Using multi-scale systems simulation to evaluate health record solutions to improve medication use by the elderly in the community

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Abstract

Elderly patients use more medications given the prevalence of co-morbidities putting them at risk of experiencing medication errors. The implementation of health record solutions, namely a mix of shared electronic health records and personal health records aims to provide information to patients, carers, doctors and pharmacists required to make more informed decisions throughout the medication use process (prescribing, dispensing, administering, monitoring of medications). However, designing this integrated health record solution taking into consideration contextual factors and its impact on existing interventions and society is difficult. Traditional methods lack the capacity to capture the scale of the problem and are inadequate in terms of time, cost, resources and applicability. Multi-scale simulations can represent the system's different spatial and temporal resolutions providing a logical and consistent framework for dynamic analysis and a means to test and design robust health record policies in a risk-free environment.

Keywords: medication errors multi-scale simulation multi-method system dynamics agent based

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Introduction

Medication Use

Medication use by older people is an increasingly important health concern. In Australia, the elderly aged 65 and over comprise 13% of the population (2.6 million, 2004), increasing to 26% - 28% by 2051 (ABS, 2006). Australians have the third highest life expectancy of all OECD countries and can expect to live for another 17.8 years (male, 82.8) and 21.1 years (female, 86.1) after they turn 65 (ABS, 2006), 42%-43% of which live free from disability (AIHW, 2006).

As people age, they tend to have more health problems and increase their medication use (McLean, Le Couteur, 2004). Older Australians are the main consumers of prescription medicine (Brown, Abello et al, 2003) with 86% of people aged 65 or over using medications, compared with 59% for the general population (AIHW, 2002). Over 50% use at least one drug on a regular basis, with the average number of medications used ranging from two to five (AIHW, 2002).

Appropriate medications can significantly enhance the quality of life of older people. However, their altered pharmaco-kinetics and pharmaco-dynamics, decreased cognitive and physical ability and complex medication regimes to manage co-morbidities make them more susceptible to medication errors (McLean, Le Couteur, 2004).

In the community, 400 000 adverse drug events are managed in Australian general practices each year (ACSQHC, 2002) with the elderly attributing to 26.8% of all general practice encounters (AIHW, 2006). 10.4% of all patients were reported to have experienced an adverse event in the past 6 months with the likelihood of an ADE increased with age to peak in those aged 65 and over (Miller, Britt et al, 2006). Up to 30% of all hospital admissions for patients aged 70 and over are medication related (Runciman, Roughead et al, 2003) with 50% of elderly patients taking their medicines incorrectly after leaving the hospital (Gray, Mahoney et al, 2001).

The Medication Use System

Improving the use of medicines by the elderly requires awareness of the environment, medication processes and individuals that encase medication use and influence or contribute to the generation of medication errors. The use of medicines can be conceptualised as a complex system with structural inter-related components spanning across multiple tiers of the health system. The core of the system includes the prescribing, dispensing, administering and monitoring of medications, with each stage susceptible to varying causes for mistakes. This process is governed by contextual factors such as the changing demographics (aging population, economic status, density), cost of drugs, rate of new drugs entering the market, available information on drugs, available information about the patient being treated as well as the education and training of practitioners. The individuals that play a role in the quality use of medicines such as health policy makers, general practitioners (GPs), patients and pharmacists, also contribute to the complexity.

Health Record Solutions

Appropriate medication use by the elderly is hindered by factors such as: poor communication between health professionals, resulting from an action from others (not the GP or patient), judgement errors, poor communication between health professionals, patients consulting other health providers and failing to recognise signs and symptoms (Hodgkinson, Koch et al, 2006). These issues propagate errors through the medication delivery pathway and thus to be combated, require interventions that take into consideration all facets of the medication use system. Such strategies include: computerised systems, education and training, the role of the pharmacist and nursing care models (Hodgkinson, Koch et al, 2006).

The development of electronic health records, a component of the computerised systems intervention, is a highly anticipated policy agenda that addresses not only patient safety issues, but improvements to activity and work patterns, cost savings, time and resource reduction (Clamp, Keen, 2005). It is of particular relevance to the environmental setting of this problem as GPs are in an optimal position to adopt electronic health records with 90% of all general practitioners in Australia using a computerised clinical package, 89% of which utilising the electronic prescribing functionality (McInnes, Saltman et al, 2006). This initiative enables improved information and access to knowledge, highlights the role of technology in supporting care coordination across the continuum of care and is the intervention that will be focussed on in this paper.

Electronic health records commonly refers to “shared electronic health records” (SEHR), a record of the patients encounter-related information managed and shared by the patients clinicians and healthcare institutions (Ball, Smith et al, 2007). These records can then be integrated with applications such as clinical decision support systems providing advice on drug doses, routes and frequencies as well as check for drug-to-drug interactions and allergies; and computerised physician order entry systems that enable the doctor to complete orders online and be presented with typical doses.

Another health record solution receiving a lot of publicity is the personal health record (Ball, Smith et al, 2007), health information managed by the individual. PHRs aim to bridge the patient-provider information gap by providing patient empowerment where they control the management of their health information and is a solution portable across the range of health care services. PHRs are not necessarily electronic, however electronic PHRs can be integrated with other self-management tools such as health status measurement, risk assessment, decision support tools, consumer focused information and education, health care benefits, financial management and community information (Ball, Smith et al, 2007).

The integration of SEHRs and PHRs is implicit in the vision of an electronic health information environment that empowers individual patients, consumers and caregivers to take an active role in their healthcare providing a basis for informed decisions throughout the medication delivery process (Ball, Smith et al, 2007). It also enables a range of options for patients to manage their health information. However, it is difficult to direct the design of such an integrated health record solution that takes into consideration contextual factors, the impact of and its impact on existing interventions and society.

Health policy makers, medication and health record experts are presented with my questions surrounding the delivery of this initiative including: What blend of SEHRs and PHRs should be considered? Where and when should the solution be implemented? What is the return on investment with respect to cost, access, safety and quality for different solutions? Directing the design of an integrated health record solution requires scientifically rigorous assessments on the value health record interventions have on patient safety. This becomes a difficult task with the use of medicines embedded in a complex health care system. Current methods used for evaluating such interventions lack the capacity to capture this complexity and accurately forecast outcomes.

Current Evaluation Methods

Current methods used to evaluate interventions such as health record solutions are typically based on retrospective observational studies on already implemented health record systems. Markov modelling, regression, correlation or other statistical analytical tools are then applied to predict the return on investment in terms of improved quality of care and costs. The feasibility of this approach to explore possibilities and direct the design of new health record solutions is limited by several factors including: time required to observe long term outcomes (and whether the intervention would be obsolete once the trial concluded), the requirements for large sample sizes to filter out random noise, the large number of options to be evaluated, the disruption of current practices to implement each option, the reluctance of general practitioners to participate, the artificial constraints applied to trial designs, lack of transferability between different settings as well as the high cost of studies (Eddy, 2007).

Multi-Scale Systems Simulation

Systems Modelling and Simulation

Modelling paradigms are metaphors used to conceptualise the world. They provide semantic frameworks to translate and allow investigation of problems by exploiting powerful inspiring analogies (Villa, 1992). A systems approach provides a view where the interaction of a system’s indivisible collection of interconnected parts as a whole produces emergent properties or behaviours which could not be readily predicted by examining each part in isolation. *"The whole is greater than the sum of the parts"*.

Many modelling paradigms exist, each suited to a particular level of abstraction of a problem. System dynamics models outline the context of a problem. It can be used to make explicit the boundaries of the medication use system, its structure and relationships. Using this approach reinforcing and balancing feedback effects, circular causation, delayed responses and the leverage points where decisions and actions bring about changes (Sterman, 2000) around the quality use of medicines can be identified. Agent based modelling captures emergent and non-linear behaviour arising from the repetitive and competitive interactions between individuals and their environment at the individual level (Bonabeau 2002; Axelrod and Tesfatsion 2007) and how the medication use system learns, adapts and self-organises itself to maintain order (Begun, Dooley et al. 2003).

Systems modelling and simulation can be used to explore, understand and improve the interaction between individuals, structures and actions (Heffernan, McDonnell, 2005) within the medication use system. It can also be used as a collaboration artefact to build consensus among different disciplines and viewpoints (Heffernan, McDonnell, 2005). Hypotheses can be developed about the mechanisms (components and their interactions) driving the current use of medicines. The simulation tests this hypothesis by enabling comparisons with data and observed behaviour with the derived behaviour. This is valuable to avoid misperceptions of the how behaviours concerning medication use are derived and thus enable assessment and selection of appropriate intervention policies.

Multi-Scale Systems Modelling and Simulation

Multi-scale systems modelling and simulation represents a system in terms of different scales (spatial and temporal) of resolution (Bassingthwaighte, 2006) and suited to characterising the functions and desirability of organisational forms (Bar-Yam, 2006). This modelling technique has the ability to adaptively switch between different levels of abstraction during real-time simulation (Bassingthwaighte, 2006).

Methods of achieving both aggregate and disaggregate views in one simulation vary. The approach taken in this paper is the use of multi-method modelling and simulation. This approach combines a number of modelling methods or paradigms each capturing different levels of abstraction. This utilizes the strengths of each paradigm and enables a view of the complexity at each level of the medication use system hierarchy and at different time scales. This process is made simpler with simulation platforms now capable of integrating and cooperating efficiently between different modelling paradigms (Borshchev and Filippov 2004).

Multi-scale systems modelling and simulation is the approach that will be taken in this study to simplify the real world to emphasize only the necessary and sufficient mechanisms and interactions that drive the use of medicines by the elderly and depicts how behaviours concerning medication use occur and change over space and time.

Multi-Scale Systems Model Formulation

Transforming the multi-scale problem into a model requires focus on the most essential information about a complex system's internal organisation. Firstly, the physical dimensions (space and time) of interest need to be identified. That is, the varying scales important entities and mechanisms simultaneously operate within and across to cause changes to the system's overall behaviour (Ewert, van Keulen et al, 2006). Various perspectives become important in representing different aspects of the system. These observed behavioural patterns in the real system at differing scales can be used to reduce uncertainty with the model structure and parameters and systematically optimise the complexity of the model (Grimm, Revilla et al, 2005).

Next, the system's capability is decomposed according to scale (Bar-Yam, 2006). Important entities, mechanisms and processes are identified, representing working hypotheses about how a portion of the overall system works (Bassingthwaighte, 2006), and classified according to their scale of operation. Observed objects and variables correspond directly to model components. The internal organisation of the real system translates into model processes (Grimm, Revilla et al, 2005).

Each level of abstraction of the problem is then modelled with a method typically suited for the level of aggregation. Here, system dynamics will be used to outline the context of the problem (described earlier) making explicit the boundaries, structure and relationships of a system. Agent based modelling will be used to describe rules of interactions between GPs, patients and pharmacists. Linking the two model levels can be achieved by matching the spatial and temporal detail of the models and of the definitions of transferred variables (Ewert, van Keulen et al, 2006).

The system dynamics and agent based models will be built and integrated in the AnyLogic6 development environment (Borshchev and Filippov 2004). AnyLogic6 is a new integrated development environment which combines System Dynamics, Agent Based and Discrete Event simulation using the Java Eclipse framework. The open architecture allows interoperability with office and corporate software, powerful software extensions including geographical information system datasets and custom modules written in Java. AnyLogic6 features a built-in optimiser and enables compelling and engaging animations that can be exported as java applets and viewed across multiple operating system platforms (XJ Tech, 2007).

Finally, a graphical use interface will be created in the AnyLogic6 development environment (Borshchev and Filippov 2004) for health policy makers, health record domain experts and medication domain experts to interact with and perform their health record decision experiments to find the answer to their questions posed earlier in this piece. Different mixes of SEHRs and PHRs can be trialled over varying times and desired locations for implementation. Indicators such as cost, access and quality can also be displayed for reference. This interface will use innovative graphics and animations to create an engaging and immersive learning environment, heightening the user's experience and encouraging more relevant and realistic decisions to be made.

Conclusion

Designing health record interventions to improve the use of medicines by the elderly in the community becomes a difficult task when factoring in the complexity inherent of the use of medicines. Traditional methods such as random controlled trials and studies lack the capacity to capture the scale of the problem and are inadequate in terms of time frames, cost, resources required, and non-applicability of trial settings. Multi-scale systems simulations extend traditional systems modelling methods enabling the representation of the system's different spatial and temporal resolutions. This provides a logical and consistent framework for dynamic analysis and a means to test and design robust health record policies in a risk-free environment.

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