

# Excitable models: Projections, targets, and the making of futures without disease

Tim Rhodes<sup>1,2</sup>  | Kari Lancaster<sup>2</sup> 

<sup>1</sup>London School of Hygiene and Tropical Medicine, London, UK

<sup>2</sup>University of New South Wales, Sydney, NSW, Australia

## Correspondence

Tim Rhodes, Department of Public Health, Environments and Society, London School of Hygiene and Tropical Medicine, 15-17 Tavistock Place, London WC1E 8HT, UK. Email: tim.rhodes@lshtm.ac.uk

## Funding information

Australian Research Council, Grant/Award Number: DP210101604; Australian Government Department of Health; UNSW SHARP; Scientia Fellowship

## Abstract

In efforts to control disease, mathematical models and numerical targets play a key role. We take the elimination of a viral infection as a case for exploring mathematical models as ‘evidence-making interventions’. Using interviews with mathematical modellers and implementation scientists, and focusing on the emergence of models of ‘treatment-as-prevention’ in hepatitis C control, we trace how projections detach from their calculative origins as social and policy practices. Drawing on the work of Michel Callon and others, we show that modelled projections of viral elimination circulate as ‘qualculations’, taking flight via their affects, including as anticipation. Modelled numerical targets do not need ‘actual numbers’ or precise measurements to perform their authority as evidence of viral elimination or as situated matters-of-concern. Modellers grapple with the ways that their models transform in policy and social practices, apparently beyond reasonable calculus. We highlight how practices of ‘holding-on’ to projections in relation to imaginaries of ‘evidence-based’ science entangle with the ‘letting-go’ of models beyond calculus. We conclude that the ‘virtual precision’ of models affords them fluid evidence-making potential. We imagine a different mode of modelling science in health, one more attuned to treating projections as qualculative, affective and relational, as excitable matter.

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**KEYWORDS**

affect, disease elimination, hepatitis C, mathematical models, projection, qualculation, targets

## INTRODUCTION

Futures are unimaginable without projection. Various fields of governance – from economics to environment to welfare and health – are replete with mathematical models and other forms of enumerated projection (Arkut et al., 2019; Bauer, 2013; Callon & Numiesa, 2005; Gunning-Schepers & Van Herten, 2000). In the field of health, global efforts to control viral outbreaks and eliminate infections provide examples (Mansnerus, 2013; Leach & Scoones, 2013; Rhodes et al., 2020; Rivers et al., 2019). In the case of efforts to eliminate chronic infections at the population level, as with HIV, viral hepatitis, tuberculosis and malaria, the evidence produced by mathematical models is shaping global policy and strategy, especially via numerical viral elimination targets (UNAIDS, 2014; WHO, 2015a, 2015b, 2016a, 2016b, 2016c). The future elimination of hepatitis C – a virus infecting over 70 million people worldwide, and predominantly affecting people who inject drugs – is evidenced into being as an effect of its modelled projections. Enumerated projections are thus an important mode of evidence-making in an anticipatory regime which orientates governance of the present in relation to the future (Adams et al., 2009; Arkut et al., 2019). Such is the pervasive presence of enumerated projections and numerical targets in the field of global health, that it is difficult to see how a science of viral elimination might be made otherwise (Rhodes & Lancaster, 2021).

In this analysis, we are interested in how mathematical models link with numerical targets to afford enumerations material effects as they travel into social practices. Concentrating on enumerated projections as they relate to the elimination of viral infection, and specifically hepatitis C through the invention of strategies of ‘treatment-as-prevention’, we explore what enumerations do; that is, how they are put-to-use and how they are made-to-matter as situated matters-of-concern, including beyond science. Drawing on qualitative interview material with mathematical modellers and implementation scientists working in the field of hepatitis C elimination, we ask: What realities and affects do enumerated projections make?; and How are modelled projections afforded life beyond their calculations as they travel in policy and practices? Our analysis treats modelled projections and numerical targets as relational beings, tracing how the evidence produced by models generates affects in relation to socially situated concerns. The virtual precision of models, as modes of qualification as well as quantification, affords them a particular flexibility. This can give rise to epistemological concern as models and their projections appear to take flight beyond their ‘evidence-based’ imaginaries. Yet, we argue, an alternative, more open, modelling science is possible.

### Enumerating governance

A body of work investigates how enumerations have governing potential in relation to health (Davis et al., 2012; Hansen & Porter, 2012; Merry, 2011; Porter, 1995; Rose, 1991; Shore & Wright, 2015). Targets, rankings, projections, predictions, metrics and audits all establish standards and benchmarks, which serve as coordination mechanisms to stabilise health and populations in particular ways (Power, 1999; Strathern, 2000; Sauder & Espeland, 2009; Law, 2004; Mol, 2002). The development of statistics and probability, in particular, has enabled the regulation of populations in relation to risk against quantified biosocial norms (Armstrong, 1995; Castels, 1991; Rose, 1991; Rowse, 2009).

Enumerations close down unknowns and sources of disease into a governable present, thereby taming risk and uncertainty, and affording a sense of security, through calculus (Castels, 1991; Hacking, 1990; Jasanoff, 1999). An immediate response in viral outbreaks, for instance, is to enumerate, including through projection, in an attempt to bridge an absence of evidence to enable policy decisions (Saminmian-Daresh, 2013; Rhodes et al., 2020; Rivers et al., 2019).

Not only is the epistemological appeal of enumerations connected to their mobilisation as ‘matters-of-fact’ (Latour, 2004), offering apparent precision in an evidence-based approach to science and policy (Hansen & Porter, 2012; Sackett et al., 2000; Saltelli & Giampietro, 2017), they are commonly approached as especially mobile objects in a universal mathematical language which promises to translate across contexts (Porter, 1995). There is particular epistemic value performed by mathematically modelled projections in the relative absence of empirical certainty (Hacking, 1990; Mansnerus, 2013; Morgan & Morrison, 1999; Sismondo, 1999), for instance regarding the anticipated potentials of interventions which have yet to be evidence-based as materialised outcomes (Lakoff, 2017; Saminmian-Daresh, 2013). Enumerated projections – including those abstracted from more ‘theoretical’ rather than ‘empirical’ models – perform a bridge in an apparent evidence gap (Morgan & Morrison, 1999), including in policy situations when so-called ‘hard evidence’ of intervention effects from randomised controlled trials or observational studies are unavailable (Wood et al., 1998). We can see this performance at work in the field of global disease control, where the modelled projection of viral elimination through reduced incidence of infection is indexed to population-level effects anticipated in the near future (usually somewhere between 10 and 20 years in the case of hepatitis C) which have yet to be materialised as ‘real world’ outcomes through intervention trials (Hickman et al., 2019). In epidemics, models work as devices to make evidence to enable policy actions in the face of uncertainty, even as outbreaks emerge (Lakoff, 2017; Rhodes & Lancaster, 2020). Such modelled evidence is brought into being as an element of the science and policy assemblages which make-up ‘evidence-based’ approaches (Mansnerus, 2013), in which the rendering of precision with translatability, and a correspondence to an assumed underlying real, are core imaginaries (Porter, 1995).

## Enumerating viral elimination

The field of hepatitis C treatment has been cast as a site of dramatic technological change generating great promise since the advent of direct-acting antivirals (DAAs). These pharmaceuticals promise near 100% cure of hepatitis C infection with near-zero side-effects (Dore & Feld, 2015; Falade-Nwulia et al., 2017). DAA medicines have moved from development to trial to implementation at an unprecedented pace. Their implementation, which began around 2014, is transformative, rupturing the previous pharmaceutical regime of Interferon-based treatments characterised by poor cure rates and debilitating side-effects. DAAs have signalled a ‘new era’ of treatment (Dore & Feld, 2015; Grebely et al., 2017a; Innes et al., 2015), of ‘ground-breaking’ and ‘revolutionary’ potential (Banerjee & Reddy, 2016; Gane, 2014). This sense of pharmaceutical promise, of pills that can cure and control infections, connects with a broader pharmaceuticalisation of disease control (Abraham, 2010; Nguyen et al., 2011; Young et al., 2016).

DAA medicines afford the promise of hepatitis C cure among chronically infected individuals, but they also potentiate curative impact at the level of populations and nations through a strategy of treatment-as-prevention (WHO, 2016b). This potential, and the numerical targets generated to help realise this future, is evidenced through enumerated projection (Hickman et al., 2015; Pitcher et al., 2018). The population-level *prevention effects* of pharmaceutical treatment are theorised in mathematical models as a function of delivering treatments at a scale sufficient to reduce the pool of infections,

and thus risk of acquisition via transmission, in the populations deemed most at risk (people who inject drugs), including accounting for rates of re-infection among those treated (Martin et al., 2011, 2013a). The invention of *treatment-as-prevention* is a foundational moment in the evidence-making of hepatitis C treatment promise.

Hepatitis C treatment-as-prevention, or TASP as it is often called, can be traced to two mathematical models (Martin et al., 2011, 2013a; Zeller et al., 2010). The first model sought to estimate the optimal level of hepatitis C treatment provision in the population of people who inject drugs in Australia, accounting first, for estimated rates of re-infection among those treated, and second, for engagement or not with methadone substitution treatment (which alters rates of hepatitis C transmission through reductions in risk practices among those in methadone treatment) (Zeller et al., 2010). The model theorised that a critical hepatitis C treatment level of 56.5% 'eventually eliminates' hepatitis C infection, which at estimated levels of chronic hepatitis C prevalence at the time (60%) required 33.9% of people who inject drugs (56.5% of 60%) to be enrolled in hepatitis C treatment. This treatment burden of 33.9% eases after 3 years when chronically infected numbers halve as hepatitis C treatment decreases prevalence.<sup>1</sup> At the time, less than 4% of people who inject drugs were estimated to have ever received hepatitis C treatment (Grebely et al., 2009; Martin et al., 2011). This mathematical model is the first to enumerate projections of reduced hepatitis C prevalence, and elimination potential, as a function of hepatitis C treatment, accentuating high levels of hepatitis C treatment coverage required to make a prevention effect.

The second model which sought to theorise the treatment-as-prevention effects of hepatitis C treatment has become a standard for the field (Martin et al., 2011, 2013a). This latter model entangled in a wave of excitement following the theoretical projection, and subsequent empirical evidencing via trials, of HIV treatment-as-prevention, also heralded as 'game-changing' (Cohen, 2011; Cohen et al., 2016). The projections from this model transformed hepatitis C from merely treatable in individuals to preventable in populations at 'modest' and 'achievable' treatment rates (Martin et al., 2011: 1141). One prime enumeration of the model, for instance, is the ratio of '20:1000': an annual treatment rate of just 20 cases per every 1000 people who inject drugs results in a 62% reduction in prevalence after 10 years in a chronic prevalence scenario of 20% (Martin et al., 2011). This model calculates a fixed annual treatment rate (such as 20:1000) that is assumed sustainable as hepatitis C prevalence reduces over time. The model enacts a 'realistic model of antiviral treatment capacity and delivery' but 'more optimistic projections' than previous projections which assumed a diminishing treatment rate as prevalence decreases (Zeller et al., 2010). The projected potentials of hepatitis C treatment-as-prevention also intensify as higher cure rates are fed into calculations in response to the evidence produced by pharmaceutical trials of DAA medicines (Martin et al., 2012, 2013a, 2013b). The projected prevention effects of DAA medicines – with assumed cure rates of 90% compared to 67%, at best, for Interferon-based regimens – yield 'substantial impact' based on 'minimal and achievable levels of treatment scale-up' (Martin et al., 2013a: 1604). For instance, projections attuned to the higher cure rates of DAA medicines show that scaling-up treatment to the modest rates of 20:1000 'could result in relative prevalence reductions within 15 years of 69% and 23% in Edinburgh and Melbourne' (1604). Higher prevalent settings, like Vancouver (estimated at 65% hepatitis C prevalence), require higher treatment rates, for instance, of 40:1000 to reduce prevalence by over 20% over 15 years. Thus, in many settings 'substantial' prevention effects are potentiated by 'minimal' increases in treatment rates.

Treatment-as-prevention then shifts again in its enactments to potentiate the *elimination* of hepatitis C at the population level. The transformation of treatment-as-prevention to treatment-as-elimination is enabled by assemblages of viral elimination promise which incorporate the models and their projections as actors alongside pharmaceuticals, clinical trials, implementation science, national policies, public health discourses, community advocacy and global strategies (Rhodes &

Lancaster, 2021). Particularly significant are efforts to project the treatment scale-up required to achieve global viral elimination targets (Fraser et al., 2018; Gountas et al., 2018; Hagan et al., 2013; Heffernan et al., 2019; Hellard et al., 2012, 2014; Innes et al., 2015; Kwon et al., 2019; Martin et al., 2013b, 2016, 2017; Razavi et al., 2017; Scott et al., 2017, 2018; Ward et al., 2018). The invention of numerical viral elimination targets is a critical evidence-making event. As part of its Global Health Sector Strategy, the World Health Organization (WHO) set, in 2016, global targets to ‘eliminate viral hepatitis as a major public health threat by 2030’ (WHO, 2016b). The prime targets are 90% reductions in new cases and 65% reductions in related deaths. Governments around the world have signed-up to achieving these global targets by 2030, or before, in what has become a ‘race to eliminate’ (Lancaster & Rhodes, 2020). Mathematical models circulate in this viral elimination assemblage by generating the evidence to track the progress of nations against these viral elimination benchmarks (Fraser et al., 2018; Gountas et al., 2018; Kwon et al., 2019; Razavi et al., 2017; Scott et al., 2017, 2018; Ward et al., 2018). Models not only create the evidence to enumerate targets but recursively loop these targets back into projections going forwards (Hacking, 2006). The projections of models and targets entangle, with pharmaceuticals among other actors, to materialise viral elimination potentials.

## APPROACH

Our focus in this paper is mathematical models, the projections they make and the effects of these, especially as they travel through numerical targets into policy and social practices. To make our analysis we draw primarily on the work of Callon and Law (2005), Verran (2015), Myers (2015) and Gomart and Henninon (1999). In keeping with an established turn towards ontology within social studies of science and evidence-making (Moreira, 2007; Woolgar & Lezaun, 2013), we emphasise the performativity and materiality of enumerations (Callon & Law, 2005; Myers, 2015; Verran, 2015). Evidence then, does not come before intervention but is made in it, as an ‘object-in-practice’ (Law, 2004; Mol, 2002). Accordingly, science does not observe a reality, as if ‘from a bridge’, but is ‘immersed’ in its making, as one actor entangling among many (Puig de la Bellacasa, 2017: 33). We have described this as an ‘evidence-making intervention’ approach (Rhodes & Lancaster, 2019). Distinct from mainstream ‘evidence-based intervention’ approaches in the field of health, which orientate to stabilising evidence and intervention to aid its translation across implementation contexts, and which hold on to the idea of correspondence with an underlying and discoverable reality, an evidence-making intervention approach accentuates evidencing and intervening as matters of becoming-with their events and situations of implementation. Entities – whether epistemic, methodological or technological – are entirely relational, made lively in their enactments (Andrews & Duff, 2019; Barad, 2007; Latour, 2005; Mol, 2002), and thus constitute ‘evidencing-making interventions’ (Zuiderent-Jerak, 2015; Rhodes & Lancaster, 2019).

Accordingly, our analysis focuses on what enumerations become and the material effects they make through their situated implementations in social and policy life. This helps us to notice how models and their projections are afforded agency through their entanglements in particular evidence-making assemblages. Here, assemblages can be treated as gatherings of multiple elements which through their entanglements materialise realities (Deleuze & Guattari, 1988; Duff, 2014). Importantly, assemblages are arrangements of ‘active and evolving practices’ rather than of ‘passive or static structure’ (Watson-Verran & Turnbull, 1995: 117), and this means that they are ‘tentative and hesitant and unfolding’, in a ‘recursive process’, in which ‘the elements put together are not fixed in shape, do not long belong to

a larger pre-given list, but are constructed at least in part as they are entangled together' (Law, 2004: 42). This means that the effects afforded to actors and objects through their assemblages are immanent as well as lively, perpetuating 'lines of flight' as transformations evolve (Deleuze & Guattari, 1988). Modelled projections then, are at once performed and performative, materialised in practices while materialising these. Accordingly, we can approach mathematically modelled projections and numerical targets as modes of enactment (Callon & Numiasa, 2005), which bring into being certain entities and realities, as 'excitable matter' (Myers, 2015). As Natasha Myers (2015: 28) reminds us in her study of protein models, 'the liveness of matter is its capacity to affect and be affected by other bodies. Matter, in other words, is excitable'.

In approaching projections and targets as modes of enactment, it is important to distinguish, as Helen Verran does, between 'numbers' and 'enumerated entities'. Whereas a number 'belongs in a stable state of being', an enumerated entity 'exists in the dynamic of emergence realness' (Verran, 2015: 367). Thus, enumerated entities are 'relational beings' because they are situated 'events or happenings in some actual present here and now' (2015: 367). Such an approach enacts enumerated entities as emergent, multiple and local, and numbers as fixed, universal and transcendent. Re-assembling numbers as enumerated entities, as we do in this analysis, seeks to make visible the processes which perform enumerations in their local enactments, by elaborating the 'everyday routines', 'collective acts' and other practices 'in which enumerated entities come to life' (Verran, 2015). We move then, from numbers stabilised as matters-of-fact to enumerated entities entangling as matters-of-concern, including in practices beyond science (Latour, 2004a). In our approach, targets and modelled enumerations come to be, as matter, in relation to what matters in situated practices.

Further, we draw attention to projections as calculations that are not necessarily or only arithmetical in form. Callon and Law (2005) describe 'qualculation' as the space in which models and other forms of synthesis do their calculative work through a mix of quantification and qualification. Models of disease elimination, for instance, synthesise various forms of heterogeneous data of different calculative forms generated in different calculative routines, such as: empirical parameters; theoretical hypotheses; metaphorical depictions; analogies; policy proposals; as well as expert subjective judgements. At the same time, the new entities produced through models and simulations are subject to various forms of qualification as they are translated in practices, including in relation to: situations; discourses; affects; interventions; policies; and targets. In this analysis, we therefore accentuate enumerated entities – projections and targets – as matters of qualculation, for these entities entangle with, and generate, situated qualifications in their modes of production and circulation as objects-in-practice (Mol, 2002).

In addition, Callon and Law draw attention to the affective relations of enumerative translations. Myers also draws attention to affect as a force of movement in how models are afforded agency as excitable matter (Myers, 2015). Here, modelled projections produce affects – embodied feeling, passion and non-calculative attachment – through their assemblages and implementations, which we can treat as a 'letting-go' of calculus. Drawing on Gomart and Hennion's (1999) work on attachment, we consider attachments to models and their projections as situated practices of 'holding-on' and 'letting-go', including in relation to 'evidence-based' imaginaries. Here, affect and calculus are not held apart but relate, with 'letting-go' and 'holding-on' a negotiated process through which modellers move-with, as well as attempt to resist, the transformations of their modelled projections as 'evidence'. We propose anticipation as one force of affect through which projections and targets 'let go', and have agency, beyond their calculative origins. We argue that the 'letting-go' of models and targets beyond 'evidence-based' calculus, through their anticipatory affects, can be constituted a 'problem' of science, yet another science, another way of doing modelling, is possible.

## CASE STUDY METHODS

This analysis attends to the agency performed by enumerated projections linked to mathematical models and quantifiable targets. This focus is prompted by our noticing of the pervasive presence and governing potentials of enumerated projections in field of infection control (Lancaster et al., 2020; Rhodes et al., 2020). Our analysis seeks to trace how modelled projections and numerical targets are afforded life and affect, as excitable matter, in social practices beyond the origins of their calculations.

To make our case study, we use data generated through in-depth interviews with 48 mathematical modellers, implementation scientists, researchers and advocates identified as global leaders in the field of hepatitis C. Our interviews were undertaken between May 2018 and February 2020, although our praxiographic engagement in the field is ongoing. Most interviews were conducted in person, in participants' offices and in private spaces around conferences and meetings, with a minority via Skype. All were undertaken with consent, audio-recorded and transcribed verbatim. Given the small number of actors involved in the field of hepatitis C implementation science and mathematical modelling, we paid particular attention to managing ethical considerations of anonymity and confidentiality (see Lancaster, 2017). Ethics approvals were granted by the University of New South Wales Human Research Ethics Advisory Panel (HC180139).

In conducting interviews and analysing interview data, we treat subjects and objects as in-process and transcript texts as materialised artefacts of the interview event (Bacchi & Bonham, 2016). Our analysis pays attention to 'things said' in terms of 'what they produce, or constitute', including in terms of 'the practices that give rise to them' (Bacchi & Bonham, 2016: 116–118). Accordingly, our focus on analysing interviews as materialisations of subjects and objects attunes to noticing the agency afforded to nonhuman elements in assemblages (Fox & Allred, 2017). We engage with our qualitative interviews, and the accounts they produce, as an 'attentiveness' which gets to know the nonhuman other of the mathematical model as an element of viral elimination realities-in-the-making (van Dooren et al., 2016). We draw parallels here with the description of 'lively' ethnographic story-telling offered by van Dooren and Rose (2016) in the field of environmental humanities, where field work and analysis is an act of 'bearing witness' through 'attention to others' in entangled human and nonhuman relationships. We therefore do not treat our interview data as simply stories of human agency and neither do we assume a separation of the narrated from the real (van Dooren & Rose, 2016). Instead, our approach treats interview accounts as always coproduced and performative, and thus, as events in which realities become materialised.

This accentuates interviews and their analyses as 'evidence-making' interventions (Rhodes & Lancaster, 2019), wherein the noticing of others – such as the effects of modelled projections and other nonhuman actors in viral elimination assemblages – constitutes a 'becoming-with' (Deleuze & Guattari, 1988), an openness to a way of doing and being which extends beyond mere framings of human agency and responsibility. In a 'lively ethnography' approach, telling stories produces excitable matter through a commitment to becoming-with the other and to enacting stories as technologies of 'world-making' (van Dooren & Rose, 2016). Our tracing of the mathematical model as excitable matter shares this commitment of bearing witness to enact an evidence-making intervention. Stories are opportunities to 'learn to be affected' (Despret, 2004: 31). As noted by Rose et al. (2017: 3): 'Unlike many other modes of giving an account, stories can allow multiple meanings to travel alongside one another [and] can hold open possibilities and interpretations and refuse the kind of closure that prevents others from speaking or becoming'. In the spirit of lively ethnography, we use our analysis tracing the mathematical model as excitable matter to engage with the evidence-making possibilities that enumerated projections might afford. If 'good story-telling is generative' because 'we don't

know quite where it will take us' (van Doorent & Rose, 2016: 91), our aim is not to use analyses of interviews as if to discover an underlying 'real' or to fix an imagined 'objective' account, but rather to notice anew, to speculate, to become-with, to do things differently and well. Through our analysis we speculate on another modelling science being possible (Stengers, 2018); one with the potential to make-up evidence and futures in relation to disease and viral eliminations differently.

## ANALYSIS

### Object transformations

The development and implementation of 'ground-breaking' DAA pharmaceuticals are cast as having ruptured hepatitis C treatment into an altogether different object, with a new order of effect potential (Dore & Feld, 2015). Our interviews enact this treatment promise and sense of object boundary shift between a previous, becoming absented, Interferon hepatitis C treatment as 'toxic', 'horrible' and 'ghastly', and a new, becoming present, DAA hepatitis C treatment as 'revolutionary', 'overwhelming', 'game-changing', 'paradigm-shifting' and, basically, 'unbelievable'. The new DAA medicines are enacted by modellers and scientists as *excitable matter*, as beyond expectation, as miracle cures:

From a technical side what was done with hepatitis C is as close as a miracle as you can get in the scientific field. I mean it is quite an achievement. It went beyond everybody's expectations... Where we are today is nothing short of a miracle. It's just unbelievable. I mean we're down to eight weeks and 90%+ cure rates. It's amazing. There is nothing like it before.

[#10]

Prime among the paradigm-shifting accolades afforded to DAAs is that they are beyond belief, an entity of surprise constituting a different order for how science and treatment can be done. These new pharmaceuticals are presented as 'simple' and 'easy' technical solutions to what was persisting as a messy and complex problem. Hepatitis C, suddenly, unexpectedly, becomes easily curable. Moreover, the speed of change is remarkable. The pace of biomedical progress in this field of science is particularly racy, moving faster than could be imagined:

Unbelievably fast... It's without parallel... I started treating hepatitis C in 1992 with 6% success rates and by 2016 I was treating patients with no side-effects and 100% effective cure rates. That is incredible. Tell me another area where that's happened that quickly?

[#11]

It's unique... The drug suddenly delivered a cure at a speed that we never believed possible... This is history, living history. It is just a staggering achievement... One could not believe the speed at which it happened. It has never happened at that speed before... And literally, if you hadn't read the journals in the last month you were likely to be hopelessly out of date... I was just gobsmacked.

[#14]



## Treatment-as-prevention

Treatment promise is made possible by ground-breaking medicines and their cure rates derived largely from clinical trials, but it is mathematical models which transform these cure rates, via enumerated projection, into population-level *prevention*, and by extension, *elimination* future. We propose the enumerated projection of treatment-as-prevention as a foundational moment in the evidence-making of hepatitis C viral elimination future. The mathematical models developed by a team at the University of Bristol in the UK have transformed hepatitis C from merely treatable in individuals to preventable in populations at ‘modest’ and ‘achievable’ treatment rates (Martin et al., 2011: 1141; Martin et al., 2013a, 2013b). The first of these theoretical models projected, as noted above, that an annual treatment rate of just 20 infections per every 1000 people who inject drugs resulted in a 62% reduction in prevalence after 10 years in a chronic prevalence scenario of 20% (Martin et al., 2011).

The model of treatment-as-prevention is transformative, performing a new entity. It refashions treatment from an individual cure of chronic infection to a population prevention of disease. This is achieved through a qualculative process which detaches, and then re-arranges, multiple and heterogeneous quantified inputs, drawn from different calculative routines and contexts, into a new common language and singular form, with a new value specifically indexed to the future. The evidence-making story moves from survey, clinical and trial inputs of different values to a singular projection and new entity. Shifts are made from individuals to populations, from empirics to abstracts, from cure rates to incident cases, from treatment to prevention, from present to future. In this process, the object of hepatitis C treatment transforms, with only weak traces of its qualculative origins. Here, one scientist makes this move:

We can now treat hepatitis C like a disease rather than as a cancer... The difficulty before was, well, the drugs and the drug treatment were always delivered as if they were a cancer cure, not of an infection, not as an antibiotic... It wasn't like a cure of an acute infection.

[#58]

Through the model, treatment-as-prevention is enacted as doable and within reach and becomes an *anticipated reality*, and this affords the enumerated object of treatment-as-prevention a power-of-acting and capacity for travel. It's partly in the maths. The model calculates treatment engagement rates differently to previous attempts to model the risk reduction impacts of treatment (Zeller et al., 2010). Rather than assuming a set percentage of a population treated each year, which results in treating fewer and fewer people as the pool of infections decline, the model works with a rate – for instance, 20:1000 – which assumes treating the same number of infected people each year from the population at risk (people who inject drugs) annually, which produces projections of manageable numbers of treated cases going forwards to bring about an increasing prevention effect as hepatitis C prevalence reduces. The combination of assuming ‘a fixed treatment rate’ that can be ‘sustained at the same rate despite a reduction in prevalence’, means ‘that as prevalence decreases, a larger proportion of [those] infected will be treated each year although the number treated remains constant’ (Martin et al., 2011: 1142). The way the model calculates its viral elimination potential – through fixed treatment rates rather than diminishing percentages – constitutes its performative appeal: ‘That was exciting... Just through the way in which you model your treatment rate gives something which was a lot more depressing or achievable’. [#42]; ‘Previously everybody had been doing a percentage [rather than a rate], so when you treat 10%, it's a diminishing 10%... It's getting progressively harder’ [#3].

With this sense of achievability, the enumeration transforms treatment-as-prevention into doable elimination:

That's when it kind of clicked... We can actually pull this off... This is doable. You look at all the aspects of hepatitis C infection. You look at what's coming down the pipe. I'm telling you this is completely doable.

[#10]

The model makes it that I'm going to treat a certain number of people every year, based on the fact that I've got a health system set up to do so... So, that's when I thought, 'Oh, I can now eliminate this disease'... I thought, 'This is going to be doable.' [#3]

Accentuating the liveliness of their models, the modellers become 'surprised' at the 'modest' and 'achievable' treatment rates produced by the model:

I think we were surprised... With those treatment rates, 20 per thousand. I think we were very surprised to see the substantial reductions in chronic prevalence that the modelling predicted.

[#44]

The enumerated projections produced by the model connect with an emerging assemblage of viral elimination promise. We are told that 'all of a sudden', the model 'becomes quite a thing' [#60]. The model is met with an 'explosion of interest' [#44]. Treatment-as-prevention 'takes fire' [#44]. In so doing, it transforms further, from mere prevention into matter of viral elimination concern:

It really took fire. As soon as people started talking about hepatitis C elimination, everyone wanted to talk about it, and all of a sudden there was a slew of workshops organised at conferences focusing on that, there were pharmaceutical lunchtime sessions focusing on that, and editorials that were being written about hepatitis C elimination. It kind of all happened at the same time. It felt like an explosion of interest.

[#44]

The object of hepatitis C treatment has moved from ground-breaking cure, to achievable prevention, to anticipated elimination through its enumeration:

The modelling data was starting to appear with the need for incredibly small numbers of treatment... As soon as it was online and I read the paper, I thought 'Shit, if this is true'... That's when the dream of elimination really started... And that's when we started to seriously plan to do it.

[#14]

I'd think, 'Hang on a minute, if it's that simple, this easy, what can we do from a public health perspective? Could this actually get rid of it?'

[#14]

## Effects and affects

Very quickly, the field of hepatitis C intervention and policy transforms. In light of models of treatment-as-prevention, clinical practice guidelines rearticulate treatment as an object of prevention (European Association for the Study of the Liver, 2015; European Association for the Study of the Liver, 2017) and hepatitis C prevention guidelines give greater attention to treatment (European Centre for Disease Prevention and Control, 2020). Most significantly, national strategies build on modelled projections to set quantifiable viral elimination targets (for example: Commonwealth of Australia, 2018; Health Protection Scotland, 2019; WHO, 2016b). Multiple models of viral elimination (and not mere treatment-as-prevention) flow, moving around the globe to evidence elimination states and futures, while contributing to target setting and calibrating models in relation to these (Razavi et al., 2017; Heffernan et al., 2019; Fraser et al., 2018; Kwon et al., 2019; Innes et al., 2015; Razavi et al., 2019; Scott et al., 2017, 2018; Ward et al., 2018; Gountas et al., 2018).

With the invention of global viral elimination targets (WHO, 2016b), hepatitis C treatment takes a new ontological turn. Elimination becomes constituted not only in the enumerated projections of models but in the enumerations of targets. As one scientist proposed: ‘You now don’t have to understand your epidemic’, you have to ‘reach a quantifiable target’. Reaching the *targets* makes an elimination state:

It's just amazing to see the huge shift from theoretical exercises, that treatment can be used for prevention, to now all of a sudden they're being used for this target setting [...] People are so excited about reaching and making these targets that they're willing to commit to them even though they don't understand what kind of epidemic they have in their country... That is fascinating, that you don't have to understand your epidemic to be willing to somehow reach some quantifiable target.

[#44]

Quantifiable targets thus materialise projected elimination futures into policies and social practices. The enumerated entities *themselves* generate a power-of-acting as technologies of evidence-making intervention and of governance. We notice, for instance, that enumerated projections of disease elimination can perform authority and make effects, in the absence of precision, or even sometimes, in the absence of enumeration. Many we interviewed emphasised incredible uncertainty regarding how to ‘actually’ enumerate hepatitis C incidence and death (the prime calculations in elimination targets and projections). As we were told, these targets can be treated as ‘magic numbers’ which are ‘completely impossible to measure’ [#62]. Particular enumeration challenges in most ‘real world’ settings, for instance, include the following: the denominator population of people who inject drugs (a population largely hidden from epidemiological gaze); the baseline local population with and without hepatitis C; the rates of transition and cessation into and from the population at risk (injecting drug use); indicators of infection incidence; and measures of disease-related mortality when these occur decades post-infection (including after the WHO target of 2030) (Grebely et al., 2017b; Larney et al., 2015; Martin et al., 2017).

Numerical targets thus perform a *virtual precision*. Projected viral elimination is here constituted as a percentage reduction (in incidence and death) against a population of referent cases of unknown size. Aside from how these proportional targets also detach from ‘real world’ complexities which affect local patterns of infection, illness and treatment response, they render, as Verran (2015) notes of enumerated projections, a ‘vague (population) whole’ into ‘specific (percentage) units’ which enable ‘governance’ in relation to ‘vague (elimination) predicates’ (parentheses added). The virtual precision performed by enumerated projections materialised in quantifiable targets thus gives life to a *virtual*

*elimination* to do its governing work. As scientists indicate of how disease elimination targets are put-to-use in policy, this is not a case of ‘trying to really eliminate it’, but ‘just getting as many people treated as possible’ [#62]. The performance of virtual precision and virtual elimination through enumerated projection does not require ‘actual numbers’.

We are proposing then, that enumerated projections do not simply perform as evidence-based matters-of-fact, but as matters of situated concern (Latour, 2004). Models and targets produce enumerated entities which are made-to-matter locally. This is perhaps why we are told by some scientists that the ‘actual numbers’, and their calculus, ‘does not matter’ [#64; #58]; that what matters is that there *are* projections and targets. Enumerated projections then, are valued as ontological interventions – things which exist – rather than as epistemological claims – as measurable things:

I don't think it matters, because what matters is that they've set a target. That's what matters to the people who are infected with hep C.

[#64]

WHO probably know that there's no hope of those targets being met. But I don't think that was their main purpose. Their prime purpose was to raise the profile of hepatitis C, and what they've done is remarkable.

[#58]

This analysis then, treats enumerations not as ‘actual numbers’ but as things; things which are more than ‘just numbers’ because they are afforded power as objects according to how they are materialised in situated practices. The power-of-acting of enumerated projections resides in their situated relations, that is, how they are put-to-use and made-to-matter, not as detached matters-of-fact, but as attachments of viral elimination concern.

We therefore draw particular attention to enumerated projections as affective matter. Following Callon and Law (2005), we emphasise that the emergent practices of detachment and attachment of enumerated projections, as these travel in different networks of action, science and policy, are fundamentally matters of qualification, and moreover, that these forms of qualification extend beyond those featuring as part of the calculation of original models. Enumerated projections at once affect, and are affected by, matters-of-concern (Myers, 2015). One affect is the sense of anticipation afforded by projecting a future, which though held imprecisely in matters-of-fact, is performed as within reach and which feels doable (Michael, 2000). Projected enumerations project beyond their models, energising for scientists the ‘dream of elimination’, the possibility of another world. Through enumerated projection of treatment-as-prevention, and of prevention-as-elimination, an anticipated elimination state is embodied in practices in the now. Here is one scientist's account of an affective attachment to enumerated projections. This account enacts anticipation as excitable matter through the performance of potentiality, and not mere possibility, including as a way of doing science and policy through living-with-models:

We were selling it as a big problem. To prevent that liver failure, and then to move it to the next stage that actually we could prevent the disease... That was so *exciting*, that this could work... It's *hugely exciting*. / There is a *visceral excitement* about it. Is it going to be true? Is it going to work?... It is that *excitement*. / It feeds backwards, and forwards, and we become, yeah, *drunk on our own publicity*. And we may be completely wrong.

*Hopefully we won't be. / The modelling has made me do what I do. I'm now following the model... It's a two-way conversation between ourselves and the model.*

[#14]

## Evidence enactments

How might modellers account for how their modelled projections take flight in policies and social practices? Here, unsurprisingly, we find that there is an epistemological concern performed regarding how enumerated entities combust beyond their 'evidence-based' imaginaries of reasoned calculus. The transformation of treatment-as-prevention as elimination, for instance, was positioned by some modellers to be: 'Not in line with the direct results from the modelling' [#44]. Elimination becomes out-of-line, an imagined epistemic boundary crossed. This was said to be because: 'People take and interpret from it [the model] what they want, and maybe overstep' [#44]. The problematic of excitable models is that their affective mattering energises non-qualitative agency (Callon & Law, 2005; Myers, 2015). Excitable matter is here performed as the antithesis of evidenced actions. As remarked of modelled projections enacted as targets of elimination concern: 'People are so excited about reaching and making these targets that they're willing to commit to them even though they don't understand what kind of epidemic they have in their country' [#44].

We see enacted here a distinction between the world of the model – constituted as an 'evidence-based' treatment-as-prevention hypothetical – and the material world – constituted in relation to 'interpretations' and 'wants' and 'desires' which actualise the model as elimination. A separation is being performed between calculations and interpretations, science and society, evidence and practice, models and people, as a means to pull back treatment-as-prevention from its lively transformations into elimination concern. We propose this as a 'holding-on' to models as science, as evidence-based matters-of-fact. We understand this as a performative intervention to handle the messiness of models which are enacted as 'standing between' the different worlds of the actual and the imagined, the known and the desired, the present we know and the future we anticipate. This process is messy also, because modellers themselves, as we have seen above, are bound up in their models at once as modes of knowing and as flights of anticipation. Practices of holding-on present an imagined epistemic boundary line. Holding-on enacts an attachment to models as works of correspondence to a real in a science of reasonable calculus, with this performance acting at once as critique and intervention to tame how enumerated entities 'actually' transform otherwise in practices. For instance, here a modeller holds on to the science of the published model as if detached and separate from the talk and practice of its implementations as elimination:

The first papers were just about hepatitis C treatment and treatment-as-prevention, and people were starting to talk about elimination. All they were talking about was we can just scale-up treatment and we'll eliminate hepatitis C, that's all we need to do.

[#44]

The runaway model of treatment-as-prevention is a problem for evidence-based science. Things are messy and moving too fast. This requires some discipline in the name of science. Evidence-based scientists thus need to take better care of managing the excitability of their models as they circulate into new networks beyond those of science. Modellers of treatment-as-prevention must tread carefully when entangled in assemblages of viral elimination excitement:

We were cautious because we hadn't yet done the modelling to indicate that you could drive down incidence to levels that were that low. I was worried because we didn't have the modelling evidence. I mean the models had not looked at elimination, and they certainly hadn't looked at eradication... These models didn't even look at incidence as really the main outcome, and yet people were talking about them in the context of elimination, and meeting a reduction in incidence. So, there was already that disconnect [...] Now we're talking about elimination [...] Those were the first words that were kind of thrown around it. I felt it was further than the modelling could go at the time.

[#44]

The above account makes-up evidence in particular ways. It enacts models of treatment-as-prevention as falling short of evidencing prevention-as-elimination, including at the time because these models did not purport to calculate reductions in incidence (a core calculative element in projecting viral elimination). This is unsettling. Excitable models are making projections too unreasonable, too unpredictable. This is especially the case given that scientists may also enact modelled evidence as not 'evidence enough' to justify the changes they witness in clinical practice and policy:

The clinical guidance changed on the back of no evidence, no empirical evidence, of the impact of hepatitis C treatment as prevention. Sure, we had models that suggested that if you increased treatment among people who inject drugs you would prevent onward transmission... But to move from a theoretical to a 'this should be a change in priority settings in clinical guidance' felt to me slightly un-evidenced... There is no empirical evidence of: 'I scale-up treatment in this population and I see it decline in prevalence and incidence as a result, compared to a population where I haven't, that hasn't had that impact'.

[#58]

## Matters of fact and concern

For scientists holding on to an evidence-based science imaginary, models generate policy and other material effects on the basis of theoretical propositions (at least until these are evidenced empirically in the 'real world'), and this becomes performed as a problematic for science when enumerated projections combust too far. The matter-of-concern here for evidence-based scientists is to re-constitute models back to an 'evidence' which is closer to their origins of calculus and to an imagined empirical real. One scientist, for instance, proposes that the move towards viral elimination in policy has been made 'on the back of no real studies', because projected elimination has 'captured people's imagination' as 'the right thing to do'. Enumerated projections of 'amazingly effective' treatments side-step the need for 'getting empirical evidence' [#58]. According to this scientist, this is a case of the 'drugs are so good, and the models look OK', to the extent that there is 'no equipoise'. Apparently, we have become epistemologically (and ethically) out-of-line, because we have models, not evidence:

Where is the evidence that hepatitis C treatment as prevention works empirically? [...] A real world result is what is the prevalence of hepatitis C in the population? Has it fallen? What's the incidence? And that is what we're waiting for.

[#58]

Practices of holding-on thus coordinate how models move as evidence. Critically, models move as evidence in relation to their situated practices of enactment and afford precisely this flexibility as an effect of being performed as devices which ‘stand between’ different data forms and epistemic regimes (Bauer, 2013; Hacking, 1995; Sismondo, 1999). To illustrate this point, we can notice how scientists concerned to hold-on to models as evidence-based science also let go of models as affordances of movement in different situations of practice, such as in relation to policy and advocacy. This is the ‘model multiple’ in action. It helps to appreciate that what actually counts as evidence is an effect of how enumerated projections are made-to-matter as situated concerns.

Let us take the translation of enumerated projections into quantifiable targets of viral elimination policy as the example. These targets might be ‘arbitrary’, they might be ‘unrealistic’ and ‘unachievable’, they might be ‘impossible to measure’, they might be ‘made’ rather than ‘evidenced’, yet they have ‘currency’ [#58]. They are ‘a handle’ in a conversation [#58]. That projections and targets perform a virtual precision (as we have argued above) enacts a resource for making a difference. While imprecisions can be performed as a problematic for evidence-based science – linked, for instance, to theoretically driven but empirically ungrounded projections – this flexibility affords enumerations a useful power-of-acting in the fields of policy, advocacy and intervention. This fluidity, this movement, enables ‘good things’. It generates a qualculative space, beyond calculus, beyond the actualised real, to evidence-make policy in relation to ‘the right thing to do’ [#58]. Enumerated projections are multiply performed as epistemological concerns in response to how they combust beyond calculus, and as ontological concerns to make evidence that can be put-to-use to get things done. It is the virtual precision of models and targets that enables such movement and multiplication. As put by one modeller on performing projections as ‘hard numbers’: ‘Decision-makers like hard numbers, so you have to hedge your bets a bit’ [#62].

## DISCUSSION

Using hepatitis C viral elimination as a case study, we have treated the enumerated projections of mathematical models and quantifiable targets not as mere numbers and calculations, but as relational beings (Verran, 2015) and qualculations (Callon & Law, 2005), which make effects and affects as excitable matter (Myers, 2015). This is helpful because it notices what enumerated projections do, in social practices, as matters-of-concern, beyond their performances as matters-of-fact in an evidence-based science (Latour, 2004a). Our analysis contributes by tracing how projections and targets take flight beyond their calculative origins as excitable and affective matter, and by accentuating that projections do not need ‘actual numbers’ or numerical precision to have authority to perform, either as evidence or as intervention when situated as matters-of-concern. The virtual precision of modelled projections affords them a fluid evidence-making potential beyond calculus. We make three conclusions: projections are relational beings, with the evidence produced by models generating affects in relation to socially situated concerns; the evidence-making and intervention potentials of models are also shaped by epistemological attachments to how science is done, including ‘holding-on’ to ‘evidence-based’ imaginaries; yet another, more open, modelling science is possible.

### Relational beings as excitable matter

Our first conclusion is that enumerations are ‘nothing’ without their practices to perform them (Callon & Law, 2005). Enumerated projections are afforded value as relational practices (Verran, 2015);

they count as concerns (Latour, 2004a). We have traced how enumerated projections of hepatitis C treatment-as-prevention transform as viral elimination concerns as they are moved, in relational practices, into new networks. Our analysis emphasises projections and targets as 'evidence-making interventions' that perform authority, and generate affects, through a virtual precision. We find that the 'actualisation' of enumerated projections and numerical targets as matters-of-fact through quantified measurement co-exists with enactments of projections and targets as affects and concerns. We move from treating enumerations as mere numbers to enumerated entities (Verran, 2015); things which are more than 'just numbers' because they are afforded power according to how they are materialised as relational beings. Projections then, like all actors, generate 'unpredictable effects' and 'surprises' through their assemblages of implementation (Law & Mol, 2009: 74). As excitable matter (Myers, 2015), there is nothing fixed or predictable about predictions.

### **Evidence-making attachments: holding-on and letting-go**

When excitable models transform beyond their imagined boundaries of reasoned calculus, they can be enacted as a problem for science. As we have shown, enumerated projections taking flight generates an 'after-the-event' onto-epistemological concern for evidence-based scientists, presented as a need to pull back and tame the liveliness of enumerated transformations. This is performed as an effort to take better care of how enumerations travel. Inspired by the work of Gomart and Henninon (1999), we refer to these recursive moves as practices of 'holding-on' to models as performances of evidence-based science. Holding-on enacts models as evidence differently to practices of 'letting-go', such as when excitable models of treatment-as-prevention are afforded greater fluidity and movement in assemblages of policy, advocacy and anticipatory intervention, where they are alternatively enacted as matters of viral elimination concern.

This tells us three things. First, it tells us that practices of holding-on work in balance with practices of letting-go to afford an object a sense of boundary (holding-on) while enabling it to release and transform (letting-go). Second, it tells us that practices of holding-on and letting-go are entirely situated in their relations, and thus can make up and afford an object in multiple ways (for instance, holding-on in assemblages of evidence-based science and letting-go in assemblages of policy, advocacy and elimination desire). And third, it tells us that practices of holding-on and letting-go can be differently enacted in relation to epistemic and ontological concerns as well as in relation to modes of qualculation (holding-on) and non-qualculation (letting-go). The holding-on to models as performances of evidence-based science that we have described enacts a concern to make mathematical models less excitable and more measured (also literally) as a means to tackling the messiness of their unpredictable evidence-making. But it is important to note that a holding-on also enables a letting-go in other situations, such as when models enact a usability and doability in intervention and policy. We have argued that models and targets are afforded agency through their virtual precision. In some situations, too much imprecision might be constituted as problematic (for evidence-based science, for instance), and in other situations, virtual precision might be alternatively constituted as useful (for policy, and for getting good things done, and for imagining what might be). The boundary lines of the 'model multiple' are at once drawn in relation to matters of epistemological concern (how models are constituted as evidence) as well as ontological concern (how modelled evidence is made-to-matter).

Gomart and Henninon (1999) propose that letting-go links to passion. This helps envisage material effects as beyond calculative action, as events that 'just happen' in practices. Letting-go is a form of non-qualculation (Callon & Law, 2005). It is a movement, a passing through of moments of being, which is not calculative, nor qualculative, but relational and affective. It is a form of abandonment,



which does not hold on, or which holds on within certain boundary limits (as noted above). Gomart and Hennion's case study concerns the passionate effects of attachments to illicit drug use (like heroin) and music (like jazz), and how these generate affective matter enabled through practices of holding-on and letting-go. We are proposing, following Myers (2015), that attachments to science and other forms of evidence-making can likewise be understood as affective matter. We are imagining that enumerated projections, as excitable matter, potentiate passion, desire and affect, and that this relates to how enumerations move as evidence in situated practices. Our case study has shown this in the ways that enumerated projections of treatment-as-prevention transform into viral elimination through affects and anticipation. Anticipating a future in which disease is eliminated, in the now, and at the level of populations and nations, excites. The excitable matter of enumerated projections suggests that it is not so easy to 'draw a line', especially after-the-event, in relation to an imagined epistemic boundary as a practice of holding-on, once models have let go. This introduces our proposal, and final concluding point below, that we might think about modelling sciences differently in relation to how they enact agency, and specifically, whether we might re-imagine how they perform as evidence-based science.

### **A more open modelling science**

A key point in the analysis offered by Gomart and Hennion (1999) is that holding-on to enable a letting-go to accomplish a sense of abandonment is a skill: 'It is not exclusively passive; it involves the participation of both the person and the object' (1999: 227). The conditions of passionate abandonment have to be made: 'active work must be done in order to be moved' (1999: 227). Myers (2015) makes a parallel point in relation to protein modelling as an affective practice. Drawing on Latour's observations of how perfumers train their noses to distinguish the finest notes of a fragrance, and in so doing, learn to become articulate with their practice (Latour, 2004b), she describes how protein modellers learn 'how to be affected' by their models, and how this is at once a passion and a skill. We are therefore proposing a different modelling science, one attuned to noticing and engaging with models as excitable and affective matter. This implies a different kind of skill to reasoned calculus and evidence-based science. It accentuates travelling with, and being moved by, enumerations as they themselves transform as they are let go in different assemblages. Rather than enacting excitable models as a problem for evidence and a problem for science, and seeking to re-stabilise these objects according to their imagined fixed epistemic regimes, it notices the work that enumerated projections are actually doing as ontological interventions and, in turn, opens up the possibility of a different modelling science.

Rather than holding on to enumerations as if separate to their materiality, and to science and evidence as if it were separate from practices, the products of modelling science – models, projections, targets – can be approached on their release as entangled relational beings in assemblages of 'evidence-making intervention' (Rhodes & Lancaster, 2019). Models afford movement and novelty – in evidence and intervention, through effects and affects – because they generate a space of qualifications mixing with quantifications and because they 'stand between worlds' of the material and theoretical, actual and abstract, pragmatic and representational, and present and future (Callon & Law, 2005; Morgan & Morrison, 1999; Sismondo, 1999). It is precisely because models are a somewhat 'messy category' (Sismondo, 1999), enabling movement between different forms of evidence and expertise, that affords projections their latitude and potential as they transform as objects in policies and practices. Once we appreciate that models enable a letting-go, where a virtual precision potentiates an engagement in variable forms of evidence, we attune to projections enacted as excitable matter; that is, as situated and emergent matters-of-concern rather than as singular or stable matters-of-fact

(Latour, 2004a). This invites a different way of doing evidence, one not merely attuned to epistemological attachments in relation to how numbers are 'evidence-based' in their correspondence to an underlying real, but one more open to how enumerated entities are 'evidence-made' in multiple ways through their emergence in practices. It is our contention that we might *let go* to work with models in new, more open, relationally contingent and excitable ways.

## ACKNOWLEDGEMENTS

We thank our participants who generously gave their time to work in dialogue with us. This project is supported by an Australian Research Council Discovery Project grant (DP210101604). The Centre for Social Research in Health at the University of New South Wales (UNSW) is supported by a grant from the Australian Government Department of Health. We are grateful for support from the UNSW SHARP (Professor Tim Rhodes) and Scientia Fellowship (Dr Kari Lancaster) schemes.

## AUTHOR CONTRIBUTION

**Tim Rhodes:** Conceptualization (equal); data curation (equal); formal analysis (lead); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); writing – original draft (lead); writing – review and editing (lead). **Kari Lancaster:** Conceptualization (equal); data curation (equal); formal analysis (supporting); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); writing – original draft (supporting); writing – review and editing (supporting).

## ORCID

Tim Rhodes  <https://orcid.org/0000-0003-2400-9838>

Kari Lancaster  <https://orcid.org/0000-0002-2411-7970>

## ENDNOTE

- <sup>1</sup> In this first published model of hepatitis C treatment-as-prevention, Zeller et al (2010) investigate how engagement with methadone substitution treatment alters hepatitis C prevention. An endemic steady state of hepatitis C prevalence is projected to be lowest (4.2%) when 42% of those not in methadone treatment receive hepatitis C treatment, assuming that 50% of the total population of people who inject drugs are enrolled in hepatitis C treatment. The critical treatment level (60%) theorised to eliminate hepatitis C required an optimal allocation of hepatitis C treatment of 85% to those not in methadone treatment and 15% to those in methadone treatment. The study therefore projects methadone treatment engagement to be a key element maximising the prevention effects of hepatitis C treatment.

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**How to cite this article:** Rhodes T, Lancaster K. Excitable models: Projections, targets and the making of futures without disease. *Sociol Health Illn.* 2021;00:1–22. <https://doi.org/10.1111/1467-9566.13263>