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Personal Protective Behaviour During an Epidemic

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***Abstract*—The TELL ME simulation model is being developed to assist health authorities to understand the effects of their choices about how to communicate with citizens about protecting themselves from influenza epidemics. It will include an agent based model to simulate personal decisions to seek vaccination or adopt behaviour such as improved hand hygiene. This paper focusses on the design of the agents' decisions, using a combination of personal attitude, average local attitude, the local number of influenza cases and the case fatality rate. It also describes how personal decision making is connected to other parts of the model.**

I. Model Structure

The European funded TELL ME project includes a planning model about communication to encourage protective behaviour in response to influenza pandemics. The model has three model entity types for which interaction and behaviour rules are required:

- *Messages*, packaged as communication plans;
- *Regions*, which hold information about the local progression of the epidemic; and
- *Individuals*, who adopt protective behaviour, influenced by the messages they receive and their circumstances.

A communications plan provided as input to the model will involve multiple messages. Each message will have several properties based on the transmission oriented communication framework [1], [2]: Sender, Message, Channel, Receiver, and Effect. The Sender is always the health authority and is not explicitly provided to the model. The Effect is included in the model rules rather than the language describing the communication. The remaining three properties together define which individuals receive the message, either because they have targeted characteristics (such as high risk) or are exposed to the appropriate channel (such as social media), and the content of the message (such as a recommendation to vaccinate). The message language also provides timing and triggering mechanisms to coordinate the communication plan.

Modern understandings of communication are much more sophisticated, for example recognising that there are many contextual factors that influence how a message is encoded by the sender and decoded by the receiver [3]. Such nuanced interpretation of message content is beyond the scope of the model, but is considered in other parts of the TELL ME project.

The progress of the epidemic is managed by the region entities. Their properties include population density and the proportion of the population in specific epidemic states such as 'infected'. The most appropriate simple model for influenza transmission is the SEIR model, This process of transitions is simulated by stepping through discrete time, based on a set of differential equations [4]. : People start in the susceptible (S) state, become exposed (E) but not yet infectious, then become infectious (I) and are eventually removed from calculations (R) because they either recover and become immune or they die.

A key parameter in the transition from S to E is the force of infection, which incorporates probability of transmission given contact and contact rate. The individuals in the model do not transmit the epidemic. However, the protective behaviour of individuals, combined with the efficacy of the behaviour, is used to modify the force of infection. This is equivalent to the approach taken in many mathematical models that have feedback between personal behaviour and epidemic progress [5]. Each region is updated separately, with migration between regions to allow the epidemic to spread.

The model includes several thousand agents representing individuals, with demographic and psychological characteristics that are important for protective behaviour, such as gender and 'high risk' health status perception [6]. Individuals perceive the epidemic state of regions for risk assessment, the content of messages directed to them, and the attitude of other individuals so as to monitor norms. They adopt or abandon protective behaviour according to their policies. The theoretical basis for this behaviour and how it is operationalised in the TELL ME model is the subject of the remainder of this paper.

II. Psychology of Health Behaviour

There are several well established models from psychology that predict (or explain) behaviour and change in behaviour on the basis of other variables such as attitude or perceived risk. Three of these are particularly important. The Theory of Planned Behaviour is the dominant general purpose behaviour model in psychology. The Health Belief Model and Protection Motivation Theory are also popular in the health behaviour literature.

There is no agreement on which of these psychological models is most suitable for any specific type of behaviour, and there is insufficient detail about parameters that may be appropriate for epidemic influenza. Thus, they cannot be directly applied to determine protective behaviour for simulated individuals in the TELL ME model. Nevertheless, they provide guidance on the factors that should be included in the simulation model. Some of the explanatory factors are shared, and there have been attempts to develop a theory that combines the strengths of each.

A. *Theory of Planned Behaviour*

The Theory of Planned Behaviour is an extension of the earlier Theory of Reasoned Action, which asserts that intention is the best predictor of behaviour, and that intention is predicted by three factors [7]. According to the earlier theory, intention is increased in the presence of:

- attitude: favourable evaluation about the specific behaviour;
- subjective norms: perceived social pressure to perform the behaviour, or approval from other people; and
- behavioural control: perceived ease of undertaking the behaviour.

The Theory of Planned Behaviour extends this understanding by adding perceived behavioural control as a predictor of behaviour, in addition to its role in predicting intention [8]. This extension was introduced to recognise that many factors can interfere with intended behaviour, and that perceived control is one way to estimate the likely impact of these factors.

The model does not simply identify the important contributing factors but also proscribes the way they are combined. In particular, intention is a linear combination (weighted sum) of attitude, norms and control. However, the parameters associated with each explanatory variable depend on both the behaviour to be predicted and the situation [8]. Predictive power varies considerably, with a major review of 185 empirical studies finding that, on average, 27% of the variation in behaviour is explained by the proposed explanatory variables [9]. Thus, although the structure can be adapted for the TELL ME model, there is limited guidance on the parameter values to use in rules to control behaviour.

B. *Health Belief Model*

For preventative health behaviour, an important alternative is the Health Belief Model [10]. This asserts that behaviour arises from two dimensions that motivate action—susceptibility and severity—and two that determine the action to be taken—benefits and barriers. There is also some underlying 'cue to action' or trigger (such as symptoms or exposure to media) to stimulate the need for a decision.

There is some evidence that the model has only limited predictive power [11]. This is at least partly because the model is primarily descriptive; there are no standards about how to measure each of the four input factors or how to combine them into a prediction of behaviour, and only limited research about the triggers. Two specific reviews [12], [13] found that published studies do not support the use of the Health Belief Model as a predictive model.

C. *Protection Motivation Theory*

Protection Motivation Theory [14] and related theories such as the Extended Parallel Process Model [15] focus on the role of threat in explaining preventative health behaviour. They argue that fear motivates intent, but behaviour only occurs if there is an effective remedy available. If threat is high but capacity to cope low, Protection Motivation Theory suggests that denial or other maladaptive behaviour will occur instead.

There are six explanatory variables, divided into two groups of three, appraising threat and coping strategy respectively. Threat combines vulnerability (perceived likelihood that the threat personally applies), severity (perceived seriousness of consequences of the threat) and fear arousal (level of worry about the threat). Capacity to cope comprises response efficacy, self-efficacy (perceived ease of undertaking the behaviour) and the absence of costs or barriers that interfere with undertaking the behaviour.

There is empirical support that the framework is useful in explaining existing ongoing behaviour, but less support for its use in predicting future behaviour [16]. In particular, the threat appraisal elements are only weakly predictive, but this could be due to difficulties in varying perceived severity in an experimental setting.

D. *Combining psychological theories*

In a 1992 workshop sponsored by the (US) National Institute of Mental Health, leading supporters of different theories discussed the overlap and reached consensus on eight important factors that explain variations in behaviour [7]. For the purpose of operationalising behaviour in a simulation model, the consensus recognition that some of the explanatory factors included in separate models are essentially the same is particularly relevant. For example, the attitude measure from the Theory of Planned Behaviour is very similar to the combination of benefits and barriers from the Health Belief Model. While Protection Motivation Theory was not included in this reconciliation, it overlaps substantially with the Health Belief Model with, for example, threat appraisal adding only the emotional aspect of worry to the motivation factors of severity and susceptibility.

At least three studies [17], [18], [19] have tested influences from both the Theory of Planned Behaviour and the Health Belief Model for predicting vaccination against an influenza epidemic. All found that attitude and subjective norms from Theory of Planned Behaviour are important predictors and that predictive power increased with the addition of variables from the Health Belief Model. Systematic reviews of psychological factors associated with vaccination against epidemic influenza using the framework of Protection Motivation Theory [20], [6] found similar results, with evidence supporting that the threat appraisal variables of susceptibility and severity are associated with vaccination.

III. Operationalising Individual Behaviour

The TELL ME model focusses on attitude, subjective norms and threat as the key inputs to protective behaviour decisions.

Threat is modelled as a combination of disease severity and local prevalence.

The broad model logic is at Figure 1. The major flow of influence is the effect that communication has on attitude and hence behaviour, which affects epidemic transmission and hence prevalence. Prevalence contributes to perceived risk, which also influences behaviour, establishing a feedback relationship.

An individual's initial attitude is affected by many factors, including health status and culture. Social Judgement/Involvement Theory [21] asserts that the change in attitude induced by communication depends on two key factors, the position of the communication and the latitude of acceptance for the receiver. Conceptually, attitudinal positions have a value over some range. Both the person receiving the message and the message itself have positions. The attitude of the person receiving the message changes toward the position of the message, but only if the message has a sufficiently similar position so as not to be simply rejected (in the agent-based modelling literature, this concept is referred to as bounded confidence, as in [22]). The latitude of acceptance refers to the range of positions that are considered and integrated into the receiver's updated attitude.

For messages within the latitude of acceptance, the amount of change is proportional to the discrepancy between the individual's existing attitude position and the position of the message. Thus, a greater difference in position will result in more change. In addition to the evidence directly supporting Social Judgement / Involvement Theory, there is empirical support for change in attitude proportional to discrepancy [23], [24].

Simulated individuals within the model will be assigned two initial attitudes as values between 0 and 1, representing attitude toward vaccination and toward all non-vaccination protective measures (such as hand hygiene, face masks and social distancing). The initial attitudes will be based on survey information about willingness to adopt protective behaviour, including subpopulation specific attitudes.

Attitude scores will change in response to the messages (created as part of the input communications plan) that are received by the individual. The model will also include some attitude change arising from informal communication, such as discussion with friends or exposure to media.

Subjective norms describe how a person believes family, friends and other personally important people expect them to behave and the extent to which they feel compelled to conform. The norm will be operationalised as the average attitude of individuals in the same or nearby regions, together with some contribution from average attitude in other regions. If there is a message in the communication plan that emphasises norms, then perceived norms will be higher than the weighted average of actual attitudes.

Perceived threat will reflect both susceptibility and severity, with an adjustment intended to capture relative anxiety (that is, some people naturally worry more than others). Severity will be modelled from the case fatality rate and will therefore change as the epidemic progresses. However, early deaths and deaths that are geographically close will be given additional weight.

Following the method of [25], susceptibility will be modelled with a discounted cumulative incidence time series. That is, perceived susceptibility will increase as the epidemic spreads but recent new cases will impact more strongly than older cases. This approach also allows perceived susceptibility to increase but then gradually fade away after the peak has passed. Explicit modelling of the epidemic in the TELL ME model will allow geographical information to modify perceived susceptibility rather than rely entirely on national cumulative incidence. That is, perceived susceptibility will be higher for the simulated individuals that are close to the new cases than for those further away.

The choice of how to combine the explanatory variables and make the behaviour decisions (for example, weighted sum or logistic) will be made during calibration based on the available data. Regardless of this choice, three additional parameters will be required for behaviour policies: the thresholds at which a simulated person seeks vaccination, and adopts or ceases non-vaccination protective behaviour.

IV. Conclusion

This paper describes the planned implementation of cognition in the TELL ME model, which is currently being developed. Simulated individuals are to respond to communication with attitude change and to perceive threat based on local epidemic progress and its severity. Their attitude, perceived subjective norms (based on average attitudes) and perceived threat are used to determine their protective behaviour: seeking vaccination, adopting other protective measures or ceasing protective measures.

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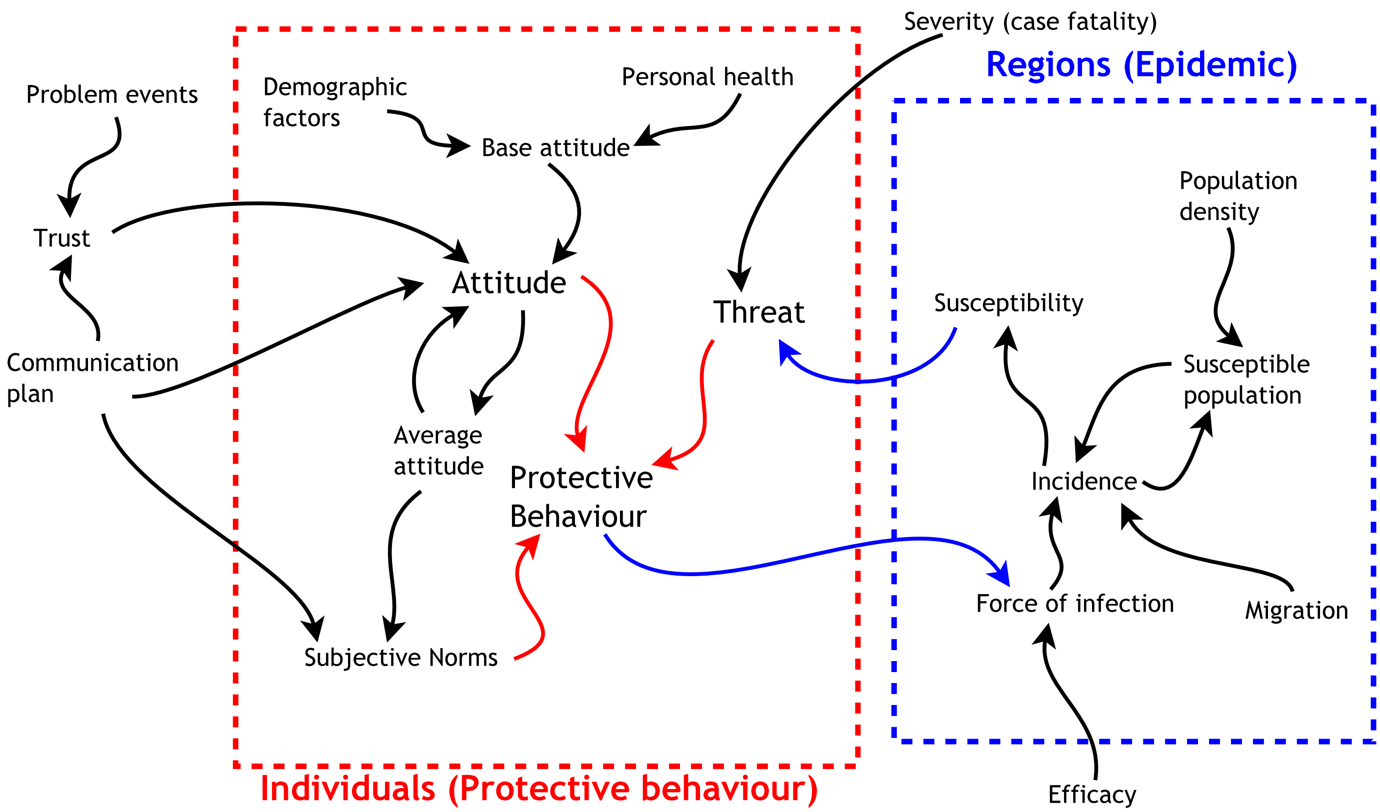

Fig. 1. TELL ME model logic, identifying the influences between variables and organised by model entity. The arrows identify the pattern of influences between properties of entities. At each timestep, attitudes of individuals are updated in response to received messages, then individuals decide their protective behaviour. Adopted behaviour and its efficacy reduces the force of infection of the epidemic and hence its spread.

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