

# A framework to provide clarity in the use of predictive technologies in health care management

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## Abstract

This paper reports on a survey of health care managers and other stakeholders which assesses the need for a framework regarding predictive technologies in health care management. In the context of this paper, predictive technologies are defined as those that enable an insight into, or measurement of, events yet to occur. A framework could include the ability to classify the problems confronting managers, and the range of possible tools and techniques that could be used to address those problems. This could be of mutual benefit to health care managers, technologists and modellers. The survey was intended to clarify the level of interest in such a framework, and also the possible dimensions that it ought to contain. Our results indicate that there is strong support for a proposed framework, with 97% of respondents indicating that a framework would be possibly or very useful. The results also show a low level of background knowledge in relation to existing tools, techniques and technologies. The draft framework is also presented. It includes dimensions relating to problem and tool definitions, scenarios to be investigated and the findings of those investigations.

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## What is known about the topic?

There is currently much activity underway in the health care industry involving predictive technologies of various kinds. There is no overarching framework in which problems and potential solutions can be evaluated or matched.

## What does this paper add?

Responses from across Australia show a high level of interest in the development of a suitable framework. A draft framework developed on the back of the results of a survey is presented, for comment by the wider audience.

## What are the implications for practitioners?

Health care managers, administrators and practitioners will benefit from having a clear framework in which to understand and define the kinds of problems they face. Technologists, modellers and information systems professionals will benefit from the engagement with stakeholders that such a framework can facilitate.

WHILE THERE IS WORK GOING ON in the broader fields of modelling and simulation in relation to key issues such as interoperability and standards,<sup>1-4</sup> there is still a lack of clarity about how such work should relate to the domain of health care management. The rationale for this paper is:

- There has been prior work in this domain,<sup>5</sup> but there are no clearly agreed relevant standards.
- There has been activity going on in relation to predictive technologies in health care for many years,<sup>6,7</sup> and the problems confronting health care managers are often quoted as the justification for the background science.<sup>8-10</sup>
- The information technology (IT) community has long advocated the role of standards in IT development.<sup>11,12</sup> In order to advance the science to the point of practical application in this area, there is a necessary role for standards. In the area of health care management there is currently no common taxonomy or understanding.

**I Response rate**

<b>Overall numbers</b>	<b>n(%)</b>
Sent	414 (100.0)
All emails bounced	88 (21.3)
Not all emails bounced	326 (78.7)
Responded*	64 (19.6)

\* 19.63% of those recipients who clearly had at least one contact not rejected.

The primary question is: do stakeholders support the need for a framework? The secondary questions are:

- Does their demographic profile, background, position or skill set influence their level of support?
- What are the features of such a framework, in the opinion of the stakeholders?

A framework could allow the various stakeholders to use a common view in order to understand a problem and the potential solution(s). In the context of a hospital, the question of how many beds will be needed for elective orthopaedic activity in 2 years time may be classified as a medium-term strategic planning problem of fine grain, as opposed to other views of the problem over different time frames. Each will imply a different type and level of solution from a technical perspective.

## Methods

The survey was developed with a multidisciplinary team of evaluators, epidemiologists and statisticians and was administered via email and web delivery to a convenience sample of stakeholders across Australia. The survey included questions pertaining to demographic details, background, current position, and respondent knowledge and opinions in relation to predictive technologies in health care management (see Appendix). Stakeholders included hospital managers and clinicians, health care executives, technologists and a range of academics and scientists relevant to the field.

Potential participants were identified by web searching for email addresses where they were clear or could be inferred, from a range of online sources. They were included where it was clear that they did have, or could have had, a role in work in relation to service planning, modelling or health care management.

The Internet locations were searched in November and December 2005, for sources with a date range of 2000–2005. The locations searched included: The Australian Resource Centre for Healthcare Innovation (ARCHI) website, hospital and government websites, patient flow collaborative websites and electronic journals (eg, Australian Journals Online).

## Data collection

Participants were advised of the research process and agreement to participate was considered informed consent. The Melbourne Health Human Research Ethics Committee approved the process. The survey was sent on a group mailing list of 414 potential participants as a Microsoft Word attachment. It was resent 3 weeks later in an attempt to increase the response rate. Finally, all potential participants were emailed a web link to the Melbourne Health website on which portable document format (pdf) and Microsoft Word versions of the survey had been placed.

Responses were to be directed to the Office Manager at the Clinical Epidemiology and Health Service Evaluation Unit, The Royal Melbourne Hospital, who was not directly involved in the survey project or data analysis, by email, post, facsimile or in person. In the event that they arrived at another email address (if emailed), they were redirected by the CEHSEU staff to the Office Manager.

Participant responses were analysed using the statistical packages SPLUS (Insightful Corporation, Seattle, Washington, USA) and STATA (Stata Corporation, College Station, Tex, USA). Given the low initial response rate, a non-responder analysis was undertaken with data collected by phone interview. This was performed to identify any important differences in the initial responder and non-responder groups. Initial non-responder

## 2 Respondent role profile

Occupation*	n (%)
Academic (health care)	15 (22.4)
Clinician	14 (20.9)
Clinician manager	10 (14.9)
Health administrator (hospital/network)	8 (11.9)
Technologist/solution developer	7 (10.4)
Academic (science/maths/statistics/OR)	5 (7.5)
Health administrator (government)	4 (6.0)
Academic (business)	1 (1.5)
Academic (management)	1 (1.5)
Data analyst	1 (1.5)
Health systems simulation consultant	1 (1.5)

\* More than one category can apply to each respondent.  
OR = operations research.

ers were again given the opportunity to participate or not when contacted by phone.

## Results

The vast majority of data fields were filled out by all participants — with a minimal number of missing or ambiguous values.

The initial response rate was disappointing, at about 20%. Notably however, the non-contact rate (based on auto generated email responses) was in the order of 20% of the total sampling frame. The inference is that in 78.7% of cases, it could be reasonably implied that the participant received either the survey, or the information about accessing the survey via the Internet.

### Demographic and role/background analysis

According to the data, responders were more likely to be males (78%,  $P < 0.001$ ) who lived in Victoria ( $P = 0.002$ ). There were no significant differences between the ages of responders. Box 2 outlines the respondent role profile.

In relation to respondent organisation, most respondents worked in a hospital (53.1%) or a university (34.3%). A smaller percentage worked in government roles (15.6%). Importantly, again, more than one category could be applicable to

each respondent. Respondents' educational background is shown in Box 3.

Most respondents were men, 40–59 years of age and from Victoria. About 36% self-identified as clinicians or clinician-managers; 22% as academics in health care; and 18% as health administrators (hospital or network). In terms of their current organisation, 53% of respondents self-identified as predominantly working in a hospital, and most were from a health care discipline in terms of educational background. It can be seen that there was a good basis on which to generalise the findings of the survey to the hospital managerial group, one of the key stakeholder groups in this area of work.

With the exception of statistical process control techniques, an area where there has been much recent work<sup>13-15</sup> (60% had some awareness), respondents had little awareness of the options presented regarding existing tools and techniques in this problem domain (Box 4). In 40% of cases or more for each option presented, participants were not at all aware of the example. The results were even less encouraging for the examples of various commercial products presented. This could reflect the relatively poor penetration of such products into the Australian commercial market at the current time.

### Framework usefulness and content analysis

The overwhelming finding of questions 8–12 was that the participants were in favour of the devel-

## 3 Respondents' educational background

Education*	n (%)
Health (medical)	31 (33.3)
Health (other)	15 (16.1)
Business/finance/management	14 (15.1)
IT/computer science	11 (11.8)
Health (nursing)	10 (10.8)
Mathematics/statistics	8 (8.6)
Operations research	4 (4.3)

\* More than one category can apply to each respondent.  
IT = information technology.

#### 4 Respondent prior knowledge of tools, techniques and technologies (Question 7)

Tool/technique/technology	Not aware n (%)	Aware (not read) n (%)	Aware (read) n (%)	Missing data n (%)	Total
Commercial products	41 (64.1)	14 (21.9)	7 (10.9)	2 (3.1)	64
Discrete event simulation	34 (53.1)	16 (25.0)	13 (20.3)	1 (1.6)	64
System dynamics simulation	37 (57.8)	15 (23.4)	9 (14.1)	3 (4.7)	64
Mathematical techniques	30 (46.9)	14 (21.9)	19 (29.7)	1 (1.6)	64
Compartment models	40 (62.5)	10 (15.6)	12 (18.8)	2 (3.1)	64
Statistical process control	25 (39.1)	14 (21.9)	23 (35.9)	2 (3.1)	64

opment of a framework as outlined in the survey. Fifty-six percent responded that it would possibly be useful, and a further 41% indicated it would be very useful (Box 5).

##### Sub-factor analysis

The sub-factor analysis showed that only prior knowledge of commercial products was associated (near to a level of  $P < 0.05$ ) with a positive response to the idea of a framework. In all other cases the  $P$  value was higher than 0.05. There were no demographic or background factors found to affect the response to Question 8 at a level of  $P < 0.05$ . Prior knowledge of commercial software products in this domain had a  $P$  value of 0.056 (Box 6).

##### Non-responder analysis

There was no significant difference between the two groups in terms of age, state, profession and education. However, there was an important difference between responders and non-responders in relation to the sector in which they worked: 58.3% of non-responders worked in a university, while only 34.3% of responders worked in a

university. The majority of responders (53.1%) worked in a hospital. Importantly, on the primary question (no. 8) there was no significant difference detected in the level of support for the concept of a framework.

##### Limitations

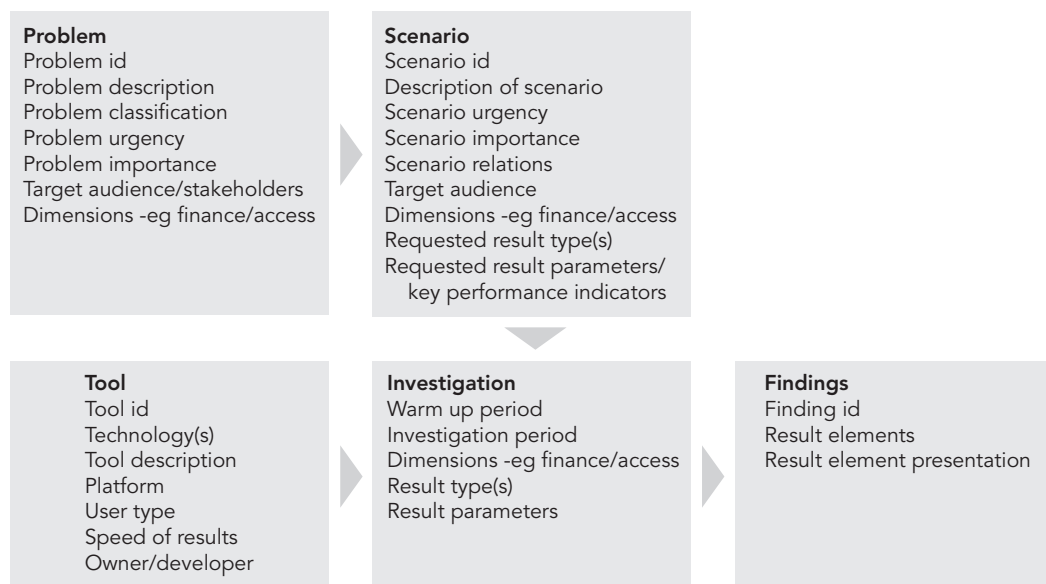
There are a number of obvious limitations in this study. These could be categorised under the following headings:

- *Sampling approach.* The relevant stakeholder population could have been sampled, for example, via the relevant professional bodies. This would have caused trade-offs in relation to project length, and the likelihood of gaining approval from the necessary range of professional bodies.
- *Survey administration/response rate.* It could also be argued that allowing the survey to be filled in online would have increased the response rate. However, there can often be issues in obtaining adequate engagement with some sections of our stakeholder group.<sup>16</sup> For example, physician engagement is often recognised as an issue in obtaining system change in hospitals

#### 5 Respondent opinions regarding framework usefulness and content

Question	Not useful n (%)	Possibly useful n (%)	Very useful n (%)	Missing data n (%)	Total
8	2 (3.1)	33 (51.6)	24 (37.5)	5 (7.8)	64
9 (definitions)	2 (3.1)	21 (32.8)	39 (60.9)	2 (3.1)	64
10 (time frames)	2 (3.1)	11 (17.2)	49 (76.6)	2 (3.1)	64
11 (target users)	2 (3.1)	26 (40.6)	31 (48.4)	5 (7.8)	64

## 6 Predictive technologies for health framework (draft)



and health services.<sup>17</sup> It was our expectation that the response rate would have been lower than ideal, no matter what technique was used.

- **Generalisability of results.** There is the potential criticism that the results aren't generalisable to the entire stakeholder group. Given that responses were obtained from a diverse range of stakeholders and there are minimal differences between the responder and non-responder groups, we believe that the thrust of the results, that the development of a potential framework is strongly supported, can be generalised to the wider stakeholder community.

Nonetheless, this is clearly the first work of its kind in this area, and it outlines an initial understanding of the needs of the various stakeholders in this domain, and a possible way forward in addressing those needs.

## Discussion

The overwhelming response from the sampled stakeholders is that a framework is likely to be useful. In relation to the other questions, given

the overall low awareness rate (11.3%) of commercial technologies, it is likely that respondents who indicated awareness are a sub-group of knowledgeable people in this area. In turn, they are also likely to be aware of the need for advances such as a framework in this problem domain. The survey revealed few useful themes in relation to the key elements that should be included in a framework. However, the strongly positive responses to Questions 9–11 indicated that definitions, time frames and user roles are all perceived to be important parts of a framework. Ideally, further information should be sought from the stakeholders identified in this research, in order to add further detail to the debate, and to gain feedback regarding the framework presented.

## Framework

The framework that follows was developed using an entity-relationship modelling technique<sup>18</sup> (Box 6) and includes stakeholder input from the survey as well as established knowledge in the problem domain. The key entities put forward in this draft framework are:

- *Problem*. This entity encompasses the idea of, and data around, the business problem being addressed. These elements would include a unique identifier, a description of the problem, urgency, and a target audience description.
- *Scenario*. A scenario is the encapsulation of the idea that any given business problem may need to be analysed via a number of potential views. These views may include different possible input or output configurations, or the comparison of a number of possible solutions. It could include a unique identifier, a description of the scenario and the dimensions across which the problem is being analysed (eg, finance or access or both).
- *Tool*. This entity exists to encapsulate the details round the particular tool being used in the predictive context, so it could again include a unique identifier, a classification of the kind of tool (eg, simulation model versus statistically based model), and the speed of results (eg, runs overnight versus instantaneous processing).
- *Investigation*. The investigation entity exists to encapsulate the combination of a tool being applied to a given scenario. By inference, different tools could be applied to different scenarios in order to produce unique investigations of a business problem.
- *Findings*. This entity encapsulates the units of outcome of a given investigation such that there is a one-to-many relationship between an investigation and its one or more findings. For example, a given investigation may deliver a finding around income and a finding around access.

## Conclusions

There is clear support for a framework to be developed in this domain. The framework presented represents a starting point. Ongoing consultation with stakeholders is essential to ensure that the needs of both “problem-holders” and “problem-solvers” are met. In summary, we would suggest that:

- this research be extended by eliciting feedback on the draft framework;

- an ontology be developed for the domain of predictive technologies in health care management; and
- other work be initiated through relevant professional groups to investigate and recommend relevant standards.

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## Competing interests

The authors declare that they have no competing interests.

## References

- 1 McCabe K. IEEE begins to revise four simulation standards. IEEE Standards Association, 2005. Available at: [http://standards.ieee.org/announcements/pr\\_simulation.html](http://standards.ieee.org/announcements/pr_simulation.html) (accessed Nov 2006).
- 2 IEEE Standards Association. Computer simulation standards. IEEE, 2005. Available at: [http://standards.ieee.org/catalog/olis/arch\\_compsim.html](http://standards.ieee.org/catalog/olis/arch_compsim.html) (accessed Nov 2006).
- 3 National Institute of Standards and Technology, Manufacturing Engineering Laboratory. Manufacturing metrology and standards for the health care enterprise. NIST, 2005. Available at: <http://www.mel.nist.gov/proj/hc.htm#pj> (accessed Mar 2006).
- 4 Fishwick PA, Miller JA. Ontologies for modeling and simulation: issues and approaches. Winter Simulation Conference; 2004 Dec 5-8; Washington, DC, USA. Available at: <http://www.wintersim.org/prog04.htm> (accessed Nov 2006).
- 5 Harper PR. A framework for operational modelling of hospital resources. *Health Care Manag Sci* 2002; 5: 165-73.
- 6 Banker RD, Conrad RF, Strauss RP. A comparative application of data envelopment analysis and translog methods: an illustrative study of hospital production. *Manage Sci* 1986; 32: 30-43.

- 7 Robinson JC, Luft HS. The impact of hospital market structure on patient volume, average length of stay and the cost of care. *J Health Econ* 1985; 4: 333-56.
- 8 Rosko MD. Impact of internal and external environmental pressures on hospital inefficiency. *Health Care Manag Sci* 1999; 2: 63-74.
- 9 Bowers J, Mould G. Ambulatory care and orthopaedic capacity planning. *Health Care Manag Sci* 2005; 8: 41-7.
- 10 Gaynor MS, Anderson GF. Uncertain demand, the structure of hospital costs, and the cost of empty hospital beds. *J Health Econ* 1995; 14: 291-317.
- 11 Isaak J. The role of government in IT standards. *Computer* [Magazine of the IEEE Computer Society] 1998; 129.
- 12 Health Level 7 Inc. What is HL-7? Available at: <http://www.hl7.org/> (accessed Nov 2006).
- 13 Garland AF, Lewczyk-Boxmeyer CM, Gabayan EN, Hawley KM. Multiple stakeholder agreement on desired outcomes for adolescents' mental health services. *Psychiatr Serv* 2004; 55: 671-6.
- 14 Gollop R, Whitby E, Buchanan D, Ketley D. Influencing sceptical staff to become supporters of service improvement: a qualitative study of doctors' and managers' views. *Qual Saf Health Care* 2004; 13: 108-14.
- 15 Burns CM, Bennett CJ, Myers CT, Ward M. The use of cusum analysis in the early detection and management of hospital bed occupancy crises. *Med J Aust* 2005; 183: 291-4.
- 16 Mohammed MA, Cheng KK, Rouse A, Marshall T. Bristol, Shipman, and clinical governance: Shewhart's forgotten lessons. *Lancet* 2001; 357: 463-7.
- 17 Scobie S, Thomson R, McNeil JJ, Phillips PA. Measurement of the safety and quality of health care. *Med J Aust* 2006; 184(10 Suppl): S51-5.
- 18 Rob C, Coronel C. Database systems: design, implementation and management. 4th ed. Cambridge, Ma: Course Technology, Thompson Learning, 2000. □

## Appendix



### Predictive Technologies in Healthcare Management Survey

This survey is designed to assess the need for a framework for healthcare professionals, managers, technologists and modelers of various kinds to relate to and work within, in relation to the development of predictive technologies to assist in healthcare management (at a unit/division, facility or system level)

For the purposes of the survey, **predictive technologies are defined broadly as those that enable an insight into, or measurement of events yet to occur.**

The framework under consideration could be thought of as a “mud map” where various stakeholders could use common terminology and common facets of both problems and models/software, to come to a common understanding of the problem to be dealt with and the potential solution(s).

For instance the question of “how many beds will we need to allocate for elective Orthopaedic activity in 2 years time?” may be classified as a **medium term, strategic planning** problem of **fine grain**, as opposed to “how many beds will we need to allocate for elective Orthopaedic activity next week?” may be classified as a **immediate, operational** problem of **fine grain**. Each will imply a different type and level of solution from a technical perspective.

It is the intention of the survey to clarify the level of interest in such a framework from a stakeholder perspective, and also the possible dimensions that such a framework ought to contain (eg- time, depth of detail required, audience/end users etc)

The survey includes questions pertaining to demographic details, background, current position, respondent knowledge and opinions in relation to predictive technologies in healthcare management, and respondent ideas for future development of tools in this domain.

**It will take 5 minutes to complete. You can return by email ([wendy.lemaire@mh.org.au](mailto:wendy.lemaire@mh.org.au)) or fax ((+61) 03 9342 7060)), or you can post it to CEHSEU, 7W- Level 7 Main Building, Melbourne Health. Parkville Vic. 3050. Australia.**

**All responses will be de-identified on return by Wendy Lemaire (CEHSEU Office Manager) before analysis. Mrs Lemaire has no direct involvement in the survey or in the analysis and presentation of results.**

#### Part A Demographic Details and Role/Background

- |   |                                |                                 |                                |                                |                              |
|---|--------------------------------|---------------------------------|--------------------------------|--------------------------------|------------------------------|
| 1. Gender:  | <input type="checkbox"/> male  | <input type="checkbox"/> female |                                |                                |                              |
| 2. Age:   | <input type="checkbox"/> 20-29 | <input type="checkbox"/> 30-39  | <input type="checkbox"/> 40-49 | <input type="checkbox"/> 50-59 | <input type="checkbox"/> 60+ |
| 3. In which state or territory are you currently working? : |                                |                                 |                                |                                |                              |
| <input type="checkbox"/> VIC                                | <input type="checkbox"/> NSW   | <input type="checkbox"/> QLD    | <input type="checkbox"/> SA    |                                |                              |
| <input type="checkbox"/> WA                                 | <input type="checkbox"/> NT    | <input type="checkbox"/> TAS    | <input type="checkbox"/> ACT   |                                |                              |



**4. Are you predominantly a:**

- ☐ Clinician ☐ Health Administrator (hospital or network)
- ☐ Health Administrator (government) ☐ Clinician-Manager
- ☐ Technologist/Solution Developer ☐ Academic – Health Care
- ☐ Academic – Science/Mathematics/Statistics/ OR
- ☐ Other \_\_\_\_\_

**5. Are you predominantly working in:**

- ☐ Hospital ☐ Government ☐ University ☐ Other

**6. Is your educational background in (select as many as apply):**

- ☐ Mathematics/Statistics ☐ Health-Medical ☐ Health-Nursing
- ☐ Health-Other ☐ Business/Finance/Management ☐ Operations Research
- ☐ Information Technology/Computer Science

**Part B Knowledge of Predictive Technologies In Healthcare Management**

**7. How aware are you of the following tools/technologies?**

	Not at all aware	Aware, have not read about	Aware and have read about
Commercial Products (including Cap Plan (by Emendo), Roadhouse Patient Flow Suite, Strata Health Solutions)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Discrete Event Simulation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
System Dynamics Simulation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mathematical Techniques – including Markov Models	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Compartment Models	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Statistical Process Control Techniques	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Part C Usefulness and content of a framework for predictive technologies in health care management**

<b>8. How do you rate the usefulness of a possible framework for predictive technologies in health care management?</b>	Not at all useful <input type="checkbox"/>	Possibly useful <input type="checkbox"/>	Very useful <input type="checkbox"/>
<b>9. Should definitions be a key part of such a framework? (eg- definition of strategic planning vs operational control model)</b>	No <input type="checkbox"/>	Possibly <input type="checkbox"/>	Yes <input type="checkbox"/>
<b>10. Should time frames be a key part of such a framework (eg- to distinguish the required duration of a request for “modeling” – for instance - how full will the hospital get next week ? VS how many operating theatres will we require in 5 years time ?)</b>	No <input type="checkbox"/>	Possibly <input type="checkbox"/>	Yes <input type="checkbox"/>
<b>11. Should target user type be a key part of such a framework (eg- to distinguish tools/software aimed at line managers VS CEO VS CFO)</b>	No <input type="checkbox"/>	Possibly <input type="checkbox"/>	Yes <input type="checkbox"/>
<b>12. Can you suggest any other features that a such a framework should contain? If so please list opposite.....</b>	<div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div>		
<p>If you would like to discuss any of the issues raised in this survey in more detail, please contact: Dr Chris Bain (<a href="mailto:christopher.bain@mh.org.au">christopher.bain@mh.org.au</a>) (03) 9342 8772.</p> <p style="text-align: center;"><i>Thank you for completing this survey</i></p>			