An exploratory case study analysis of the role evidence based communication plays in GP referral rates

Andrew White
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Abstract

Decreases in the number of GPs, increase in per-patient consultations and ageing populations are placing growing pressure on primary healthcare services around the world. At scale, effective public health initiatives are seen as a ‘prevention is better than cure’ solution to the long-term mitigation of these challenges. Health authorities offering wellbeing referral services are one method by which these challenges are being practically addressed. Despite such services presenting both primary care practitioners and their patients' additional support, they can be underutilised, through lack of awareness or misrepresentation in a domain where evidence-based medicine is de facto. To effectively measure and optimise their communication initiatives, health authorities face a need for structured tracking and analysis across services often outside of their control.

This study reviews the way in which GP referral data can be used to better inform strategic professional medical communication decisions. A cross-discipline, innovative approach is proposed for the measurement of communication activity efficacy in a public health environment. Through means of case-study research, a chronology of archival public health communication interventions was captured. The effectiveness of the interventions was quantified by utilising causal inference analysis of the trend in the number of referrals following targeted communication activities over a 37 month period.

The method proposed offered a flexible and relatively accessible solution to a complex problem. However, the results themselves proved inconclusive for the particular case study - this was, in part, attributed to nonspecific historic tracking of intervention delivery. Supporting analysis identified seasonality trends as affecting both the rate of referrals from GPs and alternative sources such as self referral. This suggested greater importance of patient participation in decision making as part of the referral process. Recommendations are proposed for the delivery, supervision and analysis of communication interventions at an organisational level in a primary healthcare setting.

Data analysis written in Python and submitted supporting this thesis in part of the fulfilment requirements for the degree of Master of Research can be found at the following website location https://andyist.github.io/mres/

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Contents

1. Introduction

The general health and wellbeing of a populous places direct demand upon national healthcare services, which operate predominantly in a reactive capacity. In the UK, ageing population, decreases in the number of full-time equivalent GPs per 100,000 patients and an increase in per patient consultations have resulted in growing pressure on primary healthcare (Hobbs, 2016). General practice exists at the forefront of this service delivery, acting as a catch-all to the population it serves. In the UK these services are responsible for delivering healthcare to a population of circa 54.3 million people (NHS 2016). As a subset of this, GPs have a pivotal role, translating stringent clinical governance, historically informed through research and statistical credibility, to human-centred patient care.

Placing GPs as the focus, is to look to their relatively unique position as an authoritative interface to the public they serve. In NHS England's GP patient survey (2017) "More than nine out of ten patients (91.9%) have confidence and trust in the last GP they saw [...] More than four out of five patients (84.5%) have confidence and trust in the last nurse they saw." This trust and confidence is a favourable resource when attempting to offer advice to the public about more general health and wellbeing. Taking this point further, it can be considered that the public with which they deal regularly are those often in need of improved wellbeing - acute conditions regularly being compounded by unhealthy lifestyles.

In light of these circumstances, this study considered how GPs themselves might be motivated in the task of facilitating the update of external organisations public health programmes. Such organisations include public health authorities, clinical commissioning groups, NHS trusts and various supporting healthcare clinics and services. These entities all share the common goal of improved patient outcomes, yet are functionally different. Therefore, communication between them which succeeds in positive patient care carries the greatest relevance. With a large variety of organisations complexity is to be in service delivery is to be expected, Boon (2007) categorises the interchange and interrelationships in these circumstances as 'complex healthcare systems' pointing to the delivery of outcomes as having "an inherent self-organizing property and that the elements of complex systems themselves interact in such a way that through the interplay of the elements new properties emerge that cannot be seen when investigating only the component parts."

The identification of evidence of effective communication was seen to inform ongoing improvement and best practice (Mogull, 2018). For healthcare authorities, the ability to communicate effectively is, and will be ever more important to deliver the most informed and (by extension) beneficial outcomes to their patients.

This study set out to identify how evidence based communication can influence GP referral

rates. It explores the relationship between public health bodies and front line general practitioners (GPs). It looks at how organisations like Public Health England attempt to improve patient healthcare through GP practice via referral based programs, and the communications supporting such initiatives. As a profession, the role of GPs spans both scientific-medical and public communication. As will be discussed, these two distinctive domains demonstrate both contrasts and similarities in approaches to communication.

The research questions guiding this study are:

RQ1: In what ways is it possible to assess strategies developed to facilitate better GP communication which results in a greater number of preventative health programme referrals?

RQ2: What measurable evidence can be used to support such findings?

1.1 Motivation

In 2015 the UK Government advised local councils to pursue programmes that would improve the sustainability of local healthcare efforts for years to come. In this capacity, council funding is applied to public health authorities which concern themselves with the incidence, distribution, and possible control of diseases and other factors relating to health. Baum, F. (2016) describes the impact of public health as “relevant to all countries, developing, transitional, or industrialized.” Improvements in efficacy in this area can, therefore, be considered a vehicle to offer far-reaching benefits to society.

Throughout the UK, regional, public health organisations funded by local governments are tasked with the continued adaptation and evolution of population wellbeing. One such authority addressing these epidemiological concerns is Public Health Dorset (PHD). Throughout its namesake county, the organisation refers to their operations as “Working as part of Bournemouth Borough Council, Dorset County Council and the Borough of Poole, we want to achieve Prevention at Scale – helping as many people as possible to stay healthier for longer; which is a key aspiration of Dorset’s Sustainability and Transformation Plan (STP).” This broadly defined activity is referred to as Prevention at Scale, where three specific service gaps are identified (Dorset Clinical Commissioning Group, 2016);

- The health and well-being gap
- Care and quality gap
- Finance and affordability gap

Much of this service is in an effort to work toward sustainable improvement of public health within the organisation's geographic authority.

Activities already undertaken by PHD that are considered relevant to this study include the gathering, processing and analysis of data from various healthcare institutions, trusts and public health programmes. Example outputs of these activities are understood to be used to forecast needs, inform decisions and work towards the goals set out in the counties response to the NHS England: Sustainability and Transformation Plan (2014).

The ultimate motivation being the enablement of such organisations to better utilise information they already have to provoke action by the target group (GPs) toward improved public health - a desirable outcome where the means to achieve it are not always communicated in an effective manner.

1.2 The Problem

The proposition of a national health system represents the modern face of UK healthcare, since its establishment the service has been evolving for over 70 years (*Greengross, 1999*) into the complex primary healthcare service seen today. Over this period, motivated in part by the continued development of medical practice, GPs exist in a community of medical professionals which, as a group, has become more specialist (Sur, 2011) through the application of increasingly sophisticated medical knowledge and evidence-based research. The development of this knowledge has a less clear relationship to public health, and various crossovers of actions which rely heavily upon successful communication practices becomes apparent.

Riley, 2018 studied stress factors affecting GPs, the increasing demands placed upon their service delivery, their inter-professional relationships ad expectations placed on operational procedure were all highlighted as major sources. Time with patients is one aspect of these pressures, a GP-patient interaction is on average 9 minutes 2 seconds (Irving G, 2017) - as multimorbidity and an aging population increase demand, patients want more time, when GPs have less available.

Continued professional development (CPD) places further demands upon GP time. This process represents an essential part of maintaining relevant and effective healthcare. However, the body of knowledge from which general practice is built upon is ever expanding, and with increasing complexity (Sur, 2011). For GPs to remain abreast of what is already an expansive field of knowledge must be factored into their working practice and interactions.

The complexity of healthcare communication (Mogull, 2018) also contributes it's own challenges to the dissemination of information by public health services, be this via GPs or dedicated public health authorities. This aspect and those supporting it are broadly the areas of investigation of this research project.

1.3 Scope

The question of developing a strategy toward better GP communication from sources outside of this target group is wide-reaching. There were aspects of both the research project and the nature of the focus organisation (Public Health Dorset) which acted as logical limiters to how expansive this study would be.

Considering human communication as a ubiquitous phenomenon, the study looks at the effectiveness of professional medical communication, the attributes of what is unique to this modality of communication and how they may be monitored in a quantifiable manner for the measurement of change. This is considered in the context of a cross-organisational, interprofessional environment, between public health and primary care practitioners. The includes categorising key factors that are influenced by scientific underpinning, such as numerical notations and data presentation, through to sentence formation and complexity of language use.

It should be noted that the study does not attempt to propose new methods of professional medical communication, drawing only upon existing research to measure and contextualise effectiveness. It therefore addresses how these known attributes can be measured with intent to optimise communication practice and affect operational change with GP's.

The study was conducted over a nine month research period, in this time all data acquisition, case study organisation investigation and methodological research had to take place. The availability of key decision makers and staff who were directly involved with the development of the programme, and their ability to provide archival data and historiographic information were critical to such a process.

Working in partnership with an external client as identified by the funding of this research, Public Health Dorset, the scope encomeases some of their challenges. Their underlying desire to apply the practical principles that could be derived from the results of this study to their operational practice. This factor did not lead the research, but it did influence some of the wider scope decisions that might not be seen in a purely academic investigation.

The geographical administration of the subject organisation would limit data to individuals within the county of Dorset. Unlike a national audience source, this point represented an immediate limitation of the populous characterised in the archival data collection. The research conducted can instead be considered a pilot study, with principals and methodological decisions that would infroma a national scale equivalent.

The participants of the study, those who existed in the archival data sources would be representative of genuine respondents. This was hoped to offer credibility to any conclusions

drawn from the research and would identify any important limitations for any subsequent studies of a similar format.

As part of the case study organisational remit (discussed previously) multiple programmes were/are in operation to achieve long-term public health goals. Focusing on one such programme allowed for a logical reduction in the scale at which this study would need to concern itself. One such programme which most suitably reflected the problem space was titled Live Well Dorset (LWD). Launched in April 2015, as part of a restructure, various wellbeing services were unified by Public Health Dorset under this one collective name. The Live Well Dorset service is freely accessible to the public who can register through various channels - one of which is in consultation with their GP. Through informal meetings with Public Health Dorset staff, this had been highlighted as a seemingly underperforming source (in reference to no-specific expectation), and therefore offered a desirable target for the study. The programme exists as a combined service, encompassing 4 pathways; smoking cessation, weight loss, alcohol intake reduction and increased physical activity. An additional point of note at the time was the development of a bespoke case management system that included an innovative management process designed around the COM-B behaviour change model (Michie, 2014). This was considered a unique advantage of the service to both practitioners and patients.

The COM-B aspect of the programme offered a relatively unique opportunity in the direction with which to take the study. Initial research was conducted to understand the potential impact of this aspect as part of the wider research question and formed part of the literature review but was later discontinued due to the relative lack of credible data.

Public Health Dorset regularly works with various healthcare data sets collected across their local authority, these are managed and presented via the web-based business intelligence service, Tableau. Initial investigation showed the data collected by the LWD system had already been presented in an analytical form to the extent of top-level categorisations and totals with regard to the various pathways of interest. Tracked quarterly, these included a number of pathway enrolments such as client progress against arbitrary goals such as weight loss (>5%) or a reduction in cigarettes smoked, etc. There was therefore extensive scope for a more rigorous understanding of correlations between client demographics, outcomes, clients who go onto adopt other services and the aforementioned GP referrals.

Attributes of both the LWD programme and cross-organisational communication by which it was delivered introduced analytical complexity. No systematic process to relate these sources of information was apparent from the discussions that took place. It was also of note that the organisation desired that any research to ideally achieve a practical outcome which could be applied to improve the service through procedural change, should potential benefits be identified.

Given the nature of LWD's available data and the desire for practical outputs, delivering evidence-based communication offered an obvious line of enquiry.

In consultation with key decision makers within the case study organisation, it was identified that no formal working practices were in place to standardise the professional communication efforts undertaken by programme organisers. More specifically, programme managers would agree an information delivery method and undertake the steps needed to deliver it without a method of measuring effectiveness. This activity was exemplary of the need for this research project and how it may improve the process toward better public health service delivery.

1.4 Outline

Chapter two concerns itself with a review of existing literature, this begins with specific identification of practical attributes that contribute to, detract from, or are incomplete when identifying effective professional medical communication. The literature review identifies a lack of domain specific research for measuring the effectiveness of communication activities across large heterogeneous structures. It subsequently looks to other domains of knowledge such as UK healthcare as highlighted earlier in this introduction.

The considerations and decisions made during the development of the research methodology are detailed in chapter three. The focus organisation, Public Health Dorset, and their range of sources made a case study strategy applicable, this was seen to utilise the data sets available for statistical modelling. To compliment this, the explanatory nature of the archival material available was undertaken in an inductive approach. Three core areas were identified as relevant to the research and analysis; attributes of professional medical communication, chronology of communication interventions, referral counts and demographics.

The fourth chapter systematically defines and details the results of the research. These are divided in a similar structure to the methodological approach considerations; the captured historical communication activities as an intervention chronology, followed by referral stratification for demographic sanity checks and time series analysis in the form of trends and seasonality.

Chapter five discusses the results, their relative significance, any anomalous findings and their cross-reference relationship when considering the purpose of the research.

chapter five discusses the results and their relative clinical significance. These results regarding/of the referral rates by GPs are reviewed in context of their relationship to communication provided by public health Dorset. We look at data relating to the impact of several variables of communication such as type, and timeframe, on these outcomes. Additional

anomalous findings obtained while running the aforementioned analysis that are felt to be of potential relevance or interest in the context or future direction of this study, will also be reviewed

Chapter six re-visits the results and discussion in such a way as to draw conclusions when evaluating the question this study set out to answer. The overriding feature of this research highlighted the importance of quality of communication tracking at an organisational level, and this point undermines the ability to accurately measure effect. To this end, further research is proposed.

2. Literature Review

2.1 Introduction

This chapter identifies attributes of professional medical communication and it's contrast to public communication - intended to be a more commonly understood paradigm. It attempts to establish the factors affecting professional medical communication and what, if any, practices have been found to invoke behavioural change amongst domain specialists. Where possible this is done so with a particular focus on general practitioners. The chapter goes on to review how it may be possible to facilitate the propagation of new ideas and procedures through continued evaluation of efficacy. To this end, the chapter provides a body of knowledge around identification and measurement of effect communication interventions can have in healthcare settings as identified in RQ1 from the previous chapter. These factors are to be understood in the context of complex organisational structures and the multiple systemic interactions discussed in chapter 1.

It is important to consider that within scientific and medical communication itself various levels of expertise and comprehension within specialisms exist. Effective communication is sympathetic to this variance by considering the levels of understanding of both specific subject matter and language of the intended audience (Mogull 2018).

Spiegelhalter's (2019) publication exemplifies many of the features of effective communication discussed later in this literature review - the use of accessible language and explanation of complex topics without the loss of technical credibility. These are backed up by clear summaries to elucidate key points and the use of commonly understood phenomena as examples.

2.2 Professional Medical Communication

2.2.1 Background

Professional medical communication literature presents a large corpus of interrelated information, the overview which follows, represents a cross-section of the factors that can be drawn upon to improve communication with general practitioners within this target domain. As a proxy between public health providers and the public they serve, the review considers the importance of interprofessional communication. This is explored in such a way that it may inform the problem in question - what attributes of communication can influence GPs, specifically in decisions surrounding the referral of patients to public health services.

Factors which affect GP referral rates will be heterogeneous by nature, intuitively, even a basic understanding of the role in which they play in healthcare, and the healthcare organisations within which they operate could be considered an example of a complex adaptive system (Goodwin, 2013). General practice within the UK takes various organisational forms where

consistency of internal and external communication can differ from practice to practice and GP to GP. This is further influenced by the varying staff and underlying processes which exist to support these services, and in-turn the range of professional bodies which govern and promote healthcare practice and their relationship to public health (The Kings Fund, 2017). In practical terms, the systems described, result in polymorphous communication considerations, forming complex linkages between information publishers and their often diverse targeted recipients.

The volume of literature sees a disproportionately small number of studies carried out in the field of professional primary care communications when compared to those which address public to primary care interactions. This can be explained by considering the relative audience sizes of primary care physicians to their patients - in the UK for example, the NHS employs 150,273 doctors and 40,584 general practitioners (GPs) which service a population of 54.3 million people (NHS 2016).

2.2.2 Attributes and outcomes

The combination of negative outcomes identified by Vermeir (2015) and the key elements of professional medical communication initiatives proposed by Schiavo (2007) offers a generalised overview for consideration when developing professional healthcare communication materials (Figure 2).

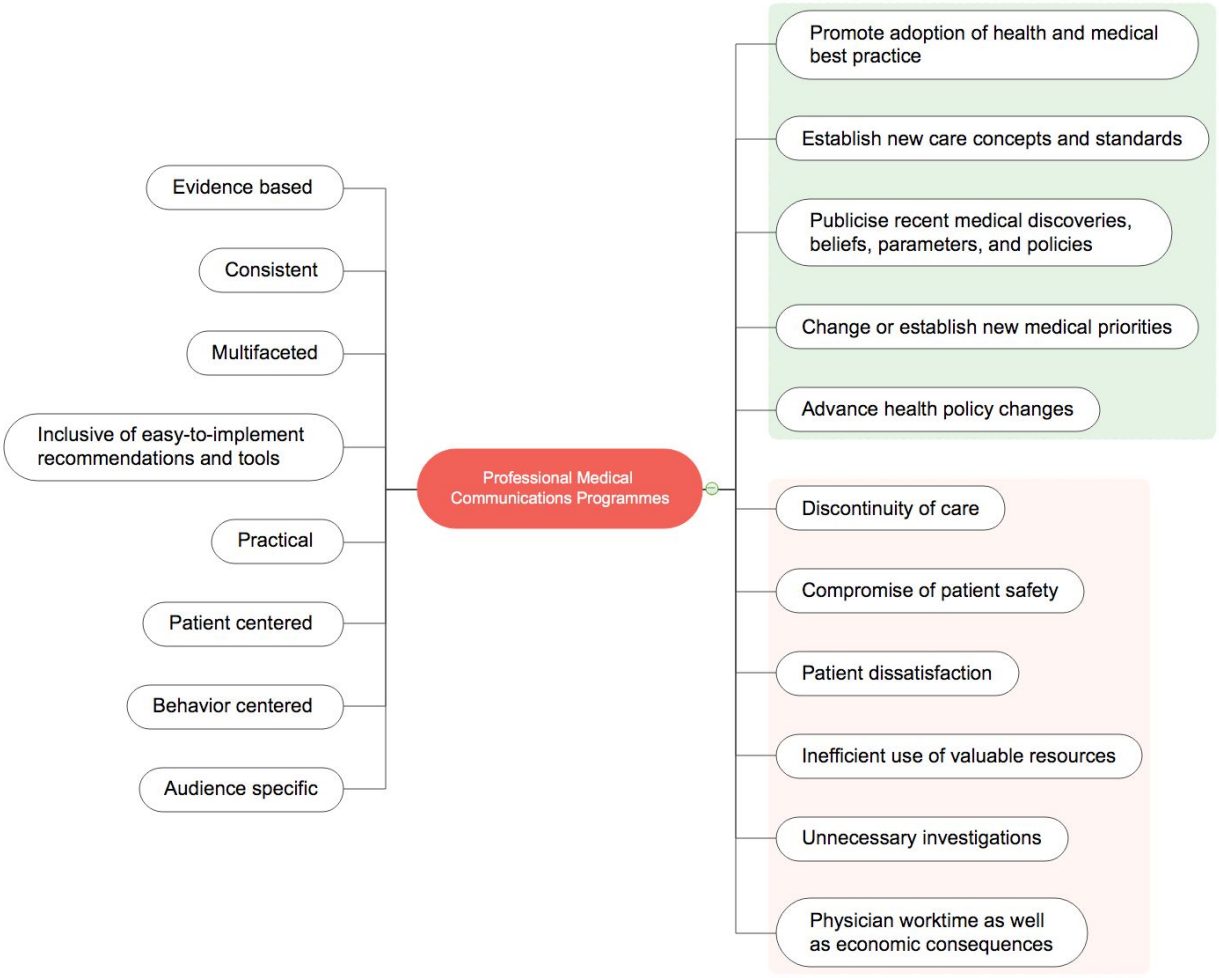


Figure 2. Attributes and potential outcomes of professional medical communication, items on the left constitute attributes of professional medical communication and the items on the right outcomes, split by green - positive, and red - negative. (personal collection).

When considering the outcomes (*Figure 2*) in a context of motivational factors, there is the opportunity to frame healthcare programmes such that they will deliver one or more of the positive outcomes, or prevent one or more negative outcomes. In other words, despite best intentions, poor communication practice is not only suboptimal in achieving its intended outcome, in some cases, it can also have wider negative impacts to healthcare practice. Opportunities for improvement could, therefore, have a significant impact on the improvement to healthcare.

Medicine and medical practice as a domain of knowledge has developed over the past 25 years as a direct result of empirical research in the form of evidence based medicine Sur (2011). Results produced through scientific evaluation have underpinned modern practice and process - the language of science is, by extension, also the language of medicine. This aspect is what

(generally speaking) both separates medical professionals from their patients (the public), while at the same time binds them inter-professionally through a common lexicon and discourse. Discussion of the merits and shortcomings of evidence-based medicine are outside the focus of this document and should be considered an expectation within the medical domain.

2.2.3

Evidence-based communication typically relays information that often includes numbers and statistics such communication always involves representation choices (CITE). When dealing with more complex data, various interpretations have the potential to influence the comprehension, and even the meaning conveyed by the figures. In this sense, consideration is given to domain specific conventions. Akl (2011) identified that health risk outcomes were "better understood when [...] presented as a natural frequency rather than a percentage" e.g. '65 of our 215 respondents' rather than '30%'. It was also concluded that "on average, people perceive risk reductions to be larger and are more persuaded to adopt a health intervention when its effect is presented in relative terms" e.g. 'one third better off when you do X'. Statistical formats were found to have no discernible difference in influencing professionals and consumers.

Looking at existing authoritative communication guidance for the current state of recommended professional medical communication practice, there are numerous examples of clinical commissioning group (CCG) strategies and guidelines. These focus primarily on patient communication and their content is not anchored in academic literature or research. A review of the volume and variation available across each healthcare authority by which they are written could represent a systematic content analysis research project of it's own. Of the documents reviewed, the general understanding of challenges faced in healthcare communication are highlighted, but in aggregate appear as though they offer relatively non-specific strategies rather than practical, actionable advice. This situation poses questions around the quality and consistency of advice being made available. This point itself being a large focus of this research. "Tools and routes" represented an example which includes detail on interprofessional communication, and referenced survey results to justify the claims, but is still not formulaic in nature.

Vermeir (2015) conducted a systematic review which identified face-to-face communication as being the most effective at producing the desired result - behavioural change. In part, this was shown to be due to the additional information body language conveys and the immediate ability to clarify complexities. There are obvious limitations to this means of communication making it regularly infeasible, especially at scale. Although, geography has become less of a concern as real-time video service becomes more readily available. A "consensus about particular advantages of written communication over face-to-face communication" was also identified by the study, namely; immediacy (in digital form) having no requirement for arranging meeting times - as would be the case with face-to-face communication. Reproducibility was also seen as

an advantage and, by extension, the ability to reference written assets. There are further advantages dependent on the method of distribution, such as email, where the ability to track engagement representantes a further advantage.

In the context of modern society, email is commonly accepted as a largely ubiquitous channel of information delivery, both inside and outside the medical service domain. As such, it is also a desirable choice for professional healthcare communication. However, despite being such a widely used channel, its impact relative to alternative modalities is not properly understood. Goyder (2015) found no evidence base to derive meaning from the use of email between healthcare professionals, suggesting rigorous studies would be required in this area. Berendsen (2009) study of the communication between 259 GPs and 232 specialists showed the use of multiple communication mediums including email. Disparities in the perception of effectiveness between the groups suggests to the researcher an element of 'better than average' bias exists and the value of self-evaluation responses to questionnaires should be approached with caution. Both GPs and Specialists showed 94.9% and 89.0% respectively that feedback was an important factor. This is a particularly prominent feature of the study and points to considerations that there is more to the process of effective communication than the point of intervention.

Mogull (2018) describes effective communication as presenting "a clear, logical, and persuasive argument articulating a case in which the evidence information (data) justifies a particular insight, interpretation, or conclusion." The review of over 500 published research findings is itself exemplary of the complexity of scientific medical communication (SMC). Information in this form would not be feasibly transferable to health staff without them becoming specialists in research publication.

The way in which evidential authority is derived - through research and studies that employ scientific method - requires demonstratable statistical significance in the findings. This process, at scale, goes on to guide decisions that become national healthcare policy. Scientists who write and subsequently publish this research are rarely specialists in communication as well as their field of expertise. They typically learn both writing style and language from the professional materials they have consumed previously through education and research. These materials are themselves written and published by other scientists, rather than persons specifically trained in communication. A process of imitation follows, creating a feedback loop of communication practice. This aspect makes scientific and medical communication susceptible to the self-perpetuation of poor practices and increasingly inaccessible language. In other words, publications are often not optimally designed and written for their primary purpose - transferring knowledge (Mogull 2018).

A tangible example of the differentiation between specialist medical communication and public discourse can be identified by the Lexile score comparison of popular media (newspapers) and that of scientific journals divergence over time (Knight 2003 cited by Mogull 2018). The Lexile score is used to measure reading comprehension; when evaluating text, a score is given based

upon algorithms which “analyzes the text's semantic (word frequency) and syntactic (sentence length) characteristics and assigns it a Lexile measure” (MetaMetrics 2019). In the case of Knight 2003 study, This divergence in language complexity (Fig 1) shows, in part, how scientific communication has become continually less accessible to the public over the last century. There is however no indication of the rate at which popular language has transformed against itself over time, that is to say it will be changing independently in its own right. Simplification of language can be used to make content indiscriminately accessible to the broadest populous (Agarwal, 2013). In that sense, the rate at which divergence has increased could in part be a result of *dumbing down* in mass-media as an attempt to expand audiences, increasing the gap between popular material and scientific literature.

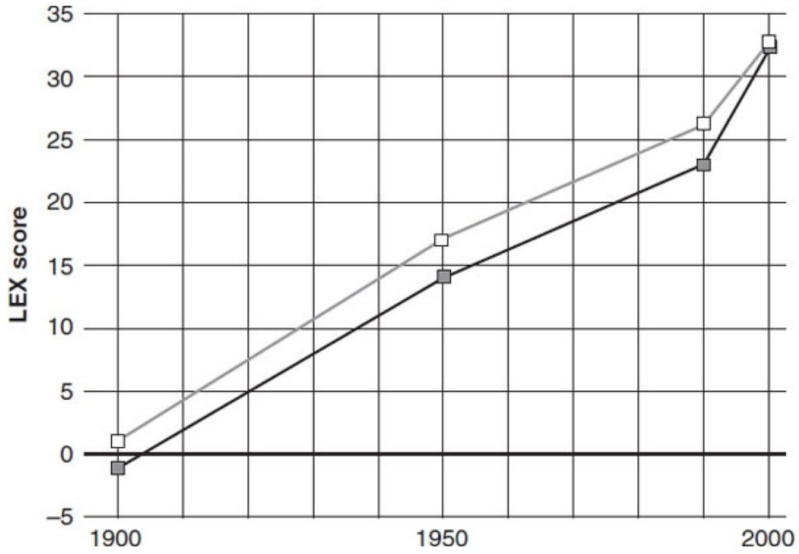


Figure 1. The lexile scores of both Science (top line) and Nature (bottom line) are seen to have dramatically increased compared to the baseline (0) of popular language defined as that used by newspapers over time. Source: Knight (2003).

“For healthcare providers, poor communication leads to additional workload as it decreases confidence in decisions” (Vermeir 2015). While this is in the context of referrals, it would be logical to suggest that additional workload is always seen as a negative if it could be avoided. It is, therefore, inferred that the opposite outcome can be considered a positive, and can be a target of effective messaging. Considering this in reference to message framing, it would suggest that positive effects (specifically around reduced workload) could offer the shift needed to improve uptake of public health communication.

It is often the case that evidenced-based information can also be framed both positively and negatively in its own right. People tend toward risk aversion when presented with positively framed information, and tend to seek risk when presented with negatively-frame information (Tversky 1981 cited by Akl 2011a). The results of Akl (2011a) systematic review did not,

however, identify a consistent impact on outcomes in either case. This suggests that both approaches are as effective as one another, or as ineffective, depending on the observer's frame of reference.

Within a practice-based environment, GPs typically work alongside various other medical professionals; nurses, practice managers, other GPs. Dadich and Hosseinzadeh (2016) examined the channels by which “primary care clinicians learnt of resources on evidence-based sexual healthcare”. The study found educational events and colleagues to be the most significant source of awareness. However, the method by which clinicians learned of resources did not appear to influence the perceived impact or, by extension, use of the resources in question.

Cognitive speech actions represent a specific class of interaction, “expressing an expert’s opinion” which serves to “impart information and as a vehicle for the production of new professional knowledge among peers” (Akl 2011b). The review also clarifies that ”It is conventionally accepted to soften categorical judgments and negation to develop communicative process in an effective way." Professional conversations between GPs in informative sessions have a formulaic structure and a basic narrative structure (Shamne and Nevzorova 2017; Horder 1986). Polite and well-structured language is typically expected, slang and other short forms should therefore be avoided unless contextually significant. Looking toward other domains that have progressed data communication best practice, specific similarities can be seen. Knaflic C (*2015*) describes data communication through narrative structures for increased engagement. Aspects such as treating the viewer as a contemporary as having similar/shared knowledge should not be assumed, echoing that of variation in specialist knowledge as mentioned previously (Mogull 2018). There are however, noticeable stylistic differences in the literature itself. Generally less formal, displaying more accessible language use than that of SMC - in a self-referential way, validating the aforementioned concerns of complexity found in professional medical communication.

The ideas around vocatives, appellatives and wider formal communication structure point, again, toward the importance of professional peer backing that has previously been highlighted as a key concept by Dadich and Hosseinzadeh (2016) - “The perceived opinions of peers and opinion leaders play a major part in influencing the attitudes of individual practitioners and, most importantly, their decisions to act on new information”. Historically, widespread changes to GP practice take time, a general consensus first forms between peers and subsequently the wider domain-community of practitioners. Longitudinal data would need to be available to analyse effects of this type. Identifying quantifiable associations between both multimedia and multimodal communication materials. Discernable shifts in referral behaviour could represent a means to developing the required understanding of how evidence-based communication attributes might best influence GP referral practice.

2.3 COM-B

Proposed by Michie (2014), COM-B is used for the planning of practical behaviour change interventions. The model proposes that an understanding of an individual's 'capability', 'opportunity' and 'motivation' should be used to direct the appropriate behavioural change intervention. In the 7 years since its proposition, it has gained popularity, but measurable implementations were limited at best.

The Behaviour Change Wheel: A Guide to Designing Interventions (Michie, 2014) followed the original proposition of the framework as a guide to its practical application and implementation, this resource was used by Live Well Dorset during the development of their client management system at the centre of this study. In the five years since publication, there appeared to be little in the way of other practical examples that offer this level of quantifiably tracked usage across multiple wellbeing pathways.

In 2018 Newcastle University's Centre for Translational Research in Public Health completed a study into the effectiveness by which the COM-B model had been implemented for the Live Well Dorset programme. The mapping of the theory was deemed to be to an excellent standard, however, the report was specific in its purpose and did not look to review the impact of the services it applied to (Rodrigues, 2018).

3. Research Methodology

3.1 Introduction

This chapter describes the concepts, decisions and methods undertaken during the research study. The methodology is expressed in several sections which cover strategy, approach, data collection methods and tools, and considers these in the context of existing research practices. Following this there is a short section describing the limitations and ethical implications.

The study set out to identify how evidence based communication can influence GP referral rates. As identified in Chapter 2, it became apparent that the circumstances under which such processes take place are (in-part) representational of the factors by which referrals might be influenced. It was decided that tests undertaken in controlled conditions would offer abstract findings that may not truly reflect the efficacy of primary care communication in practice, and be less relevant outside of the conditions under which they were collected.

The intent to invoke action amongst an audience through communication posed a desired outcome of increases in referral rates by general practitioners to public health services. Conceptually, it was proposed that relating attributes of professional medical communication to referral rate changes, in a real-world setting, would offer a suitable mechanism for measuring and quantifying this relationship. In turn, this approach would offer evidence to the efficacy of each intervention. To further extrapolate these findings, interventions would be classified based on their apparent communication attributes; distribution mode, modality, content.

The focus of the study was Public Health Dorset's 'Live Well Dorset' programme which registers, facilitates and monitors people and their progress through four wellbeing service pathways. In the domain of professional medicine, evidence based communication is de facto. Therefore, could a compelling evidence base be established from the existing data, and if so, how could it most effectively (with regard to increasing GP referrals) be communicated?

In summary, the methodology would need to address the capture of historic communication activities that were undertaken and would affect a GPs decision to refer their patients, and to what extent/magnitude this had taken place.

The studies discussed in chapter 2 identified a broad spectrum of communicative considerations, with experimental evidence for their efficacy on a per-attribute basis. In part, this was attributed to the relatively small sample sizes as a result of questionnaire based primary research. It can therefore be difficult to see how these principles translate to emergent effects across complex organisational systems, returning to the question post in the introduction of this document, RQ 2.

Having developed an understanding of the attributes that can inform the effective use of communication activities in medical practice, attention turns to how these attributes may be measured in an active healthcare environment. In the field of public health, and healthcare research in general, measuring effect is a common aspect of many academic studies. Concerning itself with the study of populations and the effect of a given treatment on those people, it is common practice to identify distributions of demographic information across a sample set, and quickly review cross-comparisons. Requirements such as these find stratification a common solution to summarising study data (Leyland, 2016).

Where stratification becomes infeasible due to exponential growth in cross comparisons such as hierarchical data, multivariate (or multilevel) analysis (MLA) is required, Mitchell (2011) summarises the advantage of this approach as "It allows you to simultaneously assess the impact of multiple independent variables on outcome." Furthermore, multilevel analysis also helps for the nearly unavoidable nature of various sample sizes. Statistical analysis approached from a healthcare research perspective caters to a domain which requires identification of response to medical treatments or interventions. Coupled with the communication literature reviewed previously where typically the approach to the measurement of efficacy was through the use of survey results, these appear to be limited in the ability to comprehend the overall effectiveness of interrelated, inter-organisational communication. A more general approach should be offered; one which could strategically inform healthcare organisations when developing their communication strategies.

Considering the time to see perceivable change in healthcare practice as identified by Dadich and Hosseinzadeh (2016), it stands to reason that trend analysis would be best suited to longitudinal data (Nakai, 2009). More specifically, in the case of GP referrals, time series data offers a suitable line of enquiry, as an already widely researched area of statistical analysis. Of the various approaches available relating communication activity effects on GP referrals would require identification that a causal relationship could be inferred. From a statistical standpoint this is a nondeterministic consideration, and requires comparison of what did happen and what would have happened without intervening (Spiegelhalter, 2019).

Taking a step away from the healthcare domain, statistical analysis in this capacity is an area which more commercial entities are already addressing at scale. From the literature of recent years, the ever increasing ubiquity of digital data capture sees large media corporations, those with funding for digital services well beyond that of healthcare, investing in statistical analysis and prediction towards the identification of effects and causal inference in time series data (Taylor, 2017, Brodersen, 2015). These solutions include mathematics far beyond the scope of this study, and the expertise of the researcher, however, importantly they have been actualised as usable tools (code libraries) removing the requirement for advanced statistical experience.

3.2 Research Strategy

Studies reviewed in Chapter 2 did not identify a specific method for measuring the effectiveness of primary care communication materials or programmes. It was therefore necessary to establish what constitutes effective professional medical communication. In other words, a system by which the primary care communications could be quantified.

With a focus on practical, real-world systems, while at the same time existing within the healthcare domain, Action Research was identified as a potentially suitable methodology choice. However, as the ownership and delivery of the research was to be conducted externally to the organisation, this did not represent a methodological best-fit (Denscombe, 2016). Intuitively, the situation presented what is more generally considered a case study scenario, and as an approach to the research, this methodology would accommodate the variety of sources, types of data and exploratory research methods which had been identified as being necessary during initial investigations.

The case study organisation presented a variety of archival source data options in varying formats which were interrelated yet not analytically compatible at source. Each source would require varying levels of processing before analysis could be conducted - both quantitative and qualitative. In the wider context of the desired outcomes of the research, the methodology would also need to address the real-world and change-centric desires of the target organisation.

Structurally, the research took the form of a part-interpretation of Kothari's (2007) five phases of case study research. The interpretation and proposed implementation of each phase is introduced and described as follows:

> "(i) Recognition and determination of the status of the phenomenon to be investigated or the unit of attention.
> (ii) Collection of data, examination and history of the given phenomenon.
> (iii) Diagnosis and identification of causal factors as a basis for remedial or developmental treatment.
> (iv) Application of remedial measures i.e., treatment and therapy (this phase is often characterised as case work).
> (v) Follow-up programme to determine effectiveness of the treatment applied."

For the purpose of this study, (i) was satisfied by the relationship between GP referral rate and communication interventions in the context of the attributes of these activities. The second aspect of the research (ii) was proposed as the collection of archival data across three areas which would together inform:

- Definitions of historical intervention activity (qualitative)
- Referrals data (quantitative)

- Attribute classification of professional medical communication (qualitative)

The diagnosis of causal factors (iii) would reply upon analysis of the aforementioned data collected through statistical analysis where relationships between intervention events were identified.
Time constraints of the study would limit the ability to achieve phases (iv) and (v), yet the results of the study were to inform such next steps for the purpose of further research.

In the first instance, a matrix of professional healthcare communication best practices was developed from the literature review corpus. To ensure relevance to the case study organisation, points extracted were considered to be practical in application, and applicable to Public Health Dorset's communication capacity.

The quantitative data representing efficacy of the communications was to be achieved by identifying associative growth in the number of referrals resulting from publication within professional medical communities. These materials included attributes of effective GP communication as identified via literature review.

To evaluate the means by which it may be possible to increase GP referral rates through communication practices was non-trivial. It was proposed that associating changes in referral trends would offer a general solution, and if these could be related to communication interventions it would provide quantifiable evidence of the efficacy of each activity.

The relative complexity of the interchange between the proposed variables and the exploratory nature of the case study resulted in no formal hypothesis being proposed, it would however be a desirable outcome to identify an association between the type and delivery of evidence based professional communication and the GP referral rates. As such, an inductive approach was taken to understanding what, if any, association can be identified between various attributes of professional GP communication and the resultant number of referrals made to the service(s) target by each communication activity. To develop the initial strategy, an informal meeting was conducted as part of the initial discovery process. This highlighted 3 potential sources of information which directly influence the Live Well Dorset programme.

- Communications aimed at highlighting the service for primary care practitioner audiences.
- Focus group feedback from primary care practitioners regarding the Live Well Dorset system.
- The client relationship management system which tracks client registration and progress through the programme.

In the context of this study, GPs were considered to act as the facilitators of the case study in question. They represented the interchange between communication materials and the patient referral data. Therefore, direct interviews offered an obvious approach to data gathering.

However, as identified in the literature review, GPs have limited time, when also considering the extensive nature of the target audience both geographically and quantifiably each with varying schedules, it was decided that the scale of interview results required was infeasible within the confines of this study. It could be argued that a smaller sample would have been practically feasible, but in this particular case the decision was made to prioritise the quantity of archival data (>17K referral records) over primary data. This decision presents its own limitations which are discussed in detail later in this chapter.

3.3 Research Approach

To develop a comprehension of what aspects of communication had most effect, a framework of activities, undertaken in logical order was actioned to gather enough information to meet the needs of the strategy outlined previously.

1. Identify known attributes of professional healthcare communication
2. Catalogue and classify examples of communication activities carried out by the case study organisation
3. Quantify service referrals and associate the communication activities
4. Attempt to infer correlation where associations are identified

The researchers' approach to achieve these 4 activities is described in the following sections of this document.

3.3.1 Identifying attributes of professional healthcare communication

The literature review demonstrated a widely researched domain of knowledge and range of factors affecting professional medical communication that offer tangible examples of communication efficacy and augment the activities undertaken by LWD with categorical information. This would become a process of classifying common and recognised communication traits identified within the chronological interventions. To understand the interventions more formally, component attributes of communication intervention e.g. medium, use of imagery, language, structural format and any numerical references were to be extrapolated through a process of content analysis. Developing an evidence base would rely upon quantitative data which would be used to both guide and support communication activities, while also identifying the efficacy of the materials.

In practice, this approach to the categorisation of communication interventions resulted in a single cohesive matrix of applicable communication practices. Both positive and negative

outcomes identified in the literature were included to allow a broader understanding of what may or may not be relevant to the growth in activities as the result of healthcare communication interventions.

The process of content analysis was conducted in isolation by the researcher and was not cross validated. With additional time and resources a more stringent classification process would offer more credibility, however, the resultant artifact (Appendix A) represents a valuable resource for further research.

3.3.2 Chronology of Case Study Communication Activities

It was deemed necessary to establish a chronological record of past communication interventions undertaken by the case-study organisation. The timeline would extend as long as there was data available. This would aid comprehension of the types of activities conducted and later facilitate temporal associations between interventions and variations in referral rates over the same time period. The process to collect the relevant data was to be conducted by requesting structured responses, issued via telephone and email. The information requested was formatted and reported as a digital spreadsheet matrix pre-formatted with informational criteria. Similar to a questionnaire, with open ended capacity for distinct responses. More specifically the approach prompted the contributor, by means of titled columns, to enter relevant data on a per-event basis by completing the following fields. The collection period ran for 6 weeks with periodic reminders.

- Promotion - A short definition of the communication activity
- Source/Facilitation - Who (person, organisation) that was credited with undertaking the activity
- Asset(s) - A copy of any original assets to be supplied where available
- Date issued - The date on which the activity commenced
- Duration - How long the activity was intended to run for
- Medium - The form of distributed
- Scope of Distribution/Audience - What was the intended scale of the activity, including demographic considerations
- Description - A more detailed explanation of the activity if relevant
- Notes - Option for the inclusion of other points of interest regarding the activity

It was considered detrimental to the analysis to discard data that was supplied in formats outside of direct entries to the matrix document. Should relevant data be returned in informal/conversational responses, in response to the request email for example, it was also to be included. In these circumstances the researcher transposed the content on behalf of the responder as best fitted the proposed collection format. Such a process was open to the introduction of possible biases, and should be considered when reviewing this data. It was proposed that this process could be undertaken by multiple researches and cross referenced to help identify such shortcomings but was beyond the scope of the project resource.

The time parameter represented an obvious common relationship between communication activities and the GP referrals. This acted as the interchange between otherwise heterogeneous variables - relativising one against the other. When considering communication interventions in a linear timeline, efficacy was considered to be present if the desired outcome was sufficiently perceptible through measurement and causal inference (Brodersen, 2015). In the case of this study, the measurement would be represented by the number of referrals by general practitioners. As such, observed changes in the rate at which referrals were registered in the LWD client system could offer evidence of causation. Subsequent findings would be extrapolated to the component attributes of communication. In aggregate these relationships would constitute a quantitative base for how evidence based communication can influence GP referral rates while also informing the suitability of measurement methodology.

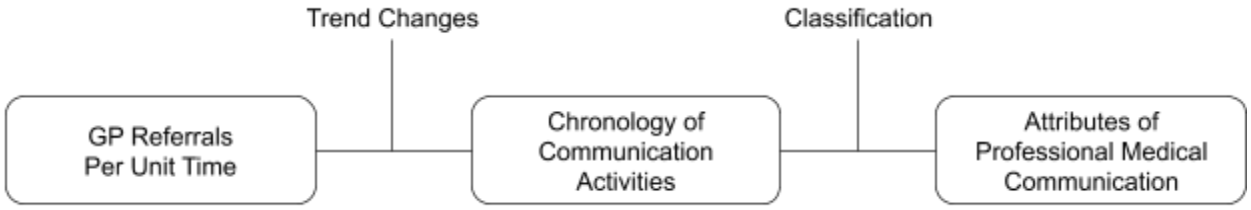


Figure 3. Relationship between referrals and attributes of professional medical communication, (personal collection).

3.3.3 Quantifying Service Referrals

The case-study organisation possessed a substantial archival data source in the form of electronic registration and client tracking records for the period 1st June 2015 to 12th January 2019. The quality of data was understood to invariably be impacted by the processes by which it was collected (at source). An initial telephone meeting was conducted with a member of staff who originally guided the development of the programme and therefore possessed intimate knowledge of the systems development and usage. From the notes taken by the researcher, the data collection process was understood and developed into the visual transaction below (Fig 4).

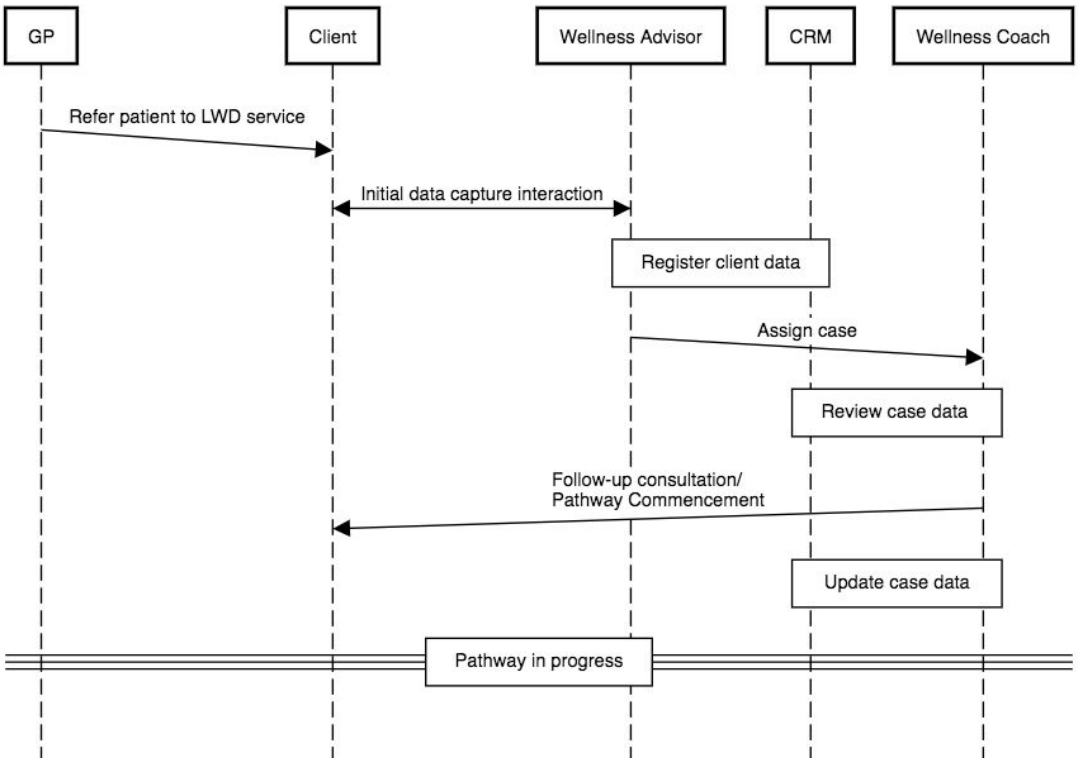


Figure 4. Example registration sequence for Live Well Dorset service, (personal collection).

In practice, the data available was analysed in an exploratory manner. *Fayyad (1996, p.5*) proposes the knowledge discovery in databases (KDD) is possible through a sequence of steps re-iterable as a process to identify and refine insights not apparent in raw form (Fig 5). The approach was adopted as a methodological process and used as a de facto approach for the analysis carried out upon the supplied dataset.

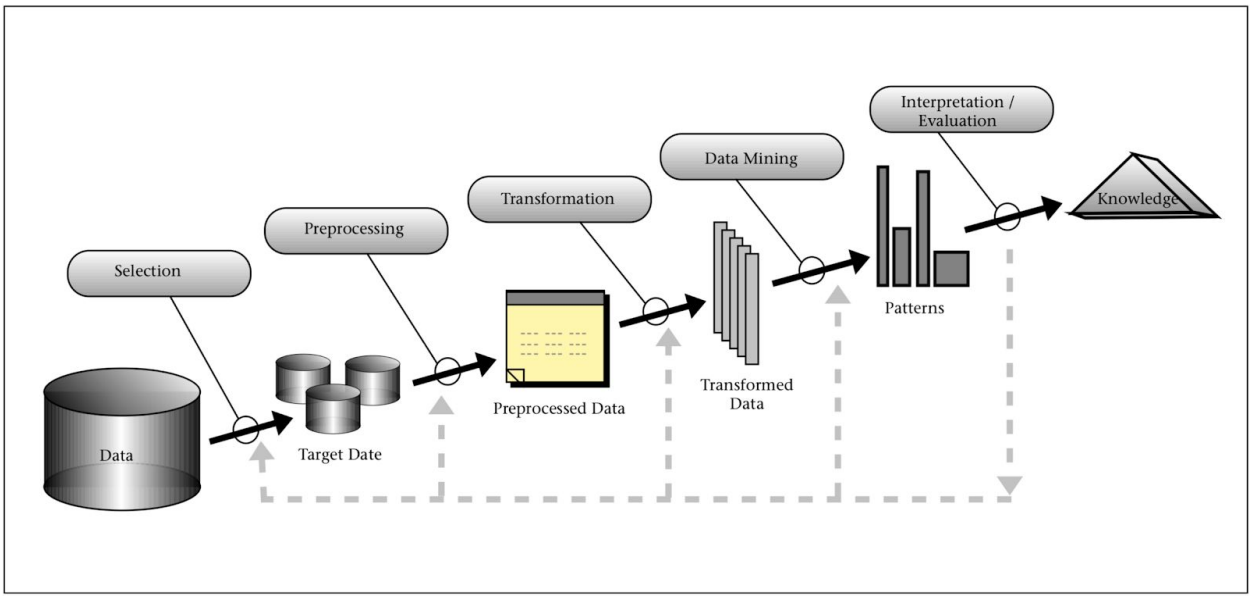


Figure 5. Knowledge Discovery Process, (Fayyad 1996, p.5).

The data supplied from the Public Health system was in a pre-consolidated format. Specific directions with which to take the analysis presented themselves through each iteration, requiring various backsteps through the sequence as logically necessary. To guide these decisions in a systematic way, a top level framework for investigatory analysis needed to be established. Decisions were to be drawn from studies identified in the literature review and practical examples.

Data collection and quality

The Live Well Dorset programme's data was collected with the cooperation of data warehouse/analysis staff at Public Health Dorset. To initially inform various methodological decisions, a request was made for the entity relationship diagram (ERD) (Appendix A), this defined what data would become available and to how it was interrelated. Having anticipated the inclusion of various irrelevant data sets, this allowed for the development of an understanding as to what would be considered relevant to the research. In an effort to make the analysis process more efficient, it was used to identify what aspects of the system could be discarded. This is a process which would be necessary when applying the same research approach to other organisations.

A subsequent meeting was conducted (21/06/2018) with database administrators and stakeholders to further interpret the available data and agree on the scope of the records to be extracted for analysis purposes. The resultant data structure can be seen below in FIG 5. The exploratory nature of the research approach concerning this area of the analysis meant a strategy which would gather as many fields that could be considered relationally relevant to each individual would be favourable. These include; physiological, categorical and demographic information. Following the meeting, an export and data delivery strategy was agreed with the database manager who would complete the data delivery task. For convenience, and where it

was deemed relevant, some data tables were also combined/flattened - a process that was understood not to have affected the integrity of the data. For the purpose of interoperability between software systems, the data itself was exported in the commonly used data exchange format of comma separated values (CSV).

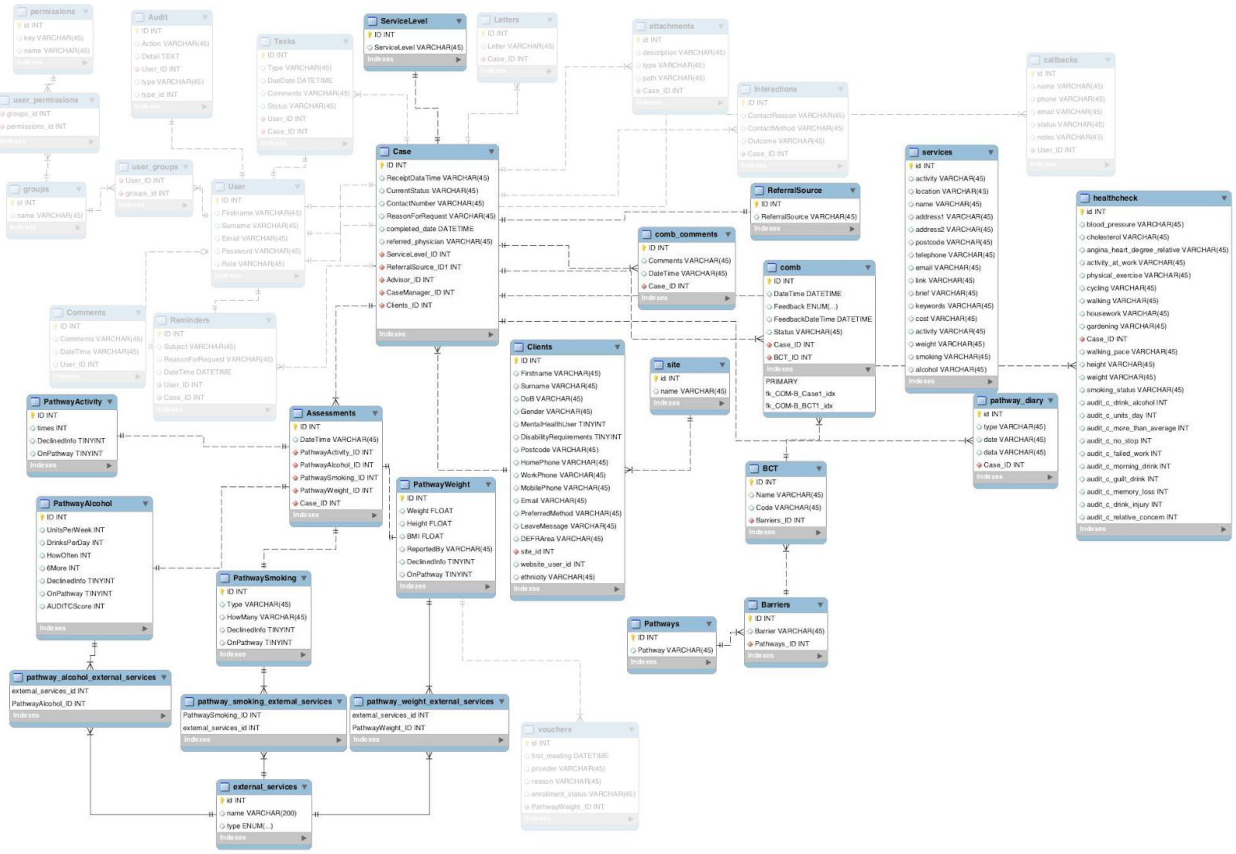


Fig 5. Reduction of supplied (Appendix B) data to only that deemed relevant to the research requirements.

As an active system that is continually collecting data, the export process was also designed to be reusable. This was to ensure that further exports could be quickly and consistently repeated as more data became available over time. Specifically in the case of the researcher's efforts, time would pass between the development of the analytical tools and so the process was made easily repeatable.

As per the specification agreed with the Public Health Dorset data team, the export was supplied on (18/01/2019). Due to its content and privacy agreements with Public Health Dorset, the data cannot be distributed freely and instead must be explicitly requested from the organisation.

Sanitisation of the data set was a key task to be carried out before computational analysis could begin. This involved cutting down to the fields within the tables of interest. Where duplicate rows

were identified, the decision was to use the initial quantities for each pathway. This was straightforward apart from the smoking per day initial reading - the column appeared to contain non-numeric values which was not in keeping with the expected data structure - investigation into mismatched columns in the source data was undertaken and resolved. Unexpected problems such as this is where the iterative nature of the data process became immediately applicable.

The process demonstrated a large potential for data inconsistency. Clients are not obligated to check in at each interval (three, six and twelve months) after registration if they do not wish. At the same time, they are not motivationally bound to the service over time beyond their original intention to improve their wellbeing. If the service were not free of charge, a financial commitment would likely see greater retention. Gross (2001) disputes this assumption, pointing to their study of the same year (Gross et al, 2001), however, the results identify what could be considered numerous confounding variables, in part, due to a specific target demographic which would not be applicable in a general study. This was not deemed relevant to the outcomes and has been disregarded. Therefore, there was an anticipation for irregular data consistency from the outset. Conversely, had a comprehensive survey (including the process of recruiting participants for the purpose of this study) been conducted, the volume of data obtained would be significantly lower than that of available from the LWD programme and not representation of the active system and processes.

Referral rate

Each registration included a range of data points (refer to Appendix B for a detailed list of all fields and their relational structure). As identified previously, the most relevant to the primary requirement of this research was the referral source and the timestamp captured at the point the client was entered into the system. Transformation of these two data points into a time series metric was used to satisfy the requirement for a ‘GP referral rate’. The dataset time variable used for this purpose was the date on which the record was registered. The field was of date-time data type and the values were found to be accurate to the minute. A brief review of the data density was conducted to identify a suitable duration of the interval for analysis e.g. referrals per hour, per day, per week, per month. The expectation was that effects of communication would at very best take days to be seen, meaning that the decision was taken to group the data. This would bin referral counts by their calendar date (removing the minute of the day accuracy). As a result of this decision the referral rate dataset was established ready for use during further analysis.

Trend and distribution

To develop a general understanding, and by extension, confidence in the referal data, a series of distribution and trend analysis processes were proposed;

- Total referrals - a univariate understanding of the total referrals over the entire time perios would identify a base to assess the relative magnitude of any records that may be identified and culled as erroneous in subsequent iterations of analysis.

- Distribution of records per month - in the context of a multi-year time series, monthly distribution of referral records was selected as a generalised method to assess the performance of the system.
- Referrals per month split by GP and non-GP (Appendix C) - splitting the record distribution by the focus variable to offer insight into its relative effect.
- Trend decomposition of the GP, non GP referral rate time series - identification of patterns brought about potential seasonal effects.

Approached as part of the knowledge discovery process, each analytical review was conducted to improve understanding of the data set in support of its ultimate purpose: causal inference of the effect of communication activities.

Demographics

An initial review of the supplied data structure (Appendix B) identified attributes suitable for demographic analysis of the client referrals. Understanding context would aid in the identification of potential confounders and biases, therefore improving the statistical confidence of any conclusions drawn as a result of the analysis. It was considered reasonable that stratification was to be used to identify areas of interest within the data. In an observational capacity, the first step was to explore data distribution and the baseline differences between groups. Specifically in the case of this research it was noted that within the case study data two groups were identified; those who were considered referred by a GP and those who were not.

3.3.4 Inferring causation

The purpose of this activity was to identify and quantify the potential effect of communication activities on the rate of GP referrals. Or, at least identify correlation between intervention types and behavioural change. A number of approaches were considered which offered statistical significance testing in time series data. During the review of the GP and non-GP referral rates it was apparent that the separation of the data was relatively poor with some inconsistent distributions. If non-GP referrals were to be considered a control, and those referred by GPs to the treatment group, then a difference in difference approach would be applicable. However, the lack of clear separation of the two populations and awareness of the flexibility of the approach made causal inference a more desirable solution. This type of analysis models the counterfactual (what would have happened with no intervention) around a discrete point in the observed time series data. In the case of this study, the number of GP referrals.

An alternative approach using statistical change detection in time series was also considered. However, with the development of a chronology of known interventions this process was deemed to be relatively redundant. If changes were identified and were not related to known events it may have proved useful to consider their impact on the study, but was also considered

an additional extension to the scope of an already large explanatory project. In summary, specific analytics looking for statistically significant rate changes that were unknown to the organisation was not taken further in this study.

The purpose of the project was to identify existing solutions to analytical processes. With reference to the researchers' background in programming rather than statistical mathematics resulted in the decision to draw upon the library arbitrarily. Of the libraries available the most well discussed and documented was [MISSING!]

The data analysis library selected for causal inference was available for both the Python and R programming languages. The researcher had little experience with either, but coming from a background in several other languages, Python was known to be the most syntactically similar to their existing expertise. Therefore, Python was used for the various data processing and analytical tasks detailed within this methodology.

3.5 Ethical Considerations & Risks

The use of personal medical data represented the primary ethical consideration in the context of this project. The intended use of the data was toward the direct benefit of the public via the Live Well Dorset health and wellbeing service. The service places no restrictions upon requests to access the benefits, and is actively encouraged within the civic locality for which it is made available. With the aim of the research to better enable, rather than diminish this activity, it did not propose to change the service itself places, resulting in considering the activities undertaken to fall within the ‘public good’ (Ballantyne, 2018).

To further exemplify the use of personal medical data the decision was made to exclude all data fields that contained personally identifiable data (name, address, date of birth). Furthermore, the one-way anonymisation of record IDs was undertaken to prevent reverse lookups. Randomly generated unique strings were inserted in place of the numeric IDs which represented individuals in the source data. Postcode locations were translated into the corresponding non specific LSOA geographic areas commonly used by the NHS (NHS, 2018). These steps were deemed to be more than adequate in meeting data protection requirements (European Union, 2016) while not impacting the meaningful attributes contained within the datasets.

The author did not foresee any noteworthy health and safety risks associated with the work to be undertaken in this research project. Digital data collection and analysis was anticipated to take place only at suitable locations and without the need of operation of unsafe equipment or exposure to unsafe practices affecting the individuals with which the study interacted.

The European Union’s General Data Protection Regulation (2016) places legal obligations around the handling and use of personally identifiable data within EU member states. The

process of anonymisation described previously as part of the ethical considerations absolved the data from the jurisdiction of these regulations; "…The principles of data protection should therefore not apply to anonymous information, namely information which does not relate to an identified or identifiable natural person or to personal data rendered anonymous in such a manner that the data subject is not or no longer identifiable." (European Union, 2016).

3.6 Assumption and Limitations

A range of assumptions were made and awareness was given to limitations that existed.

1. The study relied heavily on archival data sources, the accuracy of the data would by definition limit accuracy of results. It was therefore necessary to assume that sufficient quality of data would exist such that the methodology proposed would enable the production of accurate analysis and subsequent results. Steps were taken to develop awareness of the underlying quality of data quality as described previously in this chapter.

2. The consistency of referral data capture accuracy was considered outside the control of the study. Acquisition of real-world data offered more practically applicable results than under lab conditions, but was exposed to uncontrolled variations. The assumption was therefore made that in aggregate the process was to be considered consistent over time.

3. In the context of this study, communication interventions existed as the relationship between attributes of communication and the rate at which patients/clients were referred to wellbeing services. This aspect was therefore seen to heavily influence the effectiveness of the research, and would rely upon the quality of the historical intervention data gathered. Yet, the case-study organisation's accuracy of recording activity in this area over time was outside of the control of the researcher. It therefore posed a significant limitation and was to be a key point to consider when reviewing results. As an extension to this, where the study saw time pass between development of the analytical tools and the point at which the results were produced, meant that the process of data delivery and the consistencies in collection processes (outside the control of the study) was assumed to remain consistent. It was therefore prudent to assume that in the period of data analysis that generally the collection methods employed by the case study organisation would also have remained consistent. For the time series aspect of the data sources, in an effort to improve the analytical modelling and analysis, it was assumed that the use of data classified as 'non-GP' (referrals from sources other than those identified as GP based see 4.3.1 of this document) would represent a sufficient control data set.

4. Many of the methodological decisions were directed by identifying relationships across broad processes, yet the data was specific to a geographic area and particular

organisations. It was assumed that the results would be applicable to the case study organisation in question, and that this limitation is inherent of case study research. Operational and systemic comparisons would need to be researched to enable application to other public health organisations.

5. Of the referral data, random fluctuations were assumed to exist, therefore identification of correlations between what would already exist as loosely related observations would be inconclusive if the variance was not sufficient enough to be probabilistically determined.

6. Where the chronological data was concerned, it was assumed that the request for information responses would be accurate and consistent enough to provide a meaningful historical record of interventions. More specifically, it was assumed that if tangible communication materials would have been produced previously, copies would exist for review and classification by the researcher, and that the original distribution could be associated within a specific time period.

7. It was anticipated that demographic data would not impact the study in the form of confounding variables. This aspect of the data would be reviewed to measure the distributions for possible statistical anomalies, with the assumption being that if the demographic distribution was heterogeneous then they would not be considered to represent confounding variables.

4. Results

4.1 Introduction

This chapter describes the results of the analysis conducted during this study. The chapter begins by describing the chronology of past communication interventions and the explorative case study dataset investigation. This is then followed by the results from the cross-comparison analysis of the three data sources (intervention chronology, GP referral rate causal inference, and exploratory data analysis). Finally, the matrix developed as an extension to the literature review is defined, allowing for the classification of intervention communication activities.

Two parameters were required to satisfy the primary purpose of this research; definable communication activities with the intention of influencing GP referrals and Referral figures both before and after each communication activity. To increase confidence in the results of the primary analysis, explorative investigation was undertaken to interrogate the demographic distributions of the referrals for abnormalities and patterns which could potentially bias and/or inform the primary analysis.

4.2 Intervention Chronology

The chronology shown below (Table 1) was intended to collect details of only those communication interventions which were explicitly targeted at GPs. During the process of collection it was discovered that very few specifically identifiable interventions in this capacity had taken place over the survey time period. The decision was made to extend the collection criteria to any events considered a potential influence on referrals to the LWD system. It was proposed that this would increase the contextual understanding of referral rate analysis, and could facilitate the identification of false positives where both GP and non-GP events existed in close proximity.

Table 1. Chronology of Live Well Dorset service promotional communication initiatives

Identifier	Description	Date	GP Specific
A	'GP pack' a roughly 15 page document including posters, leaflets and cards hand delivered to each surgery by the outreach team. Details included pathway information and how to signpost / refer patients to the services.	2016	Yes
B	A one page document describing LWD and how to refer were laminated and distributed to surgeries with the intent they be on GP desks.	2017	Yes
C	Email to service stakeholders and partners about change of programme ownership from Optum to Public Health Dorset.	29th Mar 2018	No

D	New approach to social media. Personable, increased imagery.	30th Mar 2018	No
E	Updated website launched.	1st Apr 2018	No
F	Letter sent to GPs & Practice Managers from Dr Emer Forde - Local GP and Public Health Fellow.	1st Sep 2018	Yes
G	GP Email Bulletin via CCG.	1st Oct 2018	Yes
H	Supporting client tools 'My LiveWell' week long launch campaign.	18th Nov 2018	No

4.3 Referrals

4.3.1 GP and Non-GP Referral rates

The primary variable of this study which was to be analysed was the rate of referrals by GP sources. This would, by definition, reply upon statistical analysis of the records in the form of a time series.

The focus of the research was to identify the effects on referral rates, in particular those referrals from GPs. This was to be achieved through analysis of referrals to the Live Well Dorset client relationship manager dataset. An initial review of the data showed there were 21,524 client pathway records within the data set for the time period 1st June 2015 to 12th January 2019. When initially identifying the records which were understood to be referred by a GP, some immediate inconsistencies became apparent. There were 115 unique categorical values used to identify the range of referral sources across two fields (due to a historic change in data structure), with multiple values a subset of which were regarded as ‘GP’ for the purposes of this study. To standardise the data, the decision was made to augment the records with a binary classification through identification of those values which constituted a referral by a GP or by associate GP practice staff. The inclusion of practice staff was made based upon the diffusion of information within teams (Turner, G. & Shepherd, J., 1999) identified during the literature review as being an important aspect of GP communication within a practice setting. It was also assumed that this approach would maximise statistical density to the advantage of further analysis. The following referral classification values (Fig. 6) were used to filter records which would be considered GP throughout the analysis that followed.

```
['Doctor',
 'Doctor, Community Group',
 'Doctor, Doctors',
 'Practice Nurse',
 'Health Care Assistant, Doctors',
 'Midwife, Doctors',
 'Nurse, Doctors',
 'Practice Nurse, Doctors']
```

Fig 6. Programmatic output of source data referral classifications considered GP or GP influenced.

10,582 total records were identified as GP referrals after filtering had taken place.

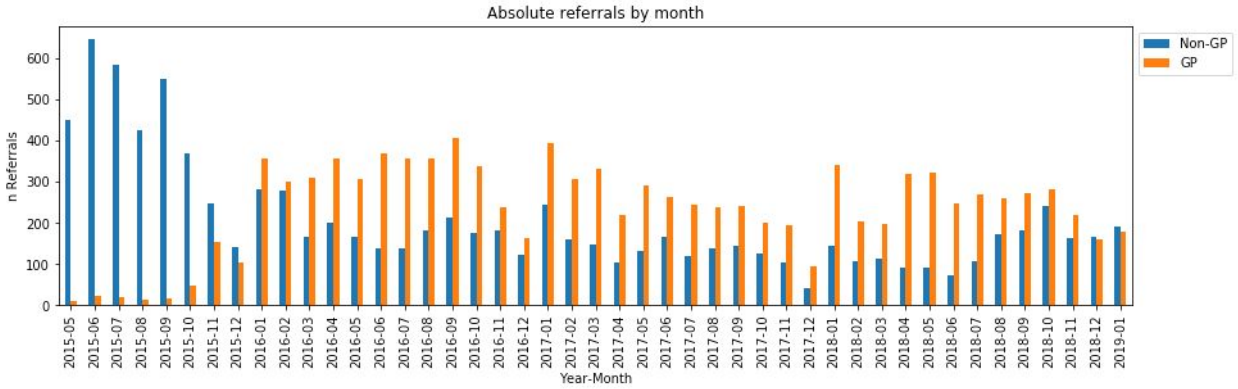
It was considered relevant to understand this figure in the wider context by identifying the number of records which had an unknown referral source. Of the 115 referral source values, two classifications were identified as constituting an 'unknown' source, specifically; "Other" and "Not asked". Records with these two values totaled 5,691. It was therefore possible to calculate GP referrals as a percentage of total known referral sources: 66.8%.

Registration distribution

Plotting total referrals by day was used to initially identify possible abnormalities in the distribution of referrals over time, the visualisation is more intuitively understood for time series data when compared to box plots or histograms. In this case it was also included to offer the researcher an overall appreciation of the density of data available to derive the results for the primary research problem. The count per-day referrals identified a significant spike on June 15th, 2016 (Appendix D), which was further identified as registrations taking place inside a two minute time period on this date. Through consultation with system staff this was described as "the CRM that our previous provider had was put in place in June 2016. The spike in data relates to historic weight loss data from our tier 2 weight management service, which needed to be uploaded into the new CRM." It was therefore considered important for the research to recognise that this import did not maintain the timestamps on which these referrals were originally gathered.

The potential impact on time series trend analysis was considered too pervasive to ignore. Therefore, the decision was made to remove the anomalous data from further analysis. This was completed by dropping all records falling within the times 17:03 and 17:04 on the date specified. As a result of this action a revised total of 10,512 GP referral records would be used for subsequent analysis.

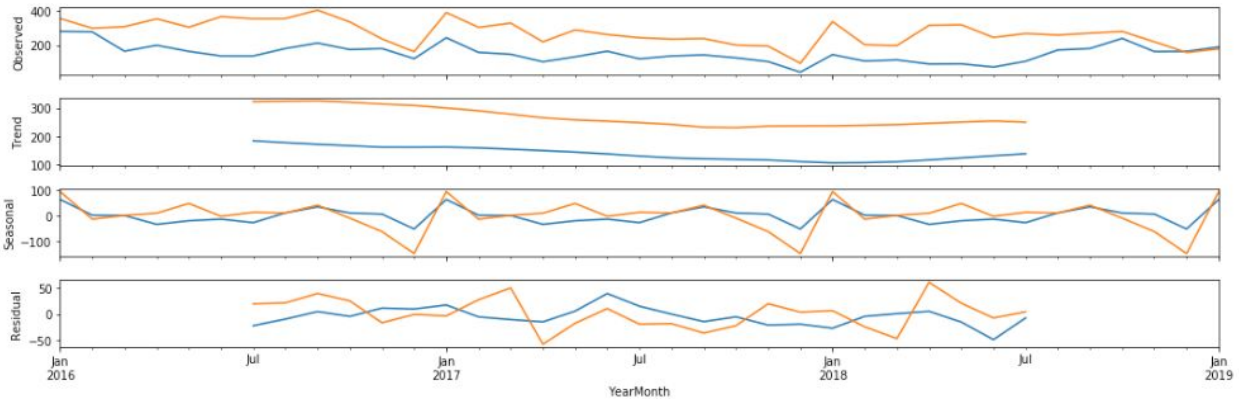
The distribution of GP and non GP referral counts by month (Graph 1) highlighted a large disparity in the time period for the months after the system went online. Aware that this period (up to and including December 2015) would impact interpretations of more recent (more relevant) trend analysis, the decision was made to remove these records from the dataset for all further time series analysis. This process resulted in 15,810 referral records, of which 10,120 were classified as from GP sources - a reduction of 3.73%.



Graph 1. Absolute GP and non-GP referral rates by calendar month.

Trend and seasonality

To understand underlying trends with regard to the number of referrals over multiple years, a decomposition of the time series was performed using the *python statsmodels* library function *seasonal_decompose*. The results were then visualised in a paired axis plot of GP and non-GP referrals; see Graph 2.



Graph 2. Time series decomposition of GP (orange) and non GP (blue) mean monthly referral rates.

Causal Inference

The causal inference analysis relied upon a distinct point in the time series being identified for each of the interventions in question. When no distinct date was available the dates analysed were themselves inferred from the results of the chronology gathering process. The researcher described the parameters that were used to standardise such circumstances as follows.

- Proximity - in cases where multiple events took place with less than an arbitrary seven day separation, interventions were combined and their midpoint selected as the intervention date for the purpose of analysis.
- Interval - interventions that spanned periods longer than one unit (a calendar day) were defined by selecting the midpoint of the time period identified in the chronology.

A 3-to-1 ratio of pre and post-intervention periods was applied. That is, the post intervention period was set to an arbitrary 60 day (2 month) interval, resulting in a 180 day (6 month) series used when modelling the post intervention counterfactual forecast.

For improved analysis, the non-GP time series was provided to the *CausalImpact* process as a control reference series. This posed a contradictory case for events which were not targeted at GPs but the decision to ensure comparison remained methodologically consistent for each intervention - the statistical implication of which is considered in the discussion.

The *CausalImpact* analysis library produced a range of statistical results for each intervention date;

1. *Predicted* - the counterfactual average number of daily referrals based upon the forecast from modeling the pre-intervention period. This value is a prediction of what would be expected, had no intervention taken place.
2. *Absolute effect* - the difference between the average observed and counterfactual (predicted) referral counts for the post intervention period.
3. *Relative effect* - a percentage difference between the average observed and counterfactual (predicted) referral counts for the post intervention period.
4. *Posterior probability p-value* - a value ≤ 0.05 suggests the null hypothesis is false, the assumption being the effect is unlikely to be a result of random fluctuations.
5. *Posterior probability of a causal effect* - percentage equivalent.

The results from analysis of each chronological intervention were collected and consolidated (Table 2). See Table 1 for details of each referenced intervention.

Table 2. Causal inference results of chronological communication interventions

			Causal Inference (Avg.)				
Intervention	Date	Actual	Predicted (SD) [95% CI]	Absolute effect (SD) [95% CI]	Relative effect (SD) [95% CI]	Posterior prob. p-value	Posterior prob. of a causal effect
A	2nd Jun 2016	9.30	11.3 (1.5) [8.2, 14.2]	-2.0 (1.5) [-4.9, 1.1]	-17.5% (13.5%) [-43.0%, 10.0%]	0.099	90.11%
B	2nd Jun 2017	10.10	9.5 (1.1) [7.3, 11.6]	0.6 (1.1) [-1.5, 2.7]	6.4% (11.5%) [-16.1%, 28.8%]	0.296	70.43%
C, D, E	29th Mar 2018	8.00	5.7 (0.8) [4.2, 7.2]	2.3 (0.8) [0.8, 3.8]	40.0% (13.1%) [14.2%, 65.7%]	0.003	99.70%

F	15th Sep 2018	10.60	12.7 (1.1) [10.5, 14.7]	-2.1 (1.1) [-4.1, 0.1]	-16.3% (8.5%) [-32.5%, 0.7%]	0.032	96.80%
G	15th Oct 2018	10.80	12.7 (1.1) [10.5, 14.9]	-1.9 (1.1) [-4.1, 0.3]	-15.0% (8.9%) [-32.6%, 2.2%]	0.042	95.80%
H	18th Nov 2018	8.80	12.4 (1.1) [10.2, 14.6]	-3.6 (1.1) [-5.8, -1.4]	-28.9% (9.0%) [-46.9%, -11.5%]	0.001	99.90%

CausalImpact model periods (where available); 180 days pre-intervention date, 60 day post-intervention date

4.3.2 Client Demographics

To investigate potential impact of referral demographics, relevant data was stratified across GP and non GP referrals. The results of which can be seen in Table 3.

Table 3. Stratification of client demographics grouped by GP referral source

			GP Referral	
		isnull	No n = 10942	Yes n= 10582
Age, median [Q1,Q3]	New ros	54	52 [38,66]	52 [38,64]
Gender, n (%)	Female	0	8316 (76.0)	7788 (73.6)
	Male		2626 (24.0)	2794 (26.4)
Local Authority, n (%)	Bournemouth	0	2919 (26.7)	2757 (26.1)
	Christchurch		477 (4.4)	507 (4.8)
	East Devon		5 (0.0)	4 (0.0)
	East Dorset		980 (9.0)	1082 (10.2)
	North Dorset		699 (6.4)	844 (8.0)
	Not Available		408 (3.7)	298 (2.8)
	Poole		2442 (22.3)	2368 (22.4)
	Purbeck		675 (6.2)	578 (5.5)
	West Dorset		1058 (9.7)	1061 (10.0)
	Weymouth and Portland		1279 (11.7)	1083 (10.2)
DeprivationQuintiles, n (%)	20 to 40% most deprived	0	2329 (21.3)	2298 (21.7)
	20% most deprived		2980 (27.2)	2808 (26.5)
	40 to 60%		1918 (17.5)	1913 (18.1)
	60 to 80% least deprived		1954 (17.9)	1897 (17.9)
	80 to 100% least deprived		1353 (12.4)	1368 (12.9)
	Not Available		408 (3.7)	298 (2.8)

4.3.3 Case Outcomes

To identify irregular distributions beyond those recognised in the limitations of this study, client-pathway interactions and subsequent health outcomes were analysed. The archival case records included detailed information about client biometrics and the associated progress through the wellbeing pathways with which they had registered. In total there were 22,793 case records for the period 1st June 2015 to 12th January 2019. With the purpose of the study surrounding referrals, the records were joined with their related client records to allow analysis of the case data to be conducted in context of the client, and importantly, their referral source.

An initial review of the data showed that the wellbeing pathway success variables did not appear to be consistent. As an example, it was noted that in the activity data, where a figure had been captured and no subsequent data existed, the status would default to a “Gone Down” which, without a measurement available, may or may not have been the case. In the interest of consistency and improved confidence (for this study), various algorithms to compute the pathway success parameters were developed (Appendix E). Beyond programmatic sanitisation logic, additional decisions were made which affect how the data was interpreted. The following list identifies the data sanitisation and potentially less intuitive parameters of the results presented in Table 4.

- A pathway is only considered active when both the activation flag and an initial measurement for that specific pathway biometric are present.
- A single record can have multiple pathway activations.
- Pathways which do not contain a second measurement at any of the 3 check-in periods are considered to have insufficient data and therefore neither a success or failure (isnull). The null value offers a measure of relative magnitude to those that complete a pathway.
- Smoking and Alcohol pathways require a reduction at the most recent check-in when compared to the initial measurement to qualify as a success.
- Weight loss pathways require a minimum of 5% reduction at the most recent check-in when compared to the initial measurement to qualify as a success.
- Activity pathways require any increase (measured in days) at the most recent check-in when compared to the initial measurement to qualify as a success.

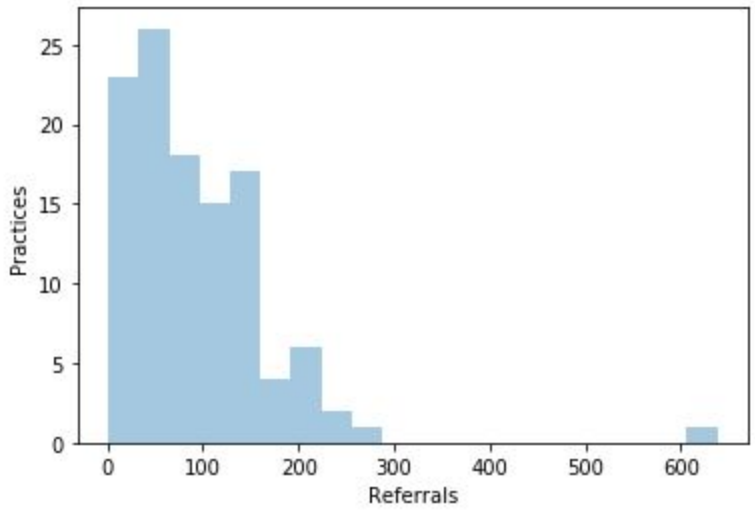
Table 4. Stratification of case pathway efficacy grouped by GP referral source

			Grouped by gp_referral	
		isnull	No n = 10762	Yes n = 10715
Registered Pathways, n (%)	0	0	907 (8)	818 (8)
	1		7724 (72)	7124 (66)
	2		1451 (13)	2065 (19)
	3		593 (6)	598 (6)
	4		87 (1)	110 (1)
No. of check-ins, n (%)	0	2050	6628 (69.2)	5031 (51.1)
	1		1730 (18.1)	2414 (24.5)
	2		1060 (11.1)	2028 (20.6)
	3		157 (1.6)	379 (3.8)
Reduced smoking, n (%)	-1	18086	233 (14.9)	128 (7.0)
	No		786 (50.3)	1464 (80.0)
	Yes		543 (34.8)	237 (13.0)
Reduced weight, n (%)	-1	5450	5941 (74.0)	4690 (58.7)
	No		997 (12.4)	1539 (19.2)
	Yes		1094 (13.6)	1766 (22.1)
Reduced alcohol, n (%)	-1	19646	732 (82.3)	683 (72.5)
	No		83 (9.3)	158 (16.8)
	Yes		74 (8.3)	101 (10.7)
Increased activity, n (%)	-1	17154	1119 (61.5)	1319 (52.7)
	No		551 (30.3)	901 (36.0)
	Yes		150 (8.2)	283 (11.3)

-1 denotes records with insufficient pathway measurements to classify the outcome

4.3.4 Practice referrals

The referral records identify 113 named GP practices that have referred patients. These accounted for 10,461 of the total referral figures analysed. The distribution of total referrals by practice was visualised in histographic form (graph 3).



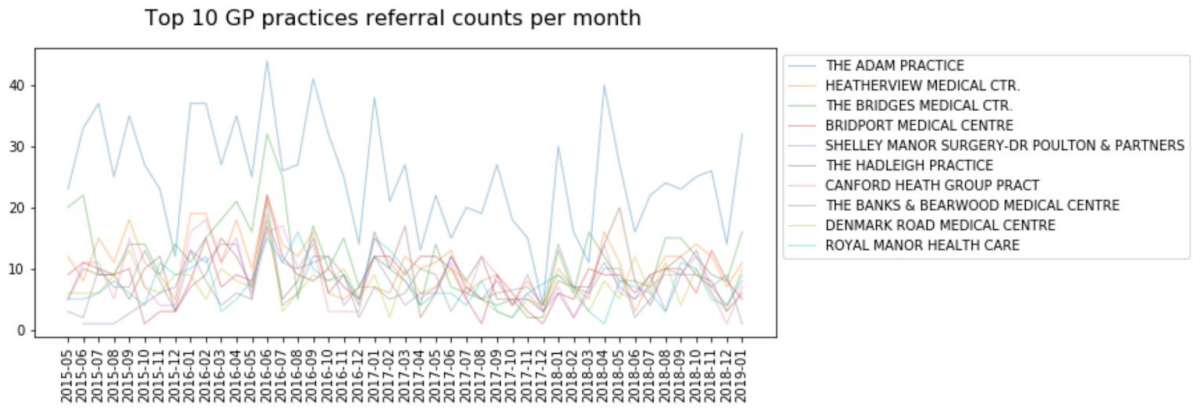
Graph 3. Histographic distribution of GP practice referral rates within the study dataset

To extrapolate further understanding of the distribution of successful referral sources and the outlier displayed in the histogram, the top 10 highest referring practices were identified by name see table 5 below. This process revealed “The Adam Practice” as the outlier outperforming the other high referring practices and is discussed in more detail in the next chapter.

Table 5. 10 highest referring GP practices

GP Practice	Total Referrals
THE ADAM PRACTICE	638
HEATHERVIEW MEDICAL CTR.	279
THE BRIDGES MEDICAL CTR.	240
BRIDPORT MEDICAL CENTRE	232
SHELLEY MANOR SURGERY-DR POULTON & PARTNERS	221
THE HADLEIGH PRACTICE	218
CANFORD HEATH GROUP PRACT	217
THE BANKS & BEARWOOD MEDICAL CENTRE	198
DENMARK ROAD MEDICAL CENTRE	196
ROYAL MANOR HEALTH CARE	193

Due to the importance of time series analysis in the context of this study, the remaining step was concerned with forming a general understanding of how greater (more desirable) referral counts were distributed and to identify any anomalous features amongst the top performing practices. To visualise the results, a plot of their competing referral activity over the complete time period was generated (Graph 4).



Graph 4. Complete time series of top 10 practices by number of referrals per month

5. Discussion

The study set out to identify a quantifiable approach to the measurement of professional healthcare communications influence on GP referral rates. The research, and by extension

results, attempted to address two methods of investigation - the analytical approach concerning itself with exploration of the data provided, and statistical approach in an attempt to provide rigour to the effect of GP communication practices. More specifically, the evidence has been formed through cross examination of qualitative chronological event intervention data and quantitative analysis of public health service records.

The primary focus of this research was to understand the relationship between interventions and statistical changes in health service referral data. A method of causal inference was adopted to achieve this. This chapter begins by discussing the chronological intervention causal inference analysis and attempts to conceptualise their meaning in the wider context. Each intervention is identified and discussed sequentially from oldest to newest.

The section that follows discusses the exploratory review of the original dataset. The purpose of which was to attempt to identify any anomalous features which may impact the understanding of the causal results previously discussed. In this supporting section (5.3) the researcher notes that this explanatory analytical process was intended only to extend contextual awareness/identification of the effect of potential confounders.

5.1 Chronology and causal inference

Generally, the quality of chronological data gathered was considered weak. In this context, good quality would be information about each intervention which accurately and fully satisfied each field of the proposed parameters detailed in section 3.3.1 of this document. While the content was suitably informative as a timeline - activities that took place historically were identified by staff - as the table of results (Table 3) displays, and interventions were recorded with wide interval periods and indeterminately tracked activities. This resulted in the need to define arbitrary, best-effort timestamp interpretations to satisfy the causal inference analysis requirements. It would, in the researchers opinion, be prudent in future research to conduct and review intervention information before deciding upon the method of causal inference.

The causal inference analysis approach was best placed to determine the effect of discrete points in a time series. This made the arbitrary selection of mid-span time points a potential point of failure for accurate results. However, the resilience to incomplete or tumultuous time series data was none the less suitable for the task. Importantly, if the case-study organisation is considered operationally typical, the quality of the intervention tracking would not be unusual in similar circumstances. This prompts the consideration of methodological changes to future studies, screening of archival intervention data before commencement of future studies, and promotion of improved tracking process at an organisational level.

Each intervention (see *Table 1* for related details) is considered in isolation before a summary is presented:

INTERVENTION A) Having selected a midpoint of a complete year of data (due to the lack of reliable intervention parameters provided), the interpretation of this intervention's results is considered highly speculative. The p-value is such that the marginal negative effect is taken to be spurious and not indicative of any action undertaken around the point in time of intervention.

INTERVENTION B) The same midpoint approach as intervention (A) was applied to the only captured communication activity in the second calendar year of data collected, 2017. The marginal increase in average referrals between the counterfactual and observed data is, again, not considered statistically significant. However, in this particular case, the like-for-like date range allows a year-on-year comparison to also be made. A marginal increase (avg. 0.8 referrals) of the observed data is seen. Marginal growth trends can be expected as immeasurable communication interactions increase awareness of the service over time.

INTERVENTION C,D,E) This intervention encompassed 3 non-GP communication activities with their midpoint used for analysis. The span of only 3 days offered confidence in this being a distinct intervention point. However, analysing GP referral data in the context of non-GP interventions presents a circumstance that is non-trivial when assessing the causal inference results. In this case, a 40% increase in average number of referrals between the observed and the counterfactual is shown to be statistically significant with a low p-value of 0.003. The counterfactual, modeled upon the previous six months, sees a post two month referral trend of average 2.3 fewer referrals than the observed values. Intuitively it would be reasonable to expect that non-GP interventions should not significantly affect the GP referral rate, which this result refutes. With this postulate in mind, the researcher considers possible confounders which would present an alternate hypothesis:

- Misclassification - non-GP referrals categorised erroneously could account for an artificial increase unrelated to communication interventions. Such a phenomenon could occur as a result of changes in collection methods or data processes (pre-database). Additional correlation analysis should be sufficient to validate this hypothesis, followed up with consultation with case study system staff.
- Increases in public requests via their GP - increased public awareness which instigates requests via a GP could account for a potential increase from non-GP communication interventions. To validate this hypothesis, further analysis of the exposure of the communication initiative and greater detail pertaining to the demographic population would be required. To see a tangible increase appear, to the researcher, to be unlikely if it is to be assumed people would not visit their GP specifically to access this service. This scenario would require a large enough subset of the original audience who require primary care during the two month post-intervention period.
- Anomalous analysis - The *CausalImpact* library, in the case of this study, relies upon the default time series modelling, there is the possibility that in this case, the pre and post-intervention periods produce an anomalous counterfactual. To test this hypothesis, a customised model which fits the dataset more accurately could be substituted for causal analysis.

- GPs affected by public communication activity - outside of their vocational environments, GPs are themselves in the public domain and are therefore exposed to the same promotional materials as the public they treat. Interventions that are not GP targeted can also impact a GP audience. In the context of this study, the literature suggested the point that many communication practices can be considered common across both audiences.
- Unidentified activity - communication activities not captured as part of the chronology gathering exist as a potential cause of referral fluctuation. In the case of this study, and the recency of the intervention date, it is not believed that a significant enough communication activity would not have been included in the responses.

When considering these points in the context of RQ1, the ability to increase GP referral rates is a desirable outcome, however, this can not meaningfully inform the research if the action taken is nonspecific. Isolation of this one event as an extension to the research would be an obvious next step to further understand the outcome and what attribute of the intervention could be applied to further communication activities.

INTERVENTION F) This intervention was written content, from a peer source, and specifically targeting at the GP audience. These communication attributes meant it was considered particularly suitable in the context of the points identified in the literature review. The causal inference analysis presented a negative trend disparity between the referrals observed and the counterfactual (forecast) figure (average -2.1, -16.3%). Considering this alongside confidence interval and standard deviation, the result is not considered to be statistically significant. In the context of the communication activity undertaken, and it's positive attributes for the purpose of informing GPs, it would also suggest these figures are more likely the result of random fluctuations. Therefore, taking the causal inference result as accurate, while aware of the limitations (section 3.5), it is considered that this intervention activity was ineffective. As an alternate conclusion, it might be proposed that the time to observe an effect from this method of intervention is beyond the arbitrary two month post period counterfactual. In this case a further study would be required which took events proven to be effective and review the effect of variable pre and post period on causal inference of this type.

INTERVENTION G) A governing body targeted at the GP audience. In much the same way as intervention (F) was described, the causal inference reports a non statistically significant result. The proximity of these two interventions means this result is not unexpected, only a 30 day time difference exists between them, so the counterfactual might be expected to be statistically similar, drawing on 66% of the same pre-period training data.

INTERVENTION H) The final intervention identified in the chronology was a public-targeted service delivery improvement. The referral dataset was insufficient to allow for comparable analysis on a two month post intervention period. As such it was omitted from causal analysis.

As a whole, four GP target communication activities, two of which demonstrated highly variable time results from the chronological causal inference analysis, suggest ineffectiveness (in terms

of statistically discernible changes) to the GP specific interventions to-date. With the method not being applied at its optimum, the questionable time parameters mean that this inference is offered with low confidence. The insights drawn are summarised in the context of the research project in chapter 6, Conclusion.

5.2 Referrals

As previously described, various processes were employed to separate GP referral sources from their non-GP counterparts (for code and explanation see Appendix D). The discussion that follows is not exhaustive, but placing the referrals counts in context of the data which they are related helps to improve the confidence. Applying the following domain knowledge also offers more understanding of how the activities surrounding the data collection and subsequent processing can be factored into the discussion of these results.

Continuous uncontrolled communication
During the collection of professional communication materials, it was identified that on-going verbal promotion of the Live Well Dorset services is conducted in an ad-hoc, unmeasured manner. This would take the form of outreach teams who facilitate both the distribution of materials but also maintain unstructured interpersonal interactions with GP practice staff. This is therefore considered an uncontrolled variable of the study, and in-part guided the methodological decision to use the results on trend analysis which it was hoped would be less susceptible to on-going communication efforts such as this. When reviewing the results these sort of activities should be considered as noise in the wider context - no record was supplied as to their proliferation geographically or over time.

Diffusion of information within interprofessional settings
Highlighted in the literature was the importance of GP to GP, or supporting practice staff to GP communication. An example scenario would be discussions of new processes such as the Live Well Dorset referral programme between GPs in external settings such as conferences, clinical commissioning group meetings, or materials being reviewed by practice staff and verbally communicated to GPs within the practice. These considerations led to the decision to include classifications which were not specifically GPs but do appear as though they would be indicative of these processes.

Misattribution
Self referrals originally incentivised by GPs being classified as non-GP. Referrals at the point of capture are informed by human consideration and input accordingly. In this sense they are interpreted and therefore open to error - a referral which may have been incentivised by a conversation with a GP could still be captured as a self referral. For example, if the individual considers the act of the registration being the source then they mark self referred, rather than GP when being directed to registration by their doctor. Further to this point, in the time during the period in which the data has been collected and analysed, a web-based referral system was

launched on the Live Well Dorset website and could be considered a further complication to source interpretation.

5.2.1 Absolute referrals by month

The absolute referrals by month (Graph 1) were presented to demonstrate the variation and comparative magnitude of the two primary variables of this study. Over the first six months (post May 2015 when data began to be collected), an obvious decline can be seen in the number of referrals until a December low point, followed by a significant uplift in January. Looking to the following two years (2016, 2017) offers some indication that this pattern is repeated, the same monthly period leading up to the new year demonstrates a sequential reduction. When considering an explanation as to this a seasonal pattern, it is generally understood in the context of fitness and health that it is common for people to begin a new year with intentions of improved lifestyle. Typically relating to health, the period leading up to this point sees these intentions deferred until the impending January 'new start' arrives. Looking at the most recent year, 2018, sees a lesser effect, and the preceding months see fewer total referrals. The lesser uplift in January can be attributed to an incomplete month of data as the final date in the dataset is known to be 06 January 2019. We would therefore anticipate a complete month to demonstrate the more regular pattern. Seasonality is discussed in more detail as part of the trend analysis section of this document.

The GP referral figures demonstrated a slow increase after the initial system implementation date. By not beginning high, a lesser drop is seen into December as the upward trend counteracts the seasonal reduction. The subsequent January (2016) figures display GP referrals overtaking the non GP referrals, this situation is consistent for the following 33 months.

The increase observed towards the end of 2015 could be symptomatic of a slower uptake of promotional information. The seasonal trend gave some confidence to this observation - not seeing this pattern in the context of a service which supports typical lifestyle/new year goals would have introduced questions as to the validity of the audience.

As part of the referrals per practice review, the "Adam Practice" was highlighted for demonstrating noticeably more referrals than the next best performing surgery (638 vs 279 across the time series). This outlier was not possible to explain within the data collected, but a query to the Public Health Dorset staff resolved the point - the explanation simply that the practice was a noticeably larger practice (see section 5.3.5 for further discussion). This pointed out a shortcoming of the study, while efforts were made to check for confounders, not all confounders were known - in future research it should be noted that collection of at least relative size of the practices should be undertaken. The understanding of how different sized practices could itself offer an area for investigation in how this affects the diffusion of information - this could be achieved by analyzing the growth in referrals in comparison to the number of GPs/supporting staff.

5.2.2 Referral Trend analysis

The seasonality component of referral rates in the time-series decomposition (Graph 2) both displayed patterns of note. The most obvious were apparent when reviewing the absolute values, the trough and peak in quick succession found pre and post respectively at the end of each calendar year. Through application of domain knowledge it is proposed that this be resultant of less incentive for people to register for health and wellbeing services in the lead up to Christmas. Followed by the subsequent motivation to improve health and wellbeing at the start of a new year. This pattern offers confidence that the data is accurate because it represents real (expected) human behaviours. This observation also suggests it could be considered good practice to promote such services in such a way that these pre-existing patterns be utilised for increased service adoption - e.g. support GPs in referring patients in January, and avoid wasted resource use in December. Or, more accurately, prepare communicators and GPs with the knowledge in December that they will have better results with January referrals. It should be said that the transferability of this will be largely societal, where populations exist that do not conform to this year-end cycle, it would offer little value. In such circumstances, seasonal composition should be run on a more applicable data set to inform similar decisions on effacicity of service promotion.

It was hoped that understanding not only the categorical source of the referrals but also the context of the practice by which the customer was associated to offer further insight into the efficacy of communication practices. As was clearly apparent in the results, one practice displayed a significantly larger referral rate than the other top performing locations (638 compared to 279). The initial reaction was that this provided a clear line of further investigation.

In consultation with Public Health it was identified that “The Adam Practice” is a particularly large GP surgery, and that this point alone is likely to account for the unusual outlier position it displayed within the referral figures. Not accounting for practice size in this aspect of the analysis was a shortcoming in the research design and will be highlighted in the conclusion of this study.

5.2.3 Demographics

Table 1 described the demographic distribution of client data. It was considered that there may be areas of investigation that would display differing demographic features between the GP and non-GP referral groupings. The consistency in numbers gives little opportunity to continue the line of enquiry.

While the results do not inform the primary concern of this study, considering the distributions outside of their referral source specificity shows regional distributions as may be expected when taking into account population density in these areas. An outlier exists in the form of East Devon

which is not within the official catchment of Dorset, so is assumed to be overspill where GP practices service their local catchment regardless of regional divisions. In all characteristics relative parity between referrals and non-referrals exists. No significant bias is seen in the delivery of referrals by GPs. The demographic results, therefore, show that the dataset is characteristic of a general distribution and should give confidence to the interoperability of further findings.

5.2.4 Case Outcomes

The case outcome results provided a top level understanding of how the service was being used. The purpose of this analysis was to see if any particular biases toward client types were seen, or results that may inform more understanding of the referral process - thus improving the ability of this study to explain the casual results obtained.

The obvious point of note was the large number of drop-offs after the initial registration/check-in. A free, no committal service is anticipated to suffer from more casual usage, so is to be expected. Taking this as an indication of the clients being referred to the service, it would be possible to extend the research into measuring retention as a factor affecting the quality of referral. The value of improved retention could also offer more validity to statistical feedback (greater confidence and potentially more successful outcomes) when engaging GPs with referring their patients. Details of such considerations go beyond the scope of this study.

As a sense check this exercise was not considered particularly informative for the primary research question. It performed it’s task, but the research would not be compelled to repeat this aspect of the analysis in repeated investigations unless a particular anomaly was identified in the data elsewhere which could be further informed by the case outcome data.

6. Conclusion

Where domain specific studies have focused predominantly on isolated attributes of professional healthcare communication, they subsequently offer disparate insight when seeking to design and advance communication practices. This study set out to consider how this may be addressed in a way which can continually inform as to the effectiveness (successful or not) of such communication efforts in a professional healthcare setting.

Taking GP referral rates as a point of analytical focus, causal inference was used as a method that has yet to be applied to healthcare communication analysis (within the scope and method of this study's research). The approach was found to be resilient to heterogeneous time series data - a common constraint of real-world systems - and as such can be a consideration in other research applications and example cases within the field of study.

Although not technologically trivial, the advantage of the causal inference implementation used is apparent - not requiring a mathematician to perform. However, its application and interpretation of the results will be dependent on a given organisation's capabilities. The researcher proposes that the outputs from the analytical procedures could, with the aid of suitable infrastructure, provide less technically experienced users with on-going awareness of their communication effectiveness. For example, the use of summarised results (possibly graphically presented) of the observed trend changes resulting from communication intervention. Therefore, overcoming the remaining limitations that may exist for less technically sophisticated teams.

For this particular research case study organisation, the causal inference results did not demonstrate meaningful enough statistical significance for any of the GP specific intervention periods that were identified and analysed. While no confident conclusion can be drawn as to the specific performance of these professional medical communication activities, it was concluded that the time periods identified were predominantly too vague for the method of analysis to provide authoritative results. In response to this, and within the context of the processes undertaken to gather the information that allowed this study to progress, the recommendation of this study is that the following steps be taken at an organisational level when designing communication activities:

1. Implement practices that capture (as a minimum) specific date, type, and quantity of audience exposure that each communication activity achieves.
2. Identify suitable pre and post-periods - referral rate statistics should exist for the complete period.
3. Collect referral data for the post period.
4. Sanitise and analyse through causal inference (as defined in this study) to identify the perceived impact of each activity.

5. Review each effective communication intervention against the attributes of professional medical communication as identified in this research and use this to inform future activities.

It is proposed that adhering to the above activities, over a period of several communication interventions, would allow for continuous evaluation and optimisation of healthcare communications at an organisational scale. Capturing accurate logs of the results would also allow the potential for further studies to elaborate on the work conducted during similar research.

Where the public communication activities appeared to identify both GP and non-GP referral rate increases where non-gp interventions took place, it is proposed that further research would be applicable in understanding this effect. It may be that shared decision making has become a key characteristic of the GP consultations, where patients exposed to the service communication materials are the key motivator behind the uplift in referrals. Specific analysis of this phenomenon may identify patient-driven GP referrals which would reduce the relevance of professional medical communication in the context of this research and the case study organisation.

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Appendixes

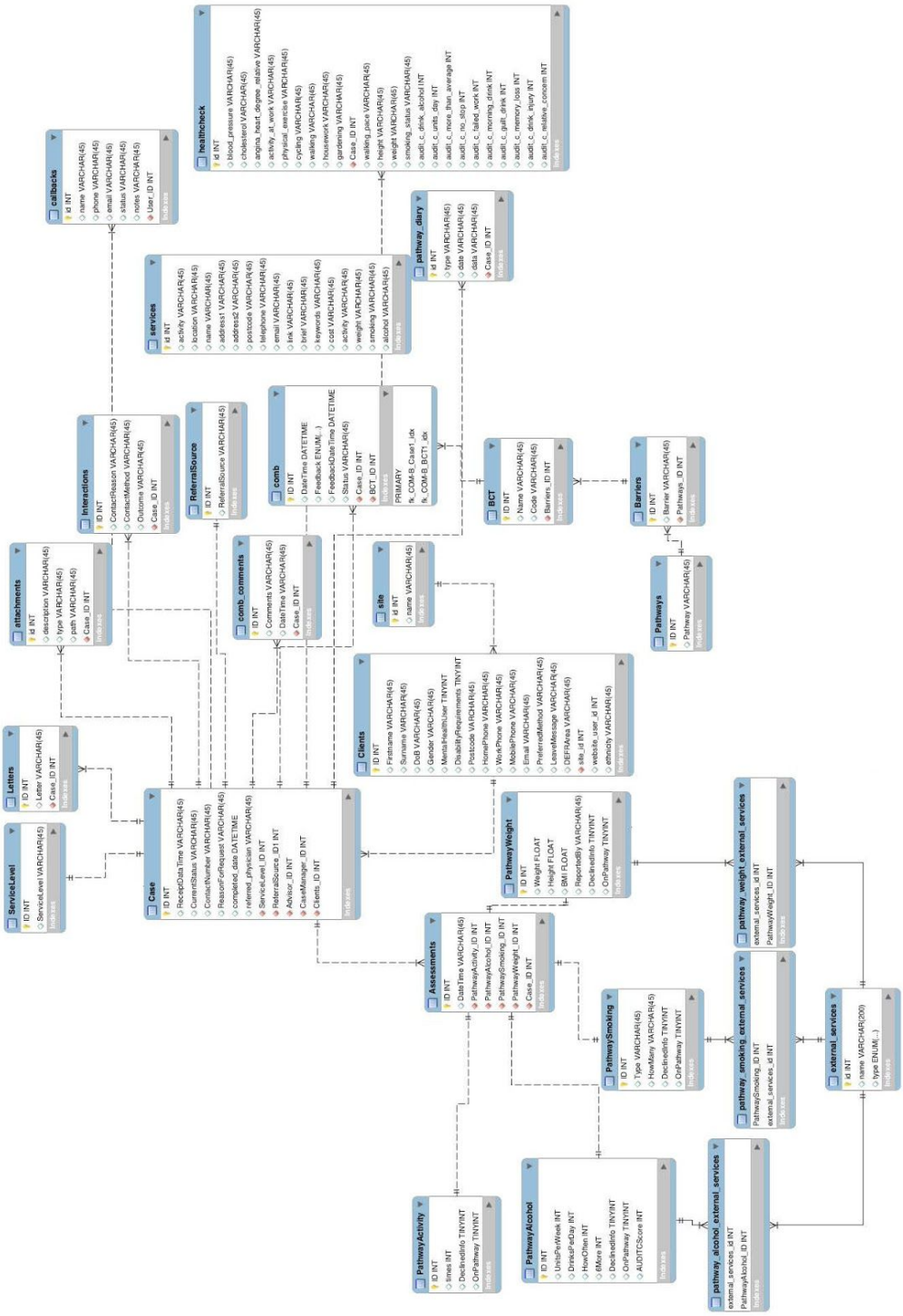
Appendix A

Matrix of professional healthcare communication best practices as identified in literature review.

Categorisation	Approach	Explanation	Example/Action	Source
Strategy & Structure	Communication basics	Medical comunication may be a specilist domain, but the target audience are still human, more generally proven communication tequnies are still relevant.	Continue to use well know and established communication techniques as long as they do not counteract the SMC specific points.	Moguli, S.A., 2018. Scientific and Medical Communication: A Guide for Effective Practice (ATTW Series in Technical and Professional Communication). | Akl, E.A. et al., 2011. Using alternative statistical formats for presenting risks and risk reductions Cochrane Consumers and Communication Group, ed. Cochrane Database of Systematic Reviews, 58(8907), pp.455–90.
Strategy & Structure	Begin with context	Be clear from the outset exactly what you wish the audience to know and the data available to support it.	Before producing materials, spend time defining explicitly why you are producing them.	*Knaflic, C.N., 2015. Storytelling with data: A data visualization guide for business professionals, John Wiley & Sons. | Rose, D., 2016. Data Science: Create Teams that Ask the Right Questions and Deliver Real Value, Apress.*
Strategy & Structure	Be concise	Irrelevant or elaborative information may introduce misinterpretation and detract from the purpose of the material.	Avoid including additional information that only 'might' be useful, stick to the core message.	Moguli, S.A., 2018. Scientific and Medical Communication: A Guide for Effective Practice (ATTW Series in Technical and Professional Communication).
Strategy & Structure	Minimum formal structure	Medical professional discourse typically adheres to at least simple presentation structures.	Minimum; introduction, main part and conclusion.	*Horder, J., Bosanquet, N. & Stocking, B., 1986. Ways of influencing the behaviour of general practitioners. J R Coll Gen Pract, 36(292), p.517.*
Strategy & Structure	Narrative structure	A typical story structure will connect and guide the audience through the content to an actionable conclusion.	Consider introducing the messaging develop characters and events culminating in a desired action.	*Rose, D., 2016. Data Science: Create Teams that Ask the Right Questions and Deliver Real Value, Apress.*
Strategy & Structure	Specify actions	Identify and explain the specific action that should be taken to achieve the messagings desired action.	Include clear, simple and practical instructions.	*Grol, R. et al., 1998. Attributes of clinical guidelines that influence use of guidelines in general practice: observational study. BMJ, pp.1–4.*
Strategy & Structure	Avoid controversy	Uptake of practice change is more difficult when actions fall outside the audiences existing values.	Gain undertsanding of the target audience with reference to the proposed messaging action.	*Grol, R. et al., 1998. Attributes of clinical guidelines that influence use of guidelines in general practice: observational study. BMJ, pp.1–4.*
Strategy & Structure	Audience review	There is no one better placed to advise upon domain specific content elements than the audience themselves.	Have comms matierals reviewed by exmaple taget audience indiviual before districtution	N/A
Strategy & Structure	Evolution	Communication is evolutionary in nature as technology and accepted norms chnage over time.	Track, measure and review communication	Moguli, S.A., 2018. Scientific and Medical Communication: A Guide for Effective Practice (ATTW Series in Technical and Professional Communication).
Text	Formal yet accessible language	Formal language offers familuarity and confidence, but it should not be unnecesarily complex because this can introduce barries to cross-discipline propogation.	Understand and include formal language, but avoiding letting this introduce unecessary or complex prose.	*Vermeir, P. et al., 2015. Communication in healthcare: a narrative review of the literature and practical recommendations. International Journal of Clinical Practice, 69(11), pp.1257–1267.*
Text	Recommend expert opinions	Expert opinions as recommendations rather than obligations are considered more polite and will be more familiar, therefore building trust.	"X sugegst that...", "X proposes..." etc.	Shamne, N.L. & Nevzorova, M.S., 2017. Lingua-pragmatic potential of speech actions in medical professional discussions. In 7th International Scientific and Practical Conference "Current issues of linguistics and didactics: The interdisciplinary approach in humanities" (CILDIAH 2017). Paris, France: Atlantis Press, pp. 1–8.
Text	Soften categorical judgments	To improve familiarity and confidence, respect the variation in confidence and understanding when offering expert opinions.	"It is belived that...", "It is understood that..." etc.	Shamne, N.L. & Nevzorova, M.S., 2017. Lingua-pragmatic potential of speech actions in medical professional discussions. In 7th International Scientific and Practical Conference "Current issues of linguistics and didactics: The interdisciplinary approach in humanities" (CILDIAH 2017). Paris, France: Atlantis Press, pp. 1–8.
Text	Include technical language	Domain specific language can promote familiarity and confidence, but should be limited to generally understood topics - very specialist knowledge may not be widely understood.	Use common technical terms/acronyms/phrases where suitable. Reviewed by a domain specalist when possible.	Moguli, S.A., 2018. Scientific and Medical Communication: A Guide for Effective Practice (ATTW Series in Technical and Professional Communication).
Text	Reference authority	Support credibility of information using references and evidence from organisations which GPs consider to be authoritative.	If the evidence is from an authority, reference them. If not, find an alternate that may be able to back the evidence.	*Dadich, A. & Hosseinzadeh, H., 2016. Communication channels to promote evidence-based practice: a survey of primary care clinicians to determine perceived effects. Health Research Policy and Systems, pp.1–12.*
Text	Framing	Postive and negative goal framing, use language to descirbed the outcome of doing or not doing an intended action and the subsiquent positive or negative outcomes.	"...patients health improved over a six month period." or "...patients who did not recive treatment X continued to deteriorate."	*Akl, E.A. et al., 2011. Framing of health information messages Cochrane Consumers and Communication Group, ed. Cochrane Database of Systematic Reviews, 22(1), pp.60–84.*
Visuals & Graphs	Numbers	Where possible, avoid unnecessary complexity, not all numbers require graphs.	With only a number or two, highlight, use clear prominent text instead of resorting to graphs.	*Knaflic, C.N., 2015. Storytelling with data: A data visualization guide for business professionals, John Wiley & Sons.*
Visuals & Graphs	Hierarchy	Use color, size, and position to visually prioritise content.		*Knaflic, C.N., 2015. Storytelling with data: A data visualization guide for business professionals, John Wiley & Sons.*
Numbers	Natural frequencies	Use natural frequencies rather than percentages when both options are valid.	Use statements like "86 out of the 1142 patients studied..." rather than "7.5% of the patients studied..."	*Akl, E.A. et al., 2011. Using alternative statistical formats for presenting risks and risk reductions Cochrane Consumers and Communication Group, ed. Cochrane Database of Systematic Reviews, 58(8907), pp.455–90.*
Numbers	Relative change	Bigger numbers of the relative changes have more impact than smaller absolute changes for the same results.	Express 12 out of 20 as 60% (being a larger more impactful number).	*Akl, E.A. et al., 2011. Using alternative statistical formats for presenting risks and risk reductions Cochrane Consumers and Communication Group, ed. Cochrane Database of Systematic Reviews, 58(8907), pp.455–90.*
Numbers	Values of risk	Absolute values are more suitable to express risk by expressing both the magnitude of reduction and the baseline risk.		*Akl, E.A. et al., 2011. Using alternative statistical formats for presenting risks and risk reductions Cochrane Consumers and Communication Group, ed. Cochrane Database of Systematic Reviews, 58(8907), pp.455–90.*
Numbers	Statistically signficance	Empiricle evidence that shows meaningful trends can inspire action.	Identify and draw upon evidence which is worthy of attention, avoid evidence that does not carry impact.	*Schiavo, R., 2007. Health communication: From theory to practice, John Wiley & Sons.*
Numbers	Scientific notation	Using the correct domain specific notation on evidence will imply legitamacy and impove confidence.	mg = milligrams	*Schiavo, R., 2007. Health communication: From theory to practice, John Wiley & Sons.*
Numbers	Clear labeling	Without clear explanation empiricle evidence will not be considered credible and can in turn detract from confidence.	Include clear source and relevance information when necessary, if this is not possible find alterntive evidence.	
Motivation	Financial incentives	Offering finaincial incentives can motivate some aufidence, however an already oversubscribed GP will be less incentivised to add more to their workload.	Review opportunity to incentivise messaging action through finaincial reward and impliment if deemed to be contextually suitable.	*Horder, J., Bosanquet, N. & Stocking, B., 1986. Ways of influencing the behaviour of general practitioners. J R Coll Gen Pract, 36(292), p.517.*
Motivation	Time saving	GP time is stretched and therefore a valuable comodity, reduced workload can be a strong motivator.	Incentivise intended action in the messaging (that can result in saved time) by idnentifying this as a positibe outcome.	
Delivery	Colleagues & Peers	Endorsment from collegues or peers offers greater credability.	Consider appealing to secondarty audiences, make materials shareable.	*Horder, J., Bosanquet, N. & Stocking, B., 1986. Ways of influencing the behaviour of general practitioners. J R Coll Gen Pract, 36(292), p.517.*
Delivery	Email distribution	Multimedia delivery and commonly used by GPs, fast, shareable and trackable.	Develop email content to send to multiple recipiets, use suitable campeign services to allow taggin for tracking of specific campeigns open rates and click through rates	*Vermeir, P. et al., 2015. Communication in healthcare: a narrative review of the literature and practical recommendations. International Journal of Clinical Practice, 69(11), pp.1257–1267.*
Delivery	Educational events	Continued personal development is a common part of GP practice, this environment is focused and credible.	Include messaging and	*Horder, J., Bosanquet, N. & Stocking, B., 1986. Ways of influencing the behaviour of general practitioners. J R Coll Gen Pract, 36(292), p.517.*

Appendix B

Data structure of archival dataset provided by the Live Well Dorset programme as at 16 May 2018.



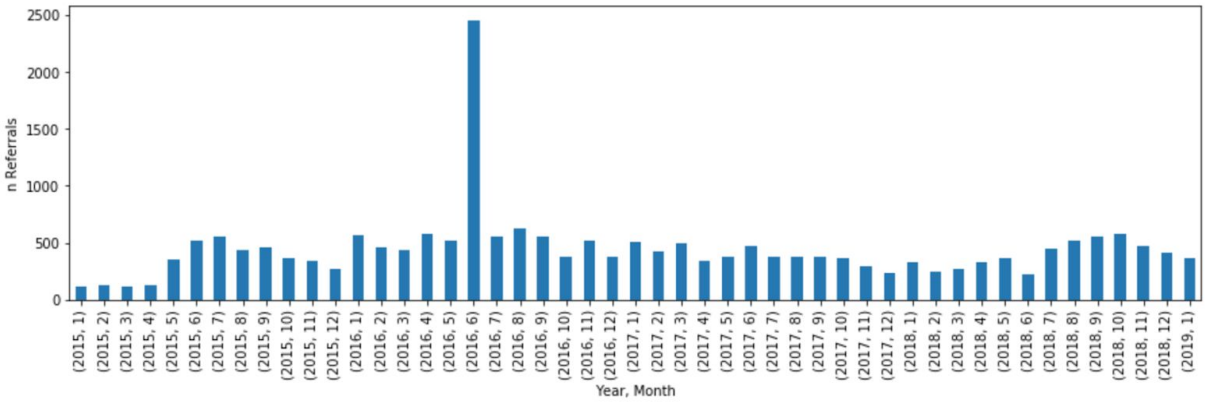
Appendix C

Raw (unfiltered) unique referral origin categories extracted from source dataset.

'Doctor' 'Event co-ordinator' 'Myself (Self-referral)' 'Friend' 'Nurse' 'Community worker' 'Pharmacy staff' 'Weight Loss Program' 'Manager at work' 'Health Visitor' "Children's centre staff" "Don't know" 'Midwife' 'Volunteer' 'Not asked' 'Exercise instructor' 'Health Care Assistant' 'Physiotherapist' 'Social worker' 'Carer' 'Occupational Therapist' 'Support Worker' 'Practice Nurse' 'Group leader' 'Doctor, Doctors' 'Event co-ordinator, LWD event' 'Nurse, Doctors' 'Nurse, Hospital' 'Community Health Worker, Community Group' 'Event co-ordinator, Health Check event' 'Nurse, Community Group' 'Doctor, Hospital' 'Pharmacy staff, Pharmacy' 'Weight Loss Program, Weight Watchers' 'Manager at work, Dorset County Council' 'Health Visitor, Doctors' "Children's centre staff, Centre" 'Manager at work, Hospital' 'Community Health Worker, Dorset & Wilts Fire and Rescue service' 'Weight Loss Program, Slimming World' 'Midwife, Hospital' 'Volunteer, Community Group' 'Doctor, Weymouth Comm Health Ctre' 'Friend, Weight Watchers' 'Nurse, Weymouth Comm Health Ctre' 'Myself (Self-referral), Doctors' 'Exercise instructor, Centre' 'Doctor, The Rosemary Health Ctr' 'Pharmacy staff, Well, 24 Crescent Street, Weymouth, DT4 7BX' 'Nurse, The Rosemary Health Ctr' 'Health Care Assistant, Doctors' 'Manager at work, Borough of Poole' 'Health Visitor, Canford Heath' 'Friend, Slimming World' 'Friend, Doctors' 'Myself (Self-referral), Social Media, Newspaper or Magazine Advert' 'Myself (Self-referral), Poster or Flyer' "Friend, Livewell's Website" 'Myself (Self-referral), Google Search' 'Health Visitor, Boscombe' 'Midwife, Dorchester' 'Midwife, Doctors' "Myself (Self-referral), Livewell's Website" 'Event co-ordinator, Active Ageing event' 'Doctor, The Panton Practice-Dr Sawyer & Partners' 'Community Health Worker, Health Check event' 'Physiotherapist, Hospital' 'Community Health Worker' "Myself (Self-referral), LiveWell's website" 'Myself (Self-referral), Social Media' 'Health Care Assistant, Hospital' 'Myself (Self-referral), Newspaper or magazine advert' 'Pharmacy staff, Doctors' 'Doctor, Cornwall Road Med Pract' 'Social worker, Dorset County Council' 'Myself (Self-referral), North Dorset' "Don't know, LWD event" 'Health Visitor, West Dorset' "Friend, LiveWell's website" 'Myself (Self-referral), Hospital' 'Myself (Self-referral), Dorchester' "Don't know, Doctors" 'Health Visitor, Purbeck' 'Doctor, The Marine & Oakridge Partnership' 'Weight Loss Program, Doctors' "Doctor, LiveWell's website" 'Doctor, Blandford St Mary, Blandford' 'Myself (Self-referral), Slimming World' 'Friend, Social Media' 'Occupational Therapist, Hospital' 'Doctor, The Poundbury Practice' 'Myself (Self-referral), Dorset County Council' 'Health Visitor, East Dorset' 'Health Visitor, Pokesdown' 'Health Visitor, Kinson, West Howe & Kingsleigh' 'Doctor, Community Group' 'Health Visitor, Dorchester' 'Friend, Hospital' 'Doctor, Townsend' 'Volunteer, Slimming World' 'Myself (Self-referral), Radio' 'Support Worker, West Dorset' "Don't know, LiveWell's website" 'Health Care Assistant, Slimming World' 'Wellbeing adviser' 'Community health worker' 'NHS health checks' 'Op Galaxy' 'Other' 'Wellbeing coach' 'Solutions4Health' 'Practice Nurse, Doctors' 'Group leader, Slimming World' 'Exercise instructor, Escape Pain Referral' 'Group leader, Weight Watchers'.

Appendix D

Distribution of referrals by month for complete data set time series including suspected false data.



Appendix E

Data sanitisation functions to support analysis procedures.

Live Well Dorset helper functions

Functions developed to specifically assist processing of Live Well Dorset wellbeing service data ready for further analysis.

```
# Load relevant libraries
import pandas as pd
import numpy as np
import math
```

1. Generate categorical values from client (demographic) data set

This function extrapolates categorical values for use during stratification and analysis. Results are returned as additional fields in the supplied pandas data frame.

- Gender (binary numeric)
- Month of year
- Age groups (10 year bins)
- Binary numeric GP referal source

```
def prepare_clients(df):
```

```
    # Numericise the gender field for arithmetic corrlations
    df['gender_numeric'] = np.nan
    df['gender_numeric'][df.Gender == 'Male'] = 0
    df['gender_numeric'][df.Gender == 'Female'] = 1

    # Bin dates by month
    df['YearMonth'] = df.Date_registered_Month_Year.map(lambda x: x.strftime('%Y-%m'))

    # Bin ages by 10 year divisions
    groups = ['0-9', '10-19', '20-29', '30-39', '40-49', '50-59', '60-69', '70-79', '80-89', '90+']
    df['age_group'] = pd.cut(df.Age, range(0, 101, 10), right=False, labels=groups)

    # Mark GP referrals by practice staff and those with "Doctor" in the referral source identifier that
are not hospital related
    ref_filter = ['GP','Doctor','Doctor, Community Group','Doctor, Doctors','Practice Nurse','Health Care
Assistant, Doctors','Midwife, Doctors','Nurse, Doctors','Practice Nurse, Doctors']
    df['gp_referral'] = 0
    df['gp_referral'].loc[df['ReferralSource'].isin(ref_filter) | df['how_a'].isin(ref_filter) |
df['how_a'].isin(ref_filter) | df['referral_combined'].isin(ref_filter)] = 1
    df['gp_referral'].sum()

    # Mark GP referrals by practice staff and those with "Doctor" in the referral source identifier that
are not hospital related
    ref_filter = ['Doctor','Doctor, Community Group','Doctor, Doctors','Practice Nurse','Health Care
Assistant, Doctors','Midwife, Doctors','Nurse, Doctors','Practice Nurse, Doctors']
    df['gp_referral'] = 0
    df['gp_referral'].loc[df['how_a'].isin(ref_filter) | df['referral_combined'].isin(ref_filter)] = 1

    # Dataframe of unknown referral sources
    #ref_filter = ['Not asked','Other']
    #unkown_refs = df.loc[df['how_a'].isin(ref_filter) & df['referral_combined'].isin(ref_filter)]

    return df
```

2. Output a list of all referral types

This function returns a list of the unique referral sources found within the data set.

```
def referral_types(df, fields=['how_a','referral_combined']):
    return pd.unique(df[fields].values.ravel('K'))
```

3. Count the number of unique referral types

This function includes the number of records found for each of the unique referral source classifications

```
def get_unique_referal_types(df):
    return pd.unique(df[['ReferralSource','how_a','referral_combined']].values.ravel('K'))
```

4. Smoking quantity standardisation

This function compares multiple related columns of varying data types and decides to what level the client is/was a smoker and translates this to a simplified numerical categorisation.

- 0 - Non smoker
- 1 - Smokes 1 to 9 times a day
- 2 - Smokes 10 to 19 times a day
- 3 - Smokes 20 or more times a day

```
def smoking_class(values):
    # Define standardise codes for various data values
    mapping = { 'a. 1-9': 1, 'a.': 1, 'b. 10-19': 2, 'c. 20+': 3, 'New non smoker': 0, 'Non-Smoker': 0, 'Non smoker': 0, 'Cigarettes': 1, 'e-Cigarettes': 1, 'Roll-ups': 1, 'Smoking (cigarettes, cigars, pipe, roll-ups)': 1, 'E-cigs / vape (E-cigarettes)': 1 }
    missing_flag = False
    zero_flag = False
    coded = False
    for value in values:
        if value in ['Missing']:
            missing_flag = True
        if value in ['0',0]:
            zero_flag = True
        if value in mapping:
            coded = mapping[value]
            continue
        if not coded:
            if value.isdigit():
                value = pd.to_numeric(value)
                if value >= 1 and value <= 9:
                    coded = 1
                elif value < 19:
                    coded = 2
                elif value >= 20:
                    coded = 3
    if not coded or missing_flag and zero_flag:
        return np.nan
```

```
    else:
        return coded
```

6. Standardise case pathway data

This function reviews and consolidates tracking data for the 4 service pathways offered by Live Well Dorset. Through initial analysis it was found that numerous aspects of the data were incomplete or poorly structured (multiple interpretable values). The formalised variables are appended to the original data frame for use in further analysis. Definitions of each pathway's 'success' state are detailed in the accompanying thesis document.

```
def prepare_cases(df):
    # Loop all case records
    for index, row in df.iterrows():
        pathway_count = 0
        followup_count = []
        pathways_success = np.NaN
         # Smoking reduction pathway
        if row['Smoking_PathwayActivatedFlag'] == 1:
            pathway_count += 1
            # Ignore rows who start as non smokers (this should be captured with the above, but better
to be sure)
            if (row['Smok_Init_Qty_Day_Group'] != '0') & (row['Smoking_InitialQtyPerDay'] != 'Non
smoker') & (row['Smoking_InitialQtyPerDay'] != '0'):
                smoking_followups = 0
                smoking_success = 0
                # Standardise the smoking quantities
                smoking_df = {}
                start_smoking =
smoking_class(row[['Smoking_InitialQtyPerDay','Smok_Init_Qty_Day_Group']].values)
                smoking_df['Smoker3'] =
smoking_class(row[['Smoking_ThreeMthFUpQtyPerDay','Smoking_3_Month_Daily_Quantity']].value
s)
                smoking_df['Smoker6'] =
smoking_class(row[['Smoking_SixMthFUpQtyPerDay','Smoking_6_Month_Daily_Quantity']].values)
                smoking_df['Smoker12'] =
smoking_class(row[['Smoking_TwelveMthFUpQtyPerDay','Smok_12_Months_Qty_Day_group']].valu
es)
                # Process each potential followup
                for key in smoking_df:
                    if not math.isnan(smoking_df[key]):
                        smoking_followups += 1
                        end_smoking = smoking_df[key]
                # Flag if smoking has reduced
```

```
            net_smoking_reduction = float('nan')
            if end_smoking < start_smoking:
                smoking_success = 1
                pathways_success = 1
                smoking_net_reduction = start_smoking - end_smoking
            else:
                if smoking_followups > 0:
                    smoking_success = 0
                else:
                    smoking_success = -1
            df.at[index,'smoking_followups'] = smoking_followups
            followup_count.append(smoking_followups)
            df.at[index,'smoking_success'] = smoking_success

        # Weight loss pathway
        if row['Weight_PathwayActivatedFlag'] == 1 and row['Weight_Initial'] > 0:
            pathway_count += 1
            weight_followups = 0
            weight_success = 0
            end_weight = row['Weight_Initial']
            for field in
['Weight_ThreeMthFUpWeight','Weight_SixMthFUpWeight','Weight_TwelveMthFUpWeight']:
                # Process each potential followup
                if row[field] > 0:
                    weight_followups += 1
                    end_weight = row[field]
            # Flag if weight has been lost
            net_weight_loss = float('nan')
            if end_weight < row['Weight_Initial']:
                weight_net_loss = row['Weight_Initial'] - end_weight
                weight_net_loss_percent = (row['Weight_Initial'] - end_weight) * (100/row['Weight_Initial'])
                if weight_net_loss_percent > 5: # Success is a 5% loss or more
                    weight_success = 1
                    pathways_success = 1
                else:
                    weight_success = 0
            else:
                if weight_followups > 0:
                    weight_success = 0
                else:
                    weight_success = -1
            df.at[index,'weight_followups'] = weight_followups
            followup_count.append(weight_followups)
            df.at[index,'weight_success'] = weight_success
            df.at[index,'net_weight_loss'] = net_weight_loss
```

```
        # Alcohol reduction pathway
        # Ignore rows who start as non drinkers (this should be captured with the above, but better to
be sure)
        if row['Alcohol_PathwayActivatedFlag'] == 1 and row['Alcohol_InitialAlcoholUnit'] != 0:
            pathway_count += 1
            alcohol_followups = 0
            alcohol_success = 0
            end_alcohol = row['Alcohol_InitialAlcoholUnit']
            for field in
['Alcohol_ThreeMthFUpAlcoholUnit','Alcohol_SixMthFUpAlcoholUnit','Alcohol_TwelveMthFUpAlcohol
Unit']:
                # Process each potential followup
                if row[field] != -1:
                    alcohol_followups += 1
                    end_alcohol = row[field]
            # Flag is alcohol has reduced
            net_alcohol_reduction = float('nan')
            if end_alcohol < row['Alcohol_InitialAlcoholUnit']: # This is not units, they have to have
droppped a banding to be 'successful'
                alcohol_success = 1
                pathways_success = 1
            else:
                pathways_success = 0
                # alcohol_net_reduction = row['Alcohol_InitialAlcoholUnit'] - end_alcohol This is a
categorised value - not calculable
            df.at[index,'alcohol_followups'] = alcohol_followups
            followup_count.append(alcohol_followups)
            if alcohol_followups > 0:
                df.at[index,'alcohol_success'] = alcohol_success
            else:
                # If there were no followups it is unfair to say the pathway did not succeed
                df.at[index,'alcohol_success'] = -1
            df.at[index,'net_alcohol_reduction'] = net_alcohol_reduction

        # Increased activity pathway
        if row['Activity_PathwayActivatedFlag'] == 1 and row['Activity_InitialActivityLevel'] > -1:
            pathway_count += 1
            activity_followups = 0
            activity_success = 0
            end_activity = row['Activity_InitialActivityLevel']
            for field in
['Activity_ThreeMthFUpActivityLevel','Activity_SixMthFUpActivityLevel','Activity_TwelveMthFUpActivi
tyLevel']:
                # Process each potential followup
```

```
            if row[field] != -1:
                activity_followups += 1
                end_activity = row[field]
        # Flag is activity has increased
        net_activity_increase = float('nan')
        if end_activity > row['Activity_InitialActivityLevel']: # This is not units, they have to have
droppped a banding to be 'successful'
            activity_success = 1
            pathways_success = 1
        else:
            pathways_success = 0
            # alcohol_net_reduction = row['Alcohol_InitialAlcoholUnit'] - end_alcohol This is a
categorised value - not calculable
        df.at[index,'activity_followups'] = activity_followups
        followup_count.append(activity_followups)
        if activity_followups > 0:
            df.at[index,'activity_success'] = activity_success
        else:
            # If there were no followups it is unfair to say the pathway did not succeed
            df.at[index,'activity_success'] = -1
        df.at[index,'net_activity_increate'] = net_activity_increase

    df.at[index,'pathways_success'] = pathways_success
    df.at[index,'pathway_count'] = pathway_count
    if len(followup_count):
        df.at[index,'followup_count'] = max(followup_count)
    else:
        followup_count = 0
    return df
```

6. Client-Case join

This function joins client records to the related cases.

```
def join_clients(df, clients):
    # Merge clients with cases data set
    df = pd.merge(df, clients, left_on='clientID', right_index=True)
    # Remove duplicate case IDs
    df.drop_duplicates(subset="CaseID", keep='first', inplace=True)
    return df
```

7. Format time periods for Causal Impact analysis

With a given daily time series dataframe and a specified intervention date, this function returns a pre and post from/to value pair for use with the causal impact library. Intervals (in days) can be optionally included to override the defaults.

```
def get_periods(df, intervention, post_interval = 28, pre_multiplier = 3):
    post_from = min(item for item in df.index if item > intervention)
    post_to = intervention + timedelta(days=post_interval)
    try:
        post_to = min(item for item in df.index if item > post_to)
    except ValueError:
        # We are past the end of the dataset, use the max and inform intead
        post_to = max(df.index)
        print('Warning; max series date used for post_to: ' + str(post_to) + '. Post period = ' + str(post_to
- post_from))
    pre_from = intervention - timedelta(days=(post_interval * pre_multiplier))
    pre_from = min(item for item in df.index if item > pre_from)
    # Get date immediatly before intervention
    loc = df.index.get_loc(intervention)
    pre_to = df.index[loc]
    return [str(pre_from.date()),str(pre_to.date())], [str(post_from.date()),str(post_to.date())];
```

8. Generate table data outside of Jupyter notebook

This function is to assist with outputting tabular data for use in other formats.

```
def output_html_table_file(mytable):
    data, metadata = get_ipython().display_formatter.format(mytable)
    with open('tables/referal-demographic-stratification.html', 'w') as f:
        f.write(data['text/html'])  # Assuming the object has an HTML representation
```