iris/bitstream/10665/44102/1/9789241597906\_eng.pdf](http://apps.who.int/iris/bitstream/10665/44102/1/9789241597906_eng.pdf). (Accessed 29th January 2018).

Wiles, L., Roberts, C., and Schmidt, K. (2015). Keep it clean: a visual approach to reinforce hand hygiene compliance in the emergency department. *Journal of Emergency Nursing*, *41*(2), 119-124.

1. It is not possible to see the UV powder/gel traces in Films 1, 2 and 3 because they were filmed under normal room-lighting, not ultra-violet light. [↑](#footnote-ref-1)
2. Two statements about the pattern of spread of pseudo-pathogens are given in this film. However detailed discussion of the methodology and findings of the patterns of spread of pseudo-pathogens are beyond the scope of this paper. However briefly, the quantitative measure of “200 touches in 4 minutes during a bed change” that feature in Video 4: In Our Hands film is based on an extension of the original project to experiment with quantifying touch using novel software capabilities of MAX MSP with a touch-screen interface (engineered by Matthew Olden of The Mighty Jungulator) to analyse the filmed-record of the clinical tasks. The quantitative statement ‘Routine hand-hygiene reduced cross-contamination by upto 100%’ is a statement that uses the non-medo-scientific language of the nurses who witnessed with their naked-eyes the reduction in cross-contamination. This lay-reading of ‘up to 100%’ was supported by photos taken under UV lighting when hand-hygiene was used (n=20) and when hand-hygiene was not used (n= 25). No microbiological testing was carried out. [↑](#footnote-ref-2)