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Title: Pathways and prospects in cancer research: Securing futures and negotiating boundaries.

Abstract This paper draws on literature from the *sociology of expectations* to explore accounts of experts in cancer research and clinical practice. The cancer specialists' accounts presented in this article are taken from interviews undertaken as part of a project that aimed to develop a research agenda for the next ten to thirty years that will achieve early detection and prevention in the four main cancers: (i) bowel and colorectal, (ii) prostate, (iii) lung and (iv) breast. Drawing on secondary analysis of the interviews, this article provides a sociological exploration of both the experts' versions of the future and the interactions between the interviewer and research participant to show expectation *in the making*: the competing stories of what *is* and what *ought* to be the focus of cancer research now and in the (near) future. The building of a cancer research agenda is shown to be a contested future, represented by a *dominant* and *resistant* view of the cancer problem, in which cancer specialists must engage in performative strategies and boundary work to frame the present problem: what cancer is and how it can be detected and, subsequently, to claim credibility for a future pathway.

Keywords: Futures, sociology of expectations, cancer research, constitution of knowledge, boundary work

Introduction

In recent years, a growing number of scholars have pointed out the significance of expectations in science and technology innovation (Brown and Michael, 2003; Borup *et al.*, 2006; Brown *et al.*, 2000; Horst, 2007; Martin, 2015). To this end, contemporary biomedical science could be conceived as more of a future-oriented activity than a present one. Indeed, high expectations of a field of research or specialism are often required to mobilise scientists and resources in the first place, helping to bring together various experts to work towards a common goal (Brown and Michael, 2003; Fujimura, 1987). Further, science is conducted under regimes of speculation. Of course, science is no single thing in this regard (Gieryn, 1999), it is made up of different epistemic cultures (Knorr-Cetina, 1999), styles of reasoning (Hacking, 1992) and communities of practice (see Lave and Wenger, 1991). Thus certain research areas are intrinsically tied to particular expectations and imaginations. Biomedical research, for example, is conceived of differently to some other scientific endeavours (for example, theoretical physics) bringing with it particular promises and prospects of its future applications and implications (Morrison, 2012; Lewis and Bartlett, 2015). Biomedical science operates as a locale for individual and collective hopes centring on health. In attempting to realise these hopes, they take on political and economic materiality (Novas, 2006). Therefore, the future is itself a resource in biomedical science, often called upon when shaping and justifying present scientific activity: for example basic research into stem cell and genomic research is *expected* to lead to clinical interventions (see Charlton and Andras, 2005).

Brown and Michael (2003) argue that futures are enrolled as resources in the present and play a central role in the reception, up-take and legitimization of scientific and, ever more importantly, technological innovations. This work details the social effects of expectations, highlighting how representations of the future mobilise resources (economic, material and symbolic), stabilise fields attempting to secure coherence and reduce uncertainties (Borup *et al.*, 2006; Van Lente, 1993). It also considers the significance of expectations in scripting futures into current scientific practice (Akrich, 1992), and of building trajectories and infrastructures for prospective developments (Brown and Michael, 2003; Arribas-Ayllon *et al.* 2010; Hedgecoe and Martin, 2003). This article empirically grounds the sociology of expectations by reflecting upon a rare set of data which shows expectations *in-the-making* in the field of cancer research. Cancer research itself covers a multiplicity of scientific and clinical practices from biological, laboratory-based research to intervention studies and clinical trials (Keating and Cambrosio, 2013; Goldstein *et al.*, 2012). However, there is increasing investment in base biology (Morange, 2008) as a potential path to early detection and prevention (Goldstein *et al.*, 2012); a phenomenon being replicated across the biomedical sciences (Armstrong, 2009).

The analysis in this paper highlights the mechanisms, performances and strategies (Michael, 2000; Martin, 2015) of United Kingdom (UK) cancer research experts to embed and secure particular readings of the future, and the implications of expectation discourses for providing legitimacy to future destinations. The analysis also builds on the work of Gieryn (1983; 1999) to make connections between the

concept of boundary work and the sociology of expectations. Cancer futures are imagined, mobilised and enacted differently by various kinds of experts. In laying claim to a particular future, experts simultaneously keep out competing claims and trajectories. As the accounts of cancer experts illustrate, the concept of the future presents significant analytical difficulties when attempts are made to separate out the many versions of the future at play. Building and sustaining future expectations in scientific work requires actors to make claims to authority and resources over and above the claims of alternative experts; it necessitates boundary work (Gieryn, 1983; 1999).

Research context

The article is predicated on secondary analysis of a project undertaken by a university-based interdisciplinary collaborative team, funded by the UK Medical Research Council (MRC) and Engineering and Physical Sciences Council (EPSRC). This original project team consisted of clinical researchers, as well as informaticians and engineers with experience of working with clinical information as a resource for health improvement and the development of medical technologies. The study sought to set out a research agenda for the next ten to thirty years that would best improve the early detection and prevention of the four common cancers: (i) bowel and colorectal, (ii) prostate, (iii) lung and (iv) breast cancer. The aims of this research agenda were twofold: to improve technologies and information systems for risk prediction; and to identify the most effective clinical measures and indicators for predicting the risks of developing disease or deterioration in disease.

As a central tenet of the study, experts were interviewed in order to establish the 'state of the art' for early detection, but also to garner specialist opinion to inform a future agenda for the next ten to thirty years in cancer research. The study team envisaged the project as an opportunity for experts to be forward-thinking and to set out their ideals for the future. Experts were encouraged to provide a view of the future that was borderless, unrestricted by cost, technical capability or organisational structures:

"We are not doing the research, we are setting the agenda for research for the next ten to thirty years, so we really, really need innovative thinking and imaginary thinking. We are not restricted by the obstacles we have now." **(The interviewer during an Interview with a professor of oncology)**

However, how far experts were asked to speculate into the future was not borderless and was shaped by the broader research context of the time. The kinds of cancer research being funded during the period between 2007 and 2009 were predominantly concerned with the development of risk factors and/or biological markers to better predict and prevent disease. This approach reflected two dominant aspects of biomedical research: first, a public health approach to prioritise the identification of 'at risk' groups within the wider population (Armstrong, 2009) and second, a longer standing paradigm shift towards the 'basic to applied' model maintaining that basic (molecular-biology) research leads to clinical breakthroughs (Charlton and Andras, 2005). As a result of this paradigm shift, translation has

become an increasingly important but troublesome concept for biomedical science. Research has shown the movement of scientific discoveries from bench to bedside is socially complex and one that resembles a circuit (Lewis *et al.* 2014) or a tangled web rather than a deductive chain from bench to bedside (Keating and Cambrosio 2014). This is especially true of cancer research. Nelson *et al.*'s (2014) work illustrates how the increasingly 'bio-marker-driven' nature of clinical trials is taking on the form of experimental science, producing novel biological or clinical insights. This complexity is compounded by limited research evidence to inform the utility and effectiveness of practical applications (Khoury *et al.*, 2007) of scientific discovery and by the resulting distortion of both the science itself and the ethical practice of scientific research that can be produced by an emphasis on translation. (Maienschein *et al.*, 2007). Multiple meanings are also ascribed to translation from scientists and clinicians alike (Mittra, 2013) stressing the competing values, understandings and interests of different experts. The complexities surrounding translation necessitate boundary work from experts to assert the value of specific kinds of knowledge, particularly when setting out what constitutes future success in the field of cancer research.

The project's future orientation was also indicative of the organisational form of research gaining momentum in the field of cancer research at the time. Most studies took on the appearance of 'big science' (Galison and Hevly, 1992; Hilgartner 2013) or population studies where large data sets were collated and analysed, exploring the molecular-biological characteristics of disease and its progression with the aim of trying to predict risk (see for example, The Genetic Lung Cancer

Predisposition Study; the Molecular Epidemiology study [GELCAPS]; the identification of Men with a Genetic Predisposition to Prostate Cancer [IMPACT]; the Collaborative Oncological Gene-environment Study [COGs]).

Secondary analysis: A sociological perspective

This is an especially rare data set. Unlike most interview-based research conducted by social scientists, the interviewer in this case is a 'native' entrenched in the field of clinical research and cancer informatics with a single agenda: to determine what the future of cancer research might look like. The participants are also aware that the interviewer (and the project team) will utilise their and other experts' accounts to make recommendations to funders regarding what the research agenda should be, how it should be carried out, and who should undertake the work. These transcripts are therefore manifestos for their discipline's claim to the future of cancer, unmitigated by the usual conventions of research interviews with scientists. The material explored in this article therefore offers a view, not only into the possible futures being enacted in specialists' accounts, but also into how aspects of performativity (Brown et al 2000) manifest in a competitive context, in which experts are engaged in staking their claim to the future of cancer research.

The group of experts interviewed represent the 'core set' (those actively engaged in experimentation and theorisation [Collins, 1999]) in the field) in UK cancer research. The original project team, themselves knowledgeable and experienced in aspects of cancer research, identified this group of experts as the central protagonists with

international influence, who would have significant insight into both the current 'state of art' in cancer research, but also into its future projection. Out of the thirty originally interviewed, ten agreed to a secondary analysis of their interview. This subset was both representative of the original experts consulted by the horizon-scanning team and of the key fields of expertise shaping cancer research, which at this time included geneticists, histopathologists, informaticians and oncologists. Our analysis and interpretations also extend beyond that of the ten transcribed interviews. The original project itself is an exercise in future building and the interplay between the cancer experts, the interviewer and the project team is sociologically significant in understanding the building of expectations in cancer research. Furthermore, the article draws on the ethnographic engagement of the author, herself a member of the project team in the entire study, including being present during all interviews, contributing to the synthesising of all generated material and being heavily involved in the activities of report writing, networking activities and the building of collaborations to set out a future agenda. Author One is therefore fully aware of the original research context and is able to safeguard against any distancing between the analysis and the data (Cicourel, 1982).

Importantly, the secondary analysis draws out the processes and negotiations involved in accomplishing what is the current knowledge in cancer research and what should be the focus for the future. It is interested in how these are maintained or challenged across the disciplinary fields of the interviewer and expert participants. The analysis pays particular attention to moments of *consensus* and *contention* to show the accomplishment of future projection in action. Attention is paid to both

what is said by both interviewer and interviewee and how it is said in order to explicate knowledge-producing activities in language (McCarthy, 1990; Lynch, 1993). This is not, however, an exercise in critical discourse analysis (Fairclough, 2013) of ‘naturally occurring talk’ (Potter, 1997). Instead, by examining the content and form of the futures represented by the cancer experts, the interviews highlight how expectations produce distinct accounts of cancer that afford specific future pathways. The task for the project team undertaking the research was therefore not only to establish an agenda for future research, but to choose which particular future they wished to collaborate in/on. As part of this, they attempted to establish a consensus; a dominant view of cancer amongst the core set that might promote a particular future research agenda. Such work would stabilise and define ‘the cancer problem’ and the field of future cancer research.

Constituting cancer

The purpose of the original project team was to establish a consensus over future expectations in cancer research. A significant component of constructing these futures involved the practice of demarcation in the constitution of cancer itself. To highlight the contested nature of cancer as a disease entity, the experts’ extracts have been organised into two competing views: the *dominant* view and the *resistant* view. The team’s starting premise, prior to interviewing the cancer experts, was that the future of cancer research would focus on pre-symptomatic people at risk of developing cancer. This *dominant* view presents cancer as a continuum, a developing entity in which there is the potential for intervention; a view that

promotes early detection, risk prediction, screening and prevention. This perspective was represented in the interviewer's own contributions, it reflected the interests of members of the project team and was shared by many of the experts interviewed as the most forward thinking aspect of cancer research happening at the time. The dominance of this constitution of cancer amongst the experts and the project team is perhaps unsurprising, given the significant investment in large-scale prospective studies being conducted in cancer research at the time, of which many of the specialists interviewed would have direct involvement.

The interviewing team were also met by a distinct and competing *resistant view*. This outlook constituted cancer not in terms of pre-symptomatic risk, but on the basis of a tumour's aggressiveness and ability to progress and invade once present. Such a perspective has been termed *resistant* because it was held by only a minority of the experts interviewed and was not identified by the project team. It also speaks against the growing tide of research development in risk prediction and prevention. Expectations discourse are shown, in both the *dominant* and the *resistant* view, to constitute cancer (i) spatially, according to an actor's proximity to the coalface of research and clinical practice, (ii) materially, by the physical tools, techniques and practices that make up an actor's work and (iii) cartographically¹, by the actors' different disciplinary hinterlands (experts bring with them quite different backgrounds with different interests, ambitions, and perspectives see Lewis & Bartlett, 2013), and epistemic cultures. Furthermore, these representations of cancer as an entity, and the futures they promote, are shown to mobilise material, symbolic and economic resources. We begin with the *resistant view*:

Pussycats and tigers: The resistant view

In the resistant view account, it is the aggressiveness of the tumour that becomes the cancer of concern, not the pre-symptomatic one.

I: **“What I understood from you now is, someone may suffer prostate cancer for years and years and years and this is silent, this is quiet, more or less this man is living a usual or a normal lifestyle, but there is some point where there is a deterioration and this deterioration is something we really need to detect. Am I right in my understanding?”**

R: “Yes, you might be right. So in other words, if you think about the analogy with prostate cancer, [it] is the tiger and the pussycat and we say most prostate cancers are pussycats you know, they’re harmless, lovable little things, [but] some of them are tigers. It’s the tigers that kill people. Now the question that you’re asking is, are they tigers right from the very beginning, is it once a tiger always a tiger, once a pussycat always a pussycat or do pussycats sometimes grow up into tigers.”

I: **“Yes.”**

R: “And we don’t know the answer to that....So, the urgent need in prostate cancer is not so much just to detect it early, because in a sense that’s already starting to happen, but it’s to detect the ones that really matter and to differentiate the ones that really matter from the ones that don’t matter.” **(Professor of Oncology & Palliative Care, Specialist in Prostate Cancer)**

Although representative of the *resistant view* amongst the core set of cancer research experts, the analogy of the pussycat and the tiger is well established in pockets of cancer research and practice, particularly in prostate cancer (Mason,

2009; Kazimierczak and Skea, 2015). Here, cancer is constituted, in the first instance, according to the area of the body it affects, in this case the prostate, and subsequently as being of two breeds of the same cat family: (i) tigers, which need to be tamed as they are aggressive and can kill, and (ii) pussycats that are already tamed – and act as harmless companions. The question that follows is how do we deal with the tigers, and can some of the pussycats become feral. If they can, how can we detect the signs? The risk therefore derives not from the possibility of developing a growth or tumour, but the progression of a particularly aggressive type of tumour that does significant harm to the part of the body it invades. It is less about whether one might develop cancer and more about whether one might develop a particular breed².

The interviewer and the experts' approaches to understanding the problem of cancer and its possible future solutions are bound by their disciplinary hinterlands. The interviewer's approach is predicated upon an interest in identifying risk factors that are amenable to collation and interpretation through information systems and, at best, may form the building blocks of an algorithm to predict an individual's risk (explored in more depth in the next section). Such aims reflect the engineering foundation of the field of informatics that values quantifiable measures to inform workable solutions³. The expert's account, on the other hand, is based on the materiality of practicing oncology, the variability of presenting tumours, and the necessarily pragmatic nature of decision making over the future treatment path of cancer patients. This constitution of cancer reflects the expert's closeness to practicing oncology.

Contextual differences, even within disciplines help in accounting for an expert's alignment with either the *dominant* or the *resistant* view. Experts within the same discipline but working with different materials and in different contexts - a research geneticist as opposed to a clinical geneticist for example – can have quite different points of view on the cancer problem. As Haraway (1991) maintains, knowledge of a phenomenon is affected by how and where you look, which in turn is influenced by where you come from. Indeed some specialisms are defined by the tools that structure their work such as bioinformatics, proteomics or x-ray crystallography (see Lewis and Bartlett, 2013; Law, 1973). These materials vary greatly even within seemingly closely related fields:

“When you’re thinking about how you can predict if one person’s cancer is hereditary or sporadic, you know, a non-genetic type, this is our job because when you look down the microscope, when you look on a mammogram there is no difference as we understand things now. So it’s very difficult to say for certain, you know if someone had then got a triple negative breast cancer, you can’t say ‘oh yours must be genetic’. The best tool at the moment, of working out how likely it is that someone’s cancer is genetic, is looking at the family tree.” **(Senior training consultant in clinical genetics, clinical researcher in cancer genetics)**

The family tree was described by this clinical geneticist as the most utilised form of genetic assessment, and many respondents suggested that this would remain the case in the near future. Such an account also aligns itself to the resistant view, suggesting that genetic risk, in the clinic at least, relies on observable occurrences of

cancer in a family. Genetic lab-research relies on quite different tools to those used in clinical work, requiring sophisticated computer systems for sequencing and testing of genetic material, often across large numbers of research subjects. Boundary work therefore does not only demarcate credibility cartographically between disciplines and specialisms but also materially. These technological differences in instrumentation are significant because they frame the cancer problem differently according to specific spatial and temporal horizons. The conceptual constitution of genetic cancer, in its transition from the laboratory to the clinic, shifts considerably and in different ways that help to align experts to the dominant or resistant view. It shifts (i) temporally because in the laboratory future cancers are determined according to *present* signifiers, whereas in the clinic they are determined according to *past* events; (ii) by its subject (Michael, 2000) because in the laboratory, future cancers are associated with populations whereas in the clinic it is individuals and families who are at risk; and (iii) materially because future cancers in the laboratory are identified through DNA testing and analytical and biotechnological tools, whereas in the clinic future cancers are identified through patient histories and associated tools, such as the family tree.

Similarly, in the next extract, cancer is constituted as the interaction of tumour behaviour with wider biological processes, which is indicative of the biological materials and practices of tissue banking that make up this specialist's daily practices. These practices inform the experts de-bunking of the utility, validity and purpose of identifying those 'at risk' and re-asserts the resistant view.

I: **“We are talking about setting the agenda for research for the next ten, fifteen years. We are definitely not talking about a lady with a lump on her breast, presents it to her doctor and the doctor actually takes a biopsy...”**

R: “Except, that’s probably the best way to go 'cause a lot of this, sort of trying to identify who is going to get... the trouble is you don't know who is going to progress, and we're probably actually over treating a lot of patients who do not need to be treated 'cause their lesion is just going to sit there, it's not going to grow any further and will regress...”

I: **“For a lady who's not actually aware that there is a lump in her breast or that there's something in her breast, how can we pick up those? I'm thinking about the non-affected population?”**

R: “I think you've got to be careful how you spend your money. You could spend a lot of time helping nobody with a lot of this research. It's the same with the genetic research...You're not going to have a test like that ever, that is going to work, that tells you that patient will get a certain type of cancer, simply because we don't know – there's modifiers out there, that certainly reduce your risk as well as increase your risk, and we don't know anything about those at all. There are genes that you inherit that stop you getting cancer, and there're very difficult to find in the current way we're looking at science, and that's one of things we've not addressed. I think it's something like one in seven women have a breast cancer gene that increases their risk, but not everybody gets breast cancer. So something is wrong somewhere. We're missing part of the equation.”

The interviewer begins by stating: *‘we are definitely not talking about’* those who are already symptomatic. In order to attempt to move the interviewer away from this particular construction of the cancer problem, the interviewee employs a number of performative strategies. Firstly, they draw

upon the uncertainty of current knowledge regarding genetic risk in cancer. Uncertainty can both sweeten a bitter prospect or make a sweet prospect bitter (Michael, 2000), engendering hope on the one hand and confirming limitations on the other (Moreira and Palladino, 2005). In this case, the director of a cancer bank makes the sweet prospect - that of genetic risk profiling - bitter, by confirming its limitations and questioning to what end the research is conducted. The present and future uncertainty of cancer risk is made a symptom of the 'current way we're looking at science' and therefore provides a mechanism through which the boundaries of credibility for epistemic authority (Gieryn, 1999) on cancer are redrawn. This boundary work is significant for the building of expectations in this experts' account, as it shifts the locus of legitimacy away from the field of genetic risk and towards cellular change.

The conversation continues:

I: **"This is really what I'm looking for, because using the analogy of normal pre-cancerous..."**

R: "...But it isn't – it's not that simple. It's not that simple..."

I: **"...I know – I know it's not"**

R: "You have normal, you have something, I mean, remember the pathologist can only identify something when it's there, so it has to be something that is noticeably different, which means it must have had a growth spurt, so it's got to be growing faster than the cells. Now what happens next? That particular lump may have all the genes that enable it to invade quickly but it isn't going anywhere. It's not

growing any longer so it's stopped. It doesn't invade. You don't know what is pre-cancerous and what isn't because you never follow it." **(Director of Science Services of a large Cancer Bank, Specialist in Breast Cancer)**

Once the epistemic credibility over what cancer *is* is challenged, it is made subject to competing claims of expertise. The director, like the Professor of Oncology and Palliative Care, goes on to suggest that information about who is going to get cancer, even if its future prediction were feasible, is not as important as knowing which cancers are going to progress.

In challenging the constitution of cancer as a known evolving entity in which there is a possibility of intervention, the expert claims that the characteristics of those tumours which progress to invasive cancers and those that stop growing entirely are not yet known (known unknowns): the analogy of the pussycat and the tiger re-asserts itself. By doing this, the expert relegates the category 'pre-cancerous' to an ethereal assumption or a present unknown unknown rather than a measurable clinical sign/bio-marker. This makes the problem 'undo-able' and shifts the focus of attention for future research away from risk prediction and prevention, and towards the study of tumour progression over time. Maintaining that 'you have to be careful about how you spend your money. You could spend a lot of time helping nobody', the specialist places individual cancer sufferers as the subject of any potential future (see Michael, 2000). Part of the power for the *resistant view*, unlike the *dominant view*, is that the future subject is not a rational, cold, faceless collective but is, instead, made up of individual cancer patients, providing a greater potential for

empathy and significant moral resource through which to claim credibility over the future of cancer research.

Cancer continuum - population, risk & prediction: The dominant view

The constitution of cancer by the director of the Cancer bank, in which they state you can only identify something if an observable lump is present, was different to the kinds of research that were currently in fashion, as the interviewer remarks:

“This is actually a very new view of the future agenda, I have to say. Of all the people I've interviewed where breast cancer – they were looking more on the prevention, early detection – of average population, rather than just finding out which type of the disease is going to be aggressive.” **(Interviewer talking during an interview with the director of a cancer bank)**

Indeed, a central interest for the project team was to bring together epidemiological data about lifestyle and environment with genetic, epi-genetic and histopathological information to develop a more sophisticated system of risk prediction. The benefit of this technique, in theory, is that it would provide better indicators of risk. These indicators could provide the basis for screening, the facilitation of early diagnosis and, most significantly, a pathway to prevention by empowering people to change their lifestyle, reducing their risk by a quantifiable amount. This potential future for the field of cancer was echoed by a number of the experts themselves:

“I can see a day where you will go into your GP’s surgery and, like you have your blood pressure and cholesterol done now, you will have SNP profiling done. Then it will be a predicted marker, so basically we will enter an era I think of predictive medicine. I’ve no doubt at all it’s going to happen...people really do want to have cancer either diagnosed early or even better still, if you’re very high risk, be told, well if you take this type of preventative action, then it will lower your risk.” **(Professor of Oncogenetics, Institute of Cancer Research)**

The pre-occupation with risk is reflective of a cultural shift occurring in advanced liberal societies that constructs uncertain futures as somehow responsive to the actions of rational individuals (Groves, 2013), acting on the basis of population profiling. A significant consequence of these socio-cultural dimensions simultaneously shaping and being shaped by biomedical science is the way in which the future is increasingly constructed as a dimension of the present (Adam and Groves, 2007).

This expectation of the future therefore both constitutes and is constituted by a particular understanding of cancer itself, making up the *dominant view* amongst the cancer experts interviewed. Cancer as an object is understood as an evolving entity existing along a material and temporal continuum within which intervention is possible. The interviewer (in the previous conversation with the director of the cancer bank), draws on the analogy of a continuum from ‘normal to pre-cancerous to cancerous cells’, a well-established model in cancer research referred to as the stepwise model of cell transformation (Goldstein *et al.*, 2012). Such an understanding of cancer is necessary for a future in which individuals ‘at risk’ can be

identified at this 'pre-cancerous' stage. To draw on Fujimura's (1987) study of basic cancer research, this conception of the problem and its subsequent scientific project is compelling: there is a clear question and the techniques and technologies (bio-informatics and genetic profiling) required to answer it are in place. Moreover it is population-wide and not just focussed on individuals. The attack on the credibility of the risk hypothesis provided by the director of a cancer bank that attempted to represent the *dominant* view as an undoable project, is challenged here by the tools and information infrastructures that exist to support it.

The interviewer's interest in building a risk algorithm for the common cancers was pursued at various points in all the interviews and was shared, by many experts, as representing part of the *dominant view*. Below the director of a genetics institute and the interviewer discuss a more 'informed' system of risk prediction:

I: "Are you aware of any study that is trying to come up with any algorithm that is trying to combine them together?"

R: "Not on that kind of scale...but Biobank is the study... it's a resource that's being established specifically to enable genetic and exposure factors...so you know, environmental factors, population factors and so on...to be taken into account when looking at the causes of modern diseases. So it's exactly how people are thinking."

I: "This is the question I am keeping asking and have been looking for in the literature, if we say for instance these are the ten risk factors for breast cancer, if there is any sort of system to say if I have one, two and three, my risk is 50%, while if I have one, five and eight, I am only at the risk of 20%. What strikes me actually just to look at each individual risk factor and they assess it individually. So yes, I'm happy to give up for instance chocolate or alcohol, or whatever aspect

of my lifestyle that is unhealthy, but what's the price for that? Does this lower my risk by 10%, by 20%, by 80%?" (Director of Institute for Medical Genetics, Specialist in Lung Cancer)

The interviewer describes their own understanding of risk prediction. This type of prediction is reliant on better quality information, knowledge of clinical indicators that impart risk, better utilisation of information through standardised procedures for recording, and better mechanisms for mining data. Together, it is hoped, this will provide a more informed and balanced account of an individual's overall risk.

"If we are going to get into prevention, then there is a whole load of more information that we need because you need to know about the lifestyle of the patient, you need to know a lot of details about dietary information and if you are going to start to get into trying to lower the risk of, say, getting breast cancer, okay.. At the moment, it's all a bit...you know, genetics is all in one part and the general practitioners in another part...it's not integrated."

(Consultant Clinical Oncologist, Specialist in Breast Cancer)

The building of such an algorithm requires future commitment to the development of more integrated and powerful information systems and infrastructures in order to allow the *dominant view*, of cancer risk prediction and prevention, to unfold. This example highlights the ways in which present ways of thinking and doing in cancer research form the basis for future plans and prospects. Expectations, in this case, are built upon instrumental rather than utopian ideas of the future (Brown, 2000).

Moments of contention

Indicating the tremendous challenge facing the project team in their quest for consensus, it is important to highlight that resistances were also evident in interviews with experts expressing the *dominant view*. In this sense, the dominant and the resistant view are akin to Weber's ideal type (Bruun, 2012). In the next extract, a professor of cancer pathology describes their own interest in the identification of risk. However, it is quite different to the information-driven risk of interest to the interviewer and, subsequently, offers less opportunity for workable solutions:

R "That these lesions have both pre-cursor and risk status and people are getting more and more to the view that these are true pre-cursor lesions and I'd certainly have that view"

I: **"So, the typical hyperplasia patients. If now we are, I wouldn't say 100%, but we are more or less sure it is a pre-cancerous condition."**

R: "Yes."

I: **"So what sort of follow up observation and surveillance would we offer?"**

R: "Well... those patients would go into our follow up clinic, so that we would offer them yearly surveillance."

I: **"What, this is here?"**

R: "This is here, yes."

I: **"Is there anything on a national level?"**

R: "No. I've lobbied – the national policy is purely around genetic risk and I've argued through the College of Pathologists, to NICE that they should be looking at histological risks as well, but they haven't. I think that's wrong personally."

(Professor of Cancer Pathology, Specialist in Breast Cancer)

The materiality of the histological risk that the expert describes helps re-affirm the interviewer's analogy of cancer as an evolving entity with a pre-cancerous stage, amenable to intervention. The future, amongst the *dominant view*, is therefore concerned with future futures: a future in which the future is more malleable, controllable and preventable. Lowy (2007) describes the often neglected similarities of predictive tests grounded in the analysis of DNA sequences and those grounded in cytological observations, noting that they are both concerned with risk assessment of a-symptomatic patients and that the conceptual framing of such risk is shaped by the materiality of the expert's practice.

The tensions and resistances arise in the correlation between histological data and clinical meaning. The barriers experienced by this cancer pathologist in their attempts to include histological risk in the development of a screening programme reflects such difficulties in identifying 'pre-cursor' legions:

"So you could theoretically prevent all of those breast cancers, because the evidence from the P1 study, was that they are hormonally dependant and you will suppress their growth and development and the risk, if you offer a hormonal intervention. The problem is finding those patients, because it's not easy to detect these low – they're tiny, the microscopic lesions, you can't see them easily on mammograms, ... some patients will be detectable on mammograms, but it's very, very rare to detect that and so in terms of identifying the patients, you're going to miss lots of them, because you can't see them, you can't find them, there isn't a strategy to do them." **(Professor of Cancer Pathology, Specialist in Breast Cancer)**

The clinical implications for cancer treatment as a result of identifying these precursor lesions are enormously complex. Although the current consensus in pathology, according to the expert, suggests that lesions such as *ductal carcinoma in situ* (DCIS) are a stage in the development of invasive cancer, strengthening the view that they are pre-cancerous, they are almost impossible to detect in a clinical context. The establishment of cancer as a continuum from abnormal cells, through to pre-cancerous cells and then to cancerous cells, constituted by the *dominant view*, is made credible on the basis of 'cartographical' (Gieryn, 1999) boundary work. In other words, the material manifestation of the 'pre-cancerous' lesion in the account of a histopathologist stretches the biological pathway of cancer towards the pre-symptomatic population. Bringing these materials together with the technological advances in information infrastructures creates new knowledge through which future risk becomes increasingly more certain in the lives of people's present.

Despite being asked to speculate about futures unrestricted by borders, experts offered futures with caveats, contingencies and uncertainties. These resistances reflect the complex dynamics of expectations in biomedical science, that not only represent hope and promissory futures, but are also marred by ambiguity and uncertainty (Fitzgerald 2014), as illustrated in a growing literature on the sociology of low expectations (Pikersgill 2011; Tutton 2011). What this work illustrates are the ways in which experts negotiate an 'intermediate terrain', as Fitzgerald (2014) describes it, between hope and promise on the one hand and ambiguity and uncertainty on the other. In the context of these interviews, where experts are

making claims to the future of the field of cancer research, the oscillations between low and high expectations are a resource through which experts are able to secure knowledge regarding the constitution of cancer, while highlighting the caveats and uncertainties of others. Low expectations – or ambiguity and uncertainty – accounted for within their own fields of expertise are described as important points of complexity that require further thought and investigation (that should be undertaken by them and others in their particular field of expertise), in order to understand the cancer problem.

These 'moments of contention' between the interviewing team and the expert participants can partly be explained by the expert's proximity to direct clinical practice or to the frontline of cancer research; the socio-spatial dimension of expectations. It is well rehearsed within science and technology studies that the closer you are to knowledge production in a field, the more you are able to see the contingencies that shape the production of 'facts'. Distance, on the other hand, lends enchantment (Collins, 1997) as those further from the frontline of clinical work or biomedical research are more shielded from the complexities of scientific and clinical practice and thus able to maintain a degree of certainty over the production of the same 'facts' (Brown and Michael, 2003; Borup *et al.*, 2006; Collins, 1997; 1999; MacKenzie, 1990; 1998). Such contingencies and uncertainties are arguably even more evident in discussions and speculations of what might be, and the relationship between what we 'know' and 'don't yet know'.

Taking in to account the spatial (the degree of closeness to research at the front line) and cartographical (the demarcations made between groups of experts that make claims to knowledge) organisation of expectations, it is not surprising that the experts and the interviewer experience *moments of contention*. As an actor at some remove from the coalface of research, the interviewer is more ready to treat emergent findings from the 'core set' as facts, particularly when such ideas align with the current available resources of knowledge, skills, equipment and technologies that provide the basis for a 'do-able project' (Fujimura, 1987). Furthermore, the conceptual and epistemic aspects of the cancer problem shape and are simultaneously shaped by the available personnel, technological equipment, and resources that Fujimura identifies. In extending Fujimura's (1987) argument, this work shows the significance of the relationship between these factors for building a do-able project and creating a consensus to build a workable future solution.

In a conversation between a research geneticist and the interviewer, a discussion emerges about single nucleotide polymorphisms (SNPs). The interviewer, in seeking out measurable clinical indicators, asks about their future utility in light of what they describe as the problem of 'specificity':

I: **"But the way I understand it, it's not just looking at, okay, this particular SNP is predisposing or making you susceptible to bowel cancer and breast cancer, for instance... it's comprised of the many combinations of many SNPs together. So would this be able to tell us, in about five years' time or more... that yes, its breast cancer, nothing else? The reason I am asking this is because of... something like**

the PSA (prostate specific antigen) for instance. Yes, PSA is for prostatic cancer but it's not specific to the prostatic cancer."

R: "No!"

I: "Are we going to spend all this effort to come up with something that is really not specific...?"

R: "Yeah, probably...well, some of them will be specific and some of them won't be, I imagine, because that's the nature of the gene changes. So the gene changes for HNPCC (Hereditary Non-Polyposis Colorectal Cancer) register as predisposal for colon cancer...and register as predisposal for lots of other cancers as well! And already, as I've said, SNPs have been identified that predispose to more than one type of cancer...but then others will only be relevant to specific tissue! So yeah, it will be a combination of different SNPs to different disorders and some of them will overlap and some won't...but SNPs aren't the be all and end all of genetic susceptibility, you know...there are other types of gene variations, in addition to SNPs, that are important. They'll only account for a fraction of the genetic susceptibility." (Director of Institution for Medical Genetics, Specialist in Lung Cancer)

The geneticist responds to the challenge put forward by the interviewer by shifting attention away from focussing *only* on SNPs, to understanding SNPs in the context of other genetic variations. This 'moment of contention' reflects the socio-spatial dimension of expectations; the geneticist is much more inclined to maintain caveats and to make corrections to the more instrumental interpretations of the interviewer. However, while accounting for uncertainty and caveats, the expert also carefully manages expectations to ensure investment in genetic research as a credible future path for the cancer field (Arribas-Allyon *et al.*, 2010). Given the context of failures and delays (see Morrison, 2012), justification for the 'basic to applied model' of

biomedical research has become a key component in expectations discourse for biomedical science. In contrast, the interviewer focusses on the potential of SNP's to provide clinical indicators. To develop workable solutions to the cancer problem, through the utilisation of information systems, clinical information must be 'specific'.

Similarly, the future potential of generating sophisticated risk algorithms that link together genetic, histopathological, environmental and lifestyle data necessitates clear relationships between the common cancers and identifiable risk factors. As the director of a cancer bank describes, the evidence for the effect of lifestyle on breast cancer, for example, is uncertain:

R: "We can change behaviour to a certain extent but there will always be somebody who will ignore that advice..."

I: **"This is a question actually that keeps coming in every single interview I've done – all types of cancer I'm looking at, like the heart diseases, you have an algorithm to say, if you have these ten risk factors, if you don't want to heart failure at forty...."**

R: "Yeah."

I: **"In cancer, you always get someone who says actually I'm ready to give up my red meat and my fatty food and my chocolate if this lowers my risk by twenty per cent, but you can't really say precisely..."**

R: "You can't say that....and – and plus the fact that an awful lot of the evidence is contradictory... A colleague told me that at a meeting he'd been to where one of the big breast cancer people in the States said that alcohol was bad for you and the journal of clinical oncology, top oncology journal, this week, big paper by the group at Cambridge, highly respected saying, alcohol is not bad for you. It does not increase your risk of breast cancer, so when you have conflicting evidence like that

coming from top groups of Epidemiologists, nobody's going to listen..." (Director of Science Services of a large Cancer Bank, Specialist in Breast Cancer)

The issue of the relationship between lifestyle and cancer risk is a distinct point of disagreement in current cancer research. The interviewee in this extract, a supporter of the *resistant view*, highlights disagreements amongst experts working in the field of cancer risk and lifestyle change to attempt to enrol support for their point of view (see Hedgecoe, 2006), by questioning the validity of a thesis which contains contradictory evidence. Not only is the *resistant view* said to be more concrete and tangible, there are less disagreements amongst its advocates. The *dominant view* – researching pre-symptomatic risk - exists as a present unknown and is therefore presented as posing significant challenges for providing future promise.

Those experts who championed the work of differentiating the 'tigers' from the 'pussycats' – *the resistant view*, take seriously this contested terrain and highlight some of the uncertainties and assumptions that underpin it. These resistant voices within the 'core-set' however, still contribute to the overall progression of *the dominant view*. By championing the place of histopathological change in the development of large-scale, long-term studies that include human tissue samples and their study over time, alongside genetic, environmental and lifestyle data; they become enrolled in the *dominant view* hypothesis of 'cancer of a continuum' with tumour development becoming an additional developing risk factor. This enrolment of the *resistant view* is partly accomplished through the instrumental rationality (Michael, 2000) of cancer research futures, highlighted in many of the experts'

accounts, that tend to be determined by the means and methods of knowledge production that exist in the present. What cancer *is* and its implications becomes subsumed by the strategies, resources and expertise required to *do* cancer research.

Building future value

Expectations of future success are also central to the construction of economic value (Martin, 2015). In discussing potential futures experts refer to the ‘efficiency’ of targeting a population, while advising frugality in not putting ‘all your money there’, given the limited signs of future success. Some even drew on a betting analogy, ‘the safe bet’ or the ‘sure winner’ in their attempts to make some future projects more ‘doable’ than others. This language reflects, at least rhetorically, a shift in the public performance of success in biomedical research away from scientific discovery and the development of new knowledge, and towards scientific breakthrough and a solution to a current, well defined problem (see Brown, 2000). The way in which cancer, as a present problem, is constituted is therefore important. The boundary work undertaken to define the problem will determine which knowledge is able to obtain value and ultimately will be rewarded. The *dominant* and *resistant views*, in constituting the cancer problem, therefore have significant implications for the evaluation of future success in cancer research. Once the cancer problem is constituted, it is possible to identify the model required to solve it and make a case for the types of expertise essential for this future to unfold:

I: **“And who do you think would be the stakeholders in producing this model? Definitely I can see now pathology, the community medicine, so what are the other and the genetics of course. Who do you think would be the stakeholders in the main players?”**

R: “Well you need sort of academologists, they’re going to be absolutely and they’re the ones who have all the lifestyle information. [You] need people like [expert in cancer genetics] and [expert in cancer genetics] who have got the molecular genetic sort of information to link to lifestyle. It’s combining those two things. I’d put a plea in for pathology, because I’m a pathologist, but we understand the sort of early... things that are going on, so we can feed that sort of knowledge in there and I suppose there is the main sort of people, I would put the community medicine sided within this and epidemiologist in particular.” **(Professor of Cancer Pathology, Specialist in Breast Cancer)**

Sometimes moments of contention lead to moments of consensus. The interviewer and interviewee are engaged in negotiations over what combination of disciplinary skills and expertise are required to fulfil future needs, making explicit the networks of innovation necessary for the future (Borup *et. al.*, 2006). While doing this, the expert ensures the role of pathology is recognised. In all conversations presented in this article, experts are staking a claim to the future of cancer research by employing various strategies: constituting cancer according to specific technologies or materials that are presented as being paramount to its understanding; drawing on different types of future subjects; or, making recourse to unknowns, uncertainties or controversies. In some moments, claims to a particular kind of future are more explicit than others, highlighting what’s really at stake in these conversations: to

secure and mobilise resources across scientific communities, which has implications for research institutions, research centres, careers, jobs.

Discussion

This article brings into view expectations in-the-making of the core-set in the development of UK cancer research. The accounts described are, by their nature, specific to a particular point in time, reflecting the trajectory of cancer science during the late noughties, with future projections framed by the thinking, debates, technologies and infrastructures of a specific time and place. Expectations are, of course, contingent upon the contexts and situations in which they are produced. The future of cancer research may be accounted for in various ways across local, national and international networks or communities of practice. For example, the constitution of cancer and the future of the research field may be performed differently by experts in conversations amongst themselves, when talking to patient and relative groups or when presenting their case to policy makers and international funding bodies (see for example Kerr *et al* 2007 which accounts for ambivalences in cancer professionals' accounts with regard to developments in genetic research).

Taking account of the contexts and contingencies, representations of the future matter. They matter because of the ways in which social constructions of the future can have a self-fulfilling affect (Merton, 1951), but also because, in their performative character (Michael, 2000 building on Mead), they script the present (Akrich, 1993). Investing in certain kinds of futures over others is therefore a

political act with significant repercussions for those working in the area, and for those that cancer might effect, in the future and the present.

The contribution of this paper is to illustrate how claims to authority rely on spatial, temporal, material and cartographical demarcation. Expectations of the future are therefore shown to rely on various forms of boundary work (Gieryn, 1999) to add legitimacy to experts explanations of what cancer is, subsequently lending credibility to experts' future predictions for cancer research, both in terms of what *ought* to happen, to ensure scientific breakthroughs, but also what is meaningful, feasible and possible for the future.

Boundary work is shown to be an essential part of constituting cancer as an entity, playing a central role in shaping future expectations of cancer research. For the experts, the interviewer and the research team, such questions have important implications for the mobilisation of resources determining their own present credibility in contributing to knowledge in the field, and their capacity to secure future employment and continued career development.

Contested terrain in the field of cancer research has been shown to be triggered by a number of factors: an expert's connection to a particular technical or theoretical view – style of reasoning (Hacking, 1992); and what approach provides the greatest potential to form a 'do-able' project, accounted for on the basis of robust knowledge and epistemic authority on the one hand or practical tools, resources and infrastructures on the other (Fujimura, 1987). Others have highlighted the potency

and persuasiveness of risk prediction across a number of fields in contemporary society (Groves, 2013). In the case of these experts, risk prediction remains central to their claim-making regarding the future of cancer research, in a similar vein to that of genetic susceptibility (which so far has also offered little meaningful improvement in determining someone's risk in the clinic). Perhaps the draw of the *dominant* view is not only its potential to form a do-able project, but also its alignment to broader cultural pre-occupations with 'risk thinking' (Rose, 1999) and the curtailment of future indeterminacy (Beck, 1992; Giddens, 1998).

As the conversations presented in this article show, the overall paradigm of the 'basic to applied model' remains strong, albeit with shifted parameters of what kinds of new knowledge are necessary for success. The difficulty is, that developing greater knowledge at this base level may actually increase complexity, as illustrated in many of the experts' accounts, leading to less prognostic and diagnostic certainty (Lowy and Gaudielliere, 2008).⁴ The instrumental nature of cancer futures represented in these expert accounts, where existing ways of thinking, infrastructures and resources shape the futures that are enacted, suggest that the pussycats and tigers (and their critique of detection, risk and prediction) may be subsumed within the potent and persuasive framework of the *dominant view* - as a 'do-able project' with a greater potential payoff, quietening the roars (and the purrs) for more targeted, more effective and safer treatments for those who have cancer.

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¹ Gieryn (1994) uses the concept of cartography to describe the mapping of epistemic authority on the basis of credible methods or reliable facts, with borders that locate useful science, that are surrounded by less useful terrain. This idea helps to describe the spatial, material and ontological demarcation that occurs in the accounts and interactions of cancer research experts.

² Aligned to the concern over pussycats and tigers, although not fully explored in this expert's description, is the problem of 'lead time biases'. This refers to the length of time a 'cancer' has been detected but causes no harm, with earlier detection potentially creating years of anxiety (Etzioni *et al.*, 2002).

³ Jane Calvert's (2006; 2009) work on systems biology is useful to illustrate the engineer's approach to biology.

⁴ Futures not represented in these accounts include the potential human impact of over-diagnoses (Etzioni *et al.*, 2002) that fail to provide useful categories for clinical intervention (Welch, 2004; Black, 2000; Folkmon and Kalluri, 2004). Such futures may have provided greater credibility to the *resistant view* and further challenged the paradigm of early detection and prevention.

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