Curtin AG, Anderson V, Brockhus F, et al. Novel team-based approach to quality improvement effectively engages staff and reduces adverse events in healthcare settings. BMJ Open Qual 2020;9:e000741.

Supplementary File #1	Further description of the MEER approach used in the Epworth study				
Supplementary File #2	MEER intervention survey - analysis of reliability and inter-item consistency of survey responses				
Supplementary File #3	Process control charts and ITS analysis of Epworth MEER trial				
Supplementary File #4	Additional Data on Participation in MEER Sessions and Surveys				
Supplementary File #5	MEER intervention survey - Paired two sample ordinal test				

Supplementary File #1 – Further description of the MEER approach used in the Epworth study

Introduction

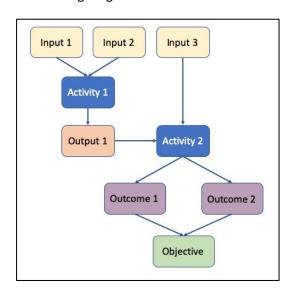
This Supplementary File provides a detailed description of the MEER approach and specific information on how this technique was applied in the Epworth study. The document includes two sections and a set of Appendices. The first section describes the MEER approach and explains how the four steps of the approach can be implemented in practical terms in any organisation. Further detail about the four steps can be found in the following article:

Cohen DR, Cohen PJ, Anderson V. Map-enabled experiential review: A novel approach to engaging healthcare staff in quality improvement. *Manag Healthc.* 2018;3(2):187–98.

The second section explains how the MEER approach was implemented in the Epworth study using an online application available for that purpose (MEERQAT; see https://meerqat.com.au). The Appendices present detailed resources that would enable any healthcare organisation to assess their own process pathways relating to *Patient ID and procedure matching*, as described in the accompanying article by Curtin *et al*.

Section 1: Overview of the MEER approach

Map-enabled experiential review – or MEER – is a technique that re-purposes tools commonly used in process management and evaluation for use in a quality improvement context. MEER uses graphical models, or *maps*, of process systems to enable structured conversations amongst teams of staff. A generic process model is illustrated in the following diagram.



By using a map that explicitly sets out key components of process pathways, this ensures the team takes a systematic approach to reviewing how well the pathways depicted in the map are being implemented, drawing on knowledge and experiences of staff. The outcomes of these structured conversations then

serve as an evidence base for a quality improvement action plan. The MEER approach comprises four steps, which are summarised below.

Step 1: Model development

This involves developing the process model for the process system(s) the team wishes to review and comprises two main tasks. The first task is to create a graphical model that depicts the relationship between the inputs, activities and outputs of a given process (or system of processes) and how these give rise to the expected outcomes and objectives of the process(es). The model can initially be drawn on paper or a whiteboard and should then be translated into an electronic format to create a more permanent version that can easily be updated, shared and displayed.

The second task is to create content that will be used in the structured conversations. For each input, activity, output, outcome and objective in the map (termed 'nodes'), this content always includes a rating question and rating options that will be considered by the group, and may also include information about the node (key characteristics; how or why the node is important to the overall outcomes; etc) that can be used in the course of the assessment activity (see Step 2 below) to educate or remind staff about important aspects of daily practice.

Each node's rating question and rating scale generally reflect an aspect of that component of the process pathway that is central to its successful implementation. Rating questions are framed in a way that can be answered by individuals, so that team members can nominate a rating that reflects their own experiences. Rating scales can be anything from a two-point 'yes/no' scale, to a three-, four- or five-point scale and should include a 'not applicable' rating option, to allow for circumstances where certain nodes (or whole process pathways) are not relevant to the team conducting the assessment. Some examples of rating questions and rating scales (excluding the *Not applicable* option) are provided in the following table:

Node rating question	Node rating scale
Is patient identity always confirmed during clinical	1. Yes
handover?	2. No
How up-to-date are your health service policies on	Policies are up to date and relevant
patient identification, procedure matching and clinical	Polices require updating
alerts?	3. Polices do not exist
How often do staff consult policies?	1. Regularly
	2. Occasionally
	3. Rarely
	4. Never
Overall, how would you rate the process of creating	1. Very good
patient ID bands?	2. Good
	3. Neither good nor poor
	4. Poor
	5. Very poor

Nodes can be designated as 'not rateable' if the node represents a component of the system that cannot — or should not — be rated. One example is a node for an external framework or standard, which is an important input to an organisation's process pathway, but is simply a fact of life for the organisation and cannot be changed. Another example is individual team members, who are an essential input to various process pathways, but should not be rated through the MEER approach.

Node content can be created and stored in any convenient electronic format, such as a table prepared in Word or Excel. This tabulated information can be used as a template for recording team members' input during the assessment step. The table should include fields documenting the node title, node description and rating question. There should also be blank fields under each rating option to allow the number of staff nominating that rating option to be recorded, as well as a blank field for recording comments, a blank field for recording the consensus rating of the group and a field for recording whether any tasks should be added to the action plan to address any of the issues raised during discussion (see Steps 2 and 3 below).

Step 2: Assessment

This involves using the process model to guide the team through discussions about how those process systems are working in the context of routine practice. In our experience, assessment sessions of 30–45 minutes duration work well, although longer sessions are possible if time and resources permit. Each session is a structured conversation between team members about what they do in the course of routine practice, why they do it that way and how they can address any issues they identify. The graphical map provides the structure for the conversation, with the node content providing contextual information and a specific focus for rating each node.

Although other methods are possible, in our experience, the sessions work best with the graphical map projected onto a wall or screen that is visible to all team members participating in the session, as shown in the following photo taken during a MEER session. One member of the team acts as facilitator for the session and this role can be rotated amongst team members.

For each node in turn, team members review node content including the rating question and rating options. The facilitator asks individual team members for their view on the most appropriate rating based on their own experiences and records the number of individuals that nominate each rating option using the template table created in Step 1. Comments made by the group in the course of the discussion can also be recorded by the facilitator in the template table.

Once discussion for a particular node has been completed, the group decides on their consensus rating for the node and this is recorded for that node in the template table. The consensus can also be recorded graphically using an agreed schema. For example, on a printed copy of the map, the facilitator might draw a

tick mark on or next to the node to indicate an above-average consensus rating; a hazard icon for an average or below-average consensus rating; 'n/a' for 'not applicable'. This graphical record is quite useful since, when the map is completed, the team has an instant snapshot of where issues have been identified in process pathways.

In the course of rating each node, the group also considers whether the node should be included in the quality improvement action plan and records this in the template table.

Depending on the number of nodes in a process model, the length of assessment sessions and the amount of time spent discussing individual nodes, a team may take several sessions to rate an entire map.

However, the goal is not simply to complete the map as quickly as possible, since the discussion component of the MEER assessment is central to the usefulness of the approach.

Step 3: Action plan development

As noted above in Step 2, development of an improvement action plan commences during the assessment sessions, when teams identify problematic nodes during their rating discussions and decide whether to include those nodes in the action plan. In our experience, the rating discussions often yield valuable suggestions for improvement, which can be recorded by the facilitator in the template table for later reference. Direct linking of the assessment step into action plan development helps ensure that useful discussions in the context of issue diagnosis are translated into actions to address any issues identified. Likewise, by linking the action plan to the issues discussed during the assessment, this helps staff understand why particular remedial activities are being implemented and encourages more buy-in from staff to those quality improvement initiatives.

Once assessment for the whole map has been completed, the team (or designated individuals) can review all areas identified as needing improvement, grouping together related nodes and identifying activities that are most likely to address underlying issues or resolve superficial problems, as appropriate. It is usually also important to prioritise tasks, set realistic due dates for completion and assign responsibility for tasks in a way that shares the workload between team members.

Step 4: Action plan implementation

This step involves team members (and others) undertaking the tasks in the improvement action plan. Completion of action plan tasks can be tracked in the template table used during the assessment or using a Kanban board, with columns labelled 'To do', 'In progress' and 'Done' and a separate index card for each node included in the action plan. Individual tasks can be written on the index cards, together with due dates and responsible team member(s). The action plan can be set up on a wall in a team workspace or

meeting room, with tasks being marked off on the index cards as they are completed. This provides a visible, collective record of the progress being made on improvement activities.

The MEER approach is based on a plan—do—review quality improvement cycle and steps 2–4 are intended to be repeated periodically. By using the same process model as the basis for assessments at different time points, or as the basis of assessments conducted by different teams, this ensures consistency in the way each assessment is conducted and thereby enables both longitudinal comparisons (i.e. comparisons over time for a single team) and cross-sectional comparisons (i.e. comparisons between different teams).

Section 2: How the MEER approach was implemented during the Epworth study

Model development

We used graphical models available in the online application MEERQAT (https://meerqat.com.au) for this study. Not only did this obviate the need for graphical models to be developed as part of the study, but the application presents maps in an interactive format, allowing all information captured during the assessment step to be recorded against its corresponding node in the map. The application also automates other aspects of the MEER approach described earlier, including presenting the consensus rating of the team graphically on the map and placing editable cards representing nodes nominated for inclusion in the action plan onto an electronic Kanban board.

At the time of commencing this study, the first edition of the National Safety and Quality Health Service (NSQHS) Standards were in use across Australia. Consequently, the template maps (termed 'basemaps' in the application) available in MEERQAT for each standard corresponded to the 1st Edition standards. [Note: The 2nd Edition of the NSQHS Standards, which were published in 2017 and implemented nationally in 2019, have been reconfigured such that *Patient ID and Procedure Matching* is no longer a stand-alone standard and is now part of a larger *Standard 6 – Communicating for Safety*.]

The details of the graphical model used in the Epworth study for teams to assess their processes associated with patient identification are presented in three appendices:

- Appendix S1.1 presents NSQHS Standard 5 Patient ID and Procedure Matching, as published by the Australian Commission on Safety and Quality in Health Care (ACSQHC) in 2012.
- Appendix S1.2 shows the MEERQAT basemap (i.e. graphical process model) based on that standard.
 The map shows the process pathways that frontline staff might routinely undertake to deliver the desired outcomes and objectives of the standard.
- Appendix S1.3 shows the corresponding node content for that basemap.

While the MEERQAT application allows users to create their own copy of each basemap and tailor the map and node content to the particular circumstances of the user's organisation, this option was not used in the Epworth study and the application's map templates were used unaltered throughout the project.

<u>Assessment</u>

The two clinical units participating in the study (ED and 4Gray) assessed themselves against NSQHS Standard 5 (1^{st} Edition) twice over the course of the project, with four months elapsing between the completion of their first assessment and the commencement of their second assessment. The basemap for NSQHS Standard 5 (1^{st} Edition) includes a total of 51 rateable nodes; for both their first and their second assessments, the ED team required a total of 4 x 35 minute sessions to complete their assessment for the whole map, whereas the 4Gray team required 3 x 35 minute sessions.

Appendix S1.4 summarises how the MEER technique was implemented using the MEERQAT application. Briefly, for each assessment session, the facilitator logged into the application and opened the team's assessment created using the NSQHS Standard 5 (1st Edition) basemap. The facilitator's computer was connected to a data projector so the map was visible to all session participants. When the facilitator clicked on a node on the map's interactive interface, that node's rating panel opened to reveal the node title, type, description, rating question and rating options. As the group discussed the node, the facilitator typed comments directly into the comments interface and as team members nominated their individual ratings, these were tallied using the clickable interface for the rating options. When the group had determined the appropriate consensus rating for the node, this was recorded using the clickable interface and the team's consensus rating was then automatically displayed on the map node, allowing team members to readily visualise which nodes and process pathways had been assessed by the group as requiring improvement.

The final step of the assessment process involved deciding whether to add the node into the action plan; if so, the node was automatically added into the 'To Do' column on the map's Kanban board for later editing.

Action plan development and implementation

The two participating clinical units varied over the course of the project in their approach to action plan development. During some assessment sessions, the teams would add nodes into their action plan and immediately decide which tasks they would undertake to address the issues identified. They might also set due dates and nominate responsible individuals for each task at that time. On other occasions, the teams would add nodes into their action plan, but return at a later stage to identify specific tasks, assign tasks to individuals and set due dates.

In the case of NSQHS Standard 5 (1st Edition), the second assessment against the standard took place late in the project and therefore the teams did not have time to undertake tasks in their second action plan for

this standard before the project concluded. Thus, the following analysis is focussed on the action plan developed by each team after their first assessment against this standard.

- The ED team added 23 of the 51 rateable nodes in the NSQHS Standard 5 (1st Edition) map to their action plan after the first assessment; the 4Gray team added 14 nodes to their action plan after the first assessment.
- There were nine nodes added to action plans that were in common between the two teams; however, the tasks identified to address issues were similar between the ED and 4Gray for only two of those nine nodes.

Taken together, these data suggest the two participating clinical units identified issues with different aspects of the process pathways for patient ID and, even when they had issues with the same nodes, their issues were expected to be resolved through different actions. This is not a surprising outcome, given that one of the participating units was the ED and the other unit was an inpatient oncology ward.

- For 4Gray, all 14 nodes added to the first Standard 5 action plan had a consensus rating of *average* or *below average* in the assessment step; for ED, their first Standard 5 action plan included 19 nodes that had a consensus rating of *average* or *below average* in the assessment step, as well as four nodes that had a consensus rating of *above average*.
- For both teams, not all nodes with a consensus rating of *average* or *below average* during the first assessment were included in action plans.

In terms of completion of action plan tasks, by the end of data collection for the project, the ED team had completed the action plan tasks for 11 of the 23 nodes in their plan and tasks were in progress for one other node, while the 4Gray team had completed the tasks for 10 of the 14 nodes in their action plan and tasks were in progress for another two nodes. Thus, by the end of the project, tasks had been completed or were in progress for 65% of the total collection of nodes included in action plans by either team.

Re-assessment

When the teams assessed their practices against the Standard 5 basemap for the second time, their second assessment consensus rating had improved compared to their first assessment consensus rating for 26% (4Gray) to 33% (ED) of basemap nodes (29% overall). Interestingly, for 46% of nodes where the second consensus rating was improved compared to the first, those nodes had <u>not</u> been specifically included in the relevant team's action plan. This suggests that some aspects of routine practice with respect to patient ID had improved as a result of mechanisms other than completion of action plan tasks. Possible mechanisms could include staff becoming aware — or being reminded — of correct procedures through the team-based discussions about each map node, or enhanced reflective practice resulting from participation in the structured MEER sessions. However, the data collected during the project did not permit any definitive

conclusions to be drawn about the mechanisms that could have contributed to improvements in routine practice.

Based on the comparison of the second assessment consensus ratings to the first assessment consensus ratings, the areas where staff perceived an improvement in routine practice included:

- Staff awareness of relevant hospital policies and protocols, including staff reading policies and relevant updates, staff consulting policies/protocols more regularly and inclusion of patient ID policies and protocols in staff induction/orientation.
- Keeping patient records up-to-date, particularly with clinical alert and other clinically relevant information.
- Confirming patient ID throughout procedures, as well as at transfer and discharge.
- Monitoring patient ID processes and following up on issues when they occur.

It should be noted that this list of improved aspects of practice reflects staff perceptions of improvement and no independent audit data was collected that could quantify improvements in these aspects of routine practice.

Appendix S1.1

This is an extract from:

Australian Commission on Safety and Quality in Health Care, National Safety and Quality Health Service Standards (September 2012). Sydney. ACSQHC, 2012.

Standard 5 – Patient Identification and Procedure Matching

The Patient Identification and Procedure Matching Standard:

Clinical leaders and senior managers of a health service organisation establish systems to ensure the correct identification of patients and correct matching of patients with their intended treatment. Clinicians and other members of the workforce use the patient identification and procedure matching systems.

The intention of this Standard is to:

Correctly identify all patients whenever care is provided and correctly match patients to their intended treatment.

Context:

It is expected that this Standard will be applied in conjunction with Standard 1, 'Governance for Safety and Quality in Health Service Organisations' and Standard 2, 'Partnering with Consumers'.

Criteria to achieve the Patient Identification and Procedure Matching Standard:

Identification of individual patients

At least three approved patient identifiers are used when providing care, therapy or services.

Processes to transfer care

A patient's identity is confirmed using three approved patient identifiers when transferring responsibility for care.

Processes to match patients and their care

Health service organisations have explicit processes to correctly match patients with their intended care.

Explanatory notes

Patient identification and the matching of a patient to an intended treatment is an activity that is performed routinely in all care settings. Risks to patient safety occur when there is a mismatch between a given patient and components of their care, whether those components are diagnostic, therapeutic or supportive.

Much of the information about the number of patient mismatching events comes from incident reporting systems. In 2008–09 there were eleven events in Australia with procedures involving the wrong patient or body part resulting in a death or major permanent loss of function.³² When less serious events from nonsurgical areas – such as pathology and radiology – are included in reporting systems the number of reported events can rise considerably.⁴⁹

Since patient identification is an activity that is performed frequently, it can often be seen as a relatively unimportant task. Taking human factors into account when planning patient safety emphasises the design of systems to consider human capabilities, limitations and characteristics. This approach suggests that the development of safety routines for common tasks (such as patient identification) provides a powerful defence against simple mistakes that may progress and cause harm. These routines allow the workforce to focus their attention on those activities that require more cognitive processing and judgement, such as the provision of clinical care. The use of tools such as the World Health Organization Surgical Safety Checklist and Ensuring Correct Patient, Correct Site, Correct Procedure protocols provide a basis for the development of such routines.

Identification of individual patients

At least three approved patient identifiers are used when providing care, therapy or services.

This criterion will be achieved by:	Actions required:
5.1 Developing, implementing and regularly reviewing the effectiveness of a patient identification system including the associated policies, procedures and/or protocols that:	5.1.1 Use of an organisation-wide patient identification system is regularly monitored
 define approved patient identifiers require at least three approved patient identifiers on registration or admission require at least three approved patient identifiers when care, therapy or other services are provided require at least three approved patient identifiers whenever clinical handover, patient transfer or discharge documentation is generated 	5.1.2 Action is taken to improve compliance with the patient identification matching system
5.2 Implementing a robust organisation-wide system of reporting, investigation and change management to respond to any patient care mismatching events	5.2.1 The system for reporting, investigating and analysis of patient care mismatching events is regularly monitored
	5.2.2 Action is taken to reduce mismatching events
5.3 Ensuring that when a patient identification band is used, it meets the national specifications for patient identification bands ⁵⁴	5.3.1 Inpatient bands are used that meet the national specifications for patient identification bands

Processes to transfer care

A patient's identity is confirmed using three approved patient identifiers when transferring responsibility for care.

This criterion will be achieved by:	Actions required:
5.4 Developing, implementing and regularly reviewing the effectiveness of the patient identification and matching system at patient handover, transfer and discharge	5.4.1 A patient identification and matching system is implemented and regularly reviewed as part of structured clinical handover, transfer and discharge processes

Processes to match patients and their care

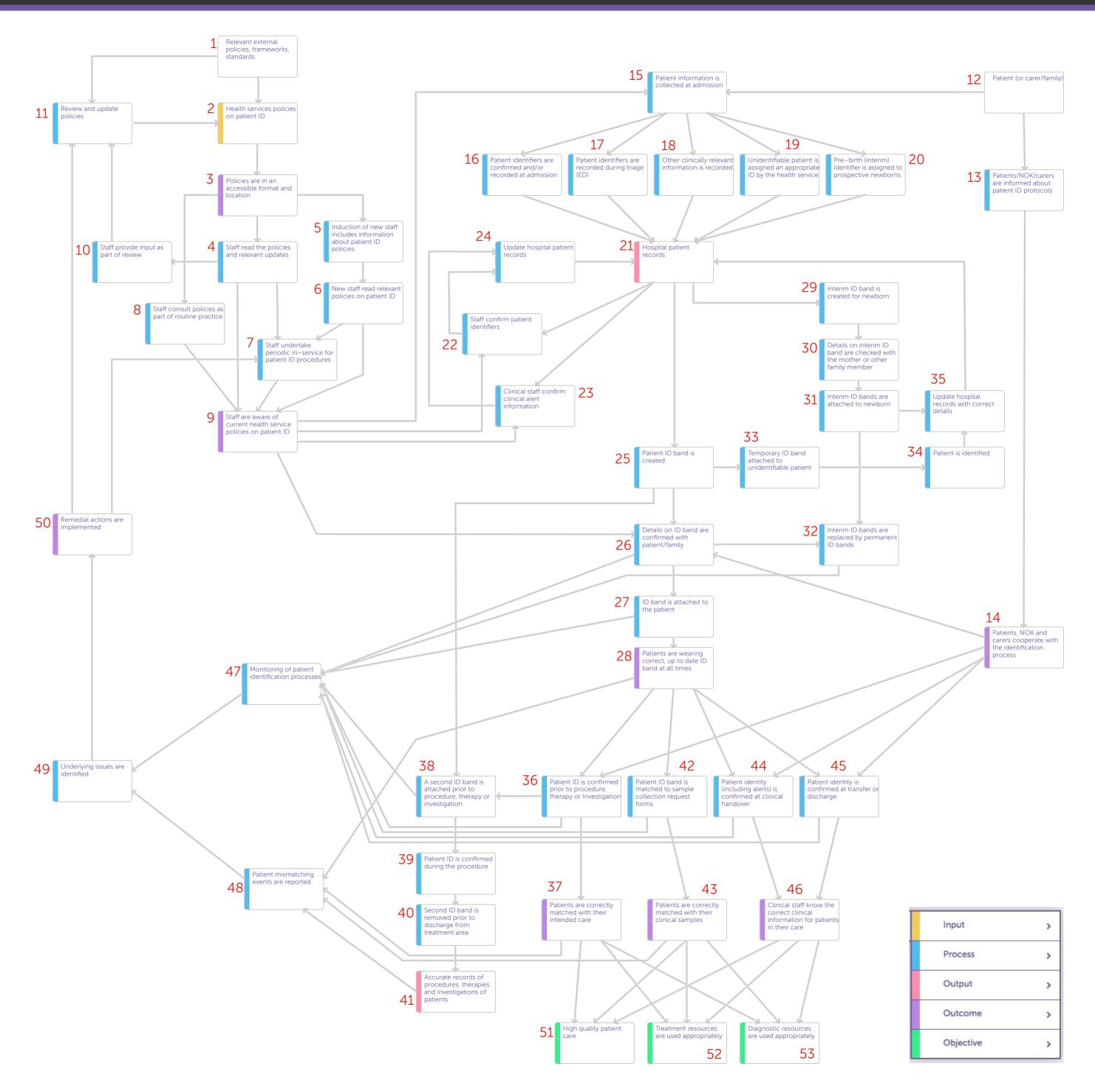
Health service organisations have explicit processes to correctly match patients with their intended care.

This criterion will be achieved by:	Actions required:
5.5 Developing and implementing a documented process to match patients to their intended procedure, treatment or investigation and implementing the consistent national	5.5.1 A documented process to match patients and their intended treatment is in use
guidelines for patient procedure matching protocol or other relevant protocols ⁵³	5.5.2 The process to match patients to any intended procedure, treatment or investigation is regularly monitored
	5.5.3 Action is taken to improve the effectiveness of the process for matching patients to their intended procedure, treatment or investigation

Note: The red numbers next to each node correspond to the Node # in Appendix S1.3.



Patient Identification (1st edition) v02



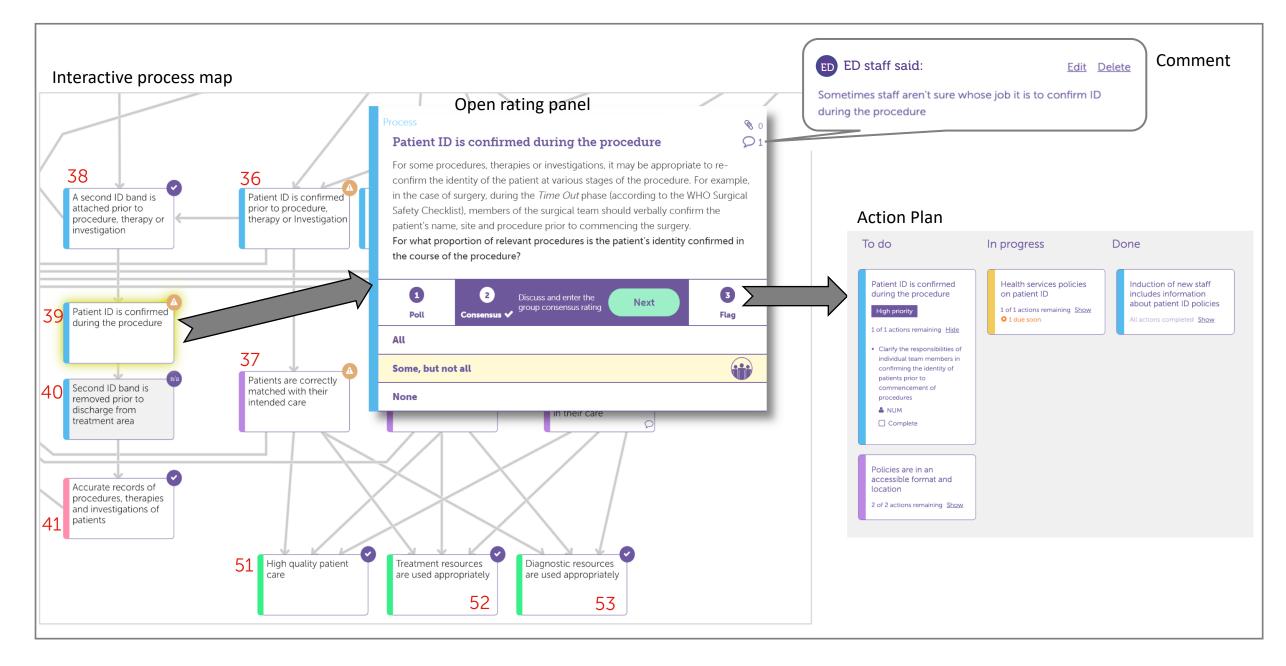
Appendix S1.3 – Node content for MEERQAT basemap NSQHS Standard 5 (1st Edition): Patient ID and Procedure Matching

Node #	Node title	Туре	Description	Rating question	Rating options
1	Relevant external policies,	Not	This input is not rateable in the context of this assessment. Continue to the next node.		J. Charles
2	frameworks, standards Health services policies on patient ID	rateable Input	Policies should outline the systems and processes in place to accurately collect and apply a minimum of three approved patient identifiers at registration, admission or birth and to correctly match each patient to their intended treatment, procedure or investigation. Clinical alerts also need to be recorded on admission to the health service. Other policies are required to outline the process, responsibilities and expectations with respect to patient identification and procedure matching for all patients in the care of the health service. Having up-to-date and relevant policies is a foundation for ensuring that clinical practice reflects best practice.	How up-to-date are your health service policies on patient identification, procedure matching and clinical alerts?	Policies are up to date and relevant Polices require updating Polices do not exist
3	Policies are in an accessible format and location	Outcome	Policies should be presented in a format that is accessible (i.e. appropriate language with consistent and clear document formatting) and should be easily located by staff (e.g. on computers or in hard copy in known locations throughout the health service) and should be read by staff.	What proportion of policies relating to patient identification, procedure matching and clinical alerts are accessible?	All Most About half Some None
4	Staff read the policies and relevant updates	Process	It is important that staff are familiar with the content of relevant policies, not just their existence, so they can implement those policies as part of routine practice. Staff should read policies relevant to them when they first join the health service and re-read the policies periodically to refresh their knowledge of the policies and to become acquainted with any amendments or updates.	Once staff have been informed about new or updated health service policies relating to patient identification, to what extent do they read those new/updated policies?	Always Mostly About half the time Sometimes Never
5	Induction of new staff includes information about patient ID policies	Process	Induction at the both the health service level and at the ward/unit level should include information about relevant health service policies and how these can be accessed.	To what extent are new staff informed about these health service policies during induction?	Always Mostly About half the time Rarely Never
6	New staff read relevant policies on patient ID	Process	It is important that new staff are aware of the content of relevant policies, not just their existence, so they can implement those policies as part of routine practice.	Do new staff read health service policies on patient identification and procedure matching?	Yes No Not sure
7	Staff undertake periodic in– service for patient ID procedures	Process	Health services should provide periodic training on patient identification policies and procedures for all staff, to assist them in maintaining their competency and improving their proficiency in this activity. Ideally, staff should participate in annual training sessions focussed on patient identification and procedure matching.	How often do staff undertake training in patient identification?	More than once per year Once per year Once every 2-3 years Can't recall Never
8	Staff consult policies as part of routine practice	Process	Staff should be consulting relevant policies on a regular basis, to refresh their awareness of the policy detail and ensure their routine practice remains compliant with those policies.	How often do staff consult policies?	Regularly Occasionally Rarely Never
9	Staff are aware of current health service policies on patient ID	Outcome	For health service policies to be effective in achieving the desired objectives, all staff must be aware of and actively implementing policies relevant to them.	To what extent are staff aware of the current health service policies in relation to patient identification, including procedure matching and notification of clinical alerts?	Thoroughly aware Reasonably well aware Somewhat aware Not at all aware
10	Staff provide input as part of review	Process	Policy review should take account of staff feedback on the content and implementation of policies. Collecting staff input as part of review of policies should be a formal, structured process.	To what extent are relevant staff asked for input as part of policy review processes?	Always Mostly About half the time Rarely Never
11	Review and update policies	Process	Policies should be reviewed regularly to ensure they reflect current statutory requirements, as well as best available evidence and current health service circumstances.	How often are the relevant policies on patient identification, procedure matching and recording of clinical alerts reviewed?	Policies are reviewed in a regular and timely manner Not sure whether policies are reviewed Policies are not reviewed
12	Patient (or carer/family)	Not	This input is not rateable in the context of this assessment. Continue to the next node.		
13	Patients/NOK/carers are informed about patient ID protocols	Process	Patient identification is repetitive in nature. Patients, next of kin (NOK) and carers should be informed that, in the interest of patient safety, all patients (when able to) will be asked by staff to identify themselves by name and DOB at all handovers, prior to any procedures or treatments and before any transfers from the health service. It should be clearly communicated to patients, NOK and carers that staff will check the name and DOB and medical record number on the patient's ID band against the patient's medical notes to ensure they correspond.	How would you rate the communication by clinicians to patients, NOK and carers in relation to explaining the patient identification process?	Very good Good Neither good nor poor Poor Very poor
14	Patients, NOK and carers cooperate with the identification process	Outcome	This outcome reflects the efforts of clinicians to communicate directly with patients, next-of-kin and carers about the repetitive steps involved in the patient identification process.	Overall, what proportion of patients, next-of-kin or carers (as appropriate) cooperate fully with the patient's identification process?	All Most Some Few None
15	Patient information is collected at admission	Process	The organisation should have systems and processes that enable and ensure all relevant and appropriate patient information is collected at the time of admission to the health service. These systems and processes should be accessible, user-friendly and efficient to use.	Overall, how would you rate the systems and processes for collecting patient information at admission?	Very good Good Neither good nor poor Poor Very poor
16	Patient identifiers are confirmed and/or recorded at admission	Process	For planned admissions to the health service, patients may have completed a preadmission booking form and their details (including items that are acceptable for use as identifiers) may have already have been entered into the patient administration system. Therefore, at the time of admission, the first step is to search the patient administration system to find an existing record. If such a record is found, the details should be confirmed with the patient and/or carer and amended as required. If a patient record is not found, a new record should be created and all patient information recorded. The patient/carer should be asked to state their full name, date of birth and address, to allow matching to the recorded information.	Is the correct protocol for recording and confirming patient identifiers at the time of admission followed for all patients?	Yes Unsure No
17	Patient identifiers are recorded during triage (ED)	Process	For patients presenting to the Emergency Department, their first contact is likely to be with the Triage Nurse, who should collect and record a minimum of three approved identifiers, usually full name, date of birth and address. This information may be obtained from the patient and/or carer.	Is the correct protocol for recording patient identifiers at triage followed for all patients?	Yes Unsure No
18	Other clinically relevant information is recorded	Process	To ensure patients are given the appropriate ID band, information about clinically relevant conditions should be collected when the patient is admitted or triaged. Clinically relevant information includes information about known allergies, current medications, implants, devices, lymphoma and infections.	Do all patients have their clinical alert status checked on admission to the health service?	Yes Unsure No
19	Unidentifiable patient is assigned an appropriate ID by the health service	Process	In circumstances where a patient's identity cannot be confirmed, a patient record should be created that reflects the unknown identifiers. For example, "UNKNOWN" should be entered in the patient name fields and the default unknown date of birth should be entered.	Is the correct protocol for handling initial patient identification followed for all unidentifiable patients?	Yes Unsure No

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Node # 20	Node title Pre-birth (interim)	Type Process	Description Prior to birth, an interim record should be created for prospective newborns in the	Rating question Are appropriate interim	Rating options Yes
20	identifier is assigned to prospective newborns	1100055	patient administration system, to allow ID bands to be generated that can be attached to the newborn prior to separation from the mother. The interim record should include the following identifiers: * "baby of" and the mother's name	patient records created for all prospective newborns?	Unsure No
21	Hospital patient records	Output	* a unique record number for that baby * the default unknown date of birth for newborns *unknown gender In the case of twins (or other multiple births), an interim record should be created for each prospective newborn. Individual patient records within the health service's patient administration system are	Overall, how would you rate	Very good
			the foundation on which all patient identification protocols are based. If the records are incomplete or incorrect, no other aspect of patient identification policy can be expected to operate as intended. One system for patient identification should be used across the whole organisation.	hospital patient records in terms of whether they are complete, correct and up-to- date?	Good Neither good nor poor Poor Very poor
22	Staff confirm patient identifiers	Process	After a patient record is created in the patient administration system and prior to generating ID bands and other identification materials, a staff member	Are patient identifiers always confirmed after admission and	Yes Unsure
23	Clinical staff confirm clinical	Process	(clerical/administrative or clinical) should confirm at least three approved patient identifiers with the patient/carer. To ensure patients are given an ID band that accurately reflects any allergies or other	prior to generating ID bands etc? Is the clinical alert status of all	No Yes
	alert information		relevant clinical alerts, clinical alert information recorded when the patient is admitted to the health service should be re-confirmed by clinical staff. If clinical alert information included in the patient record is incorrect or incomplete, the clinician should collect the relevant information to allow the patient record to be updated accordingly.	patients confirmed after their admission to the health service?	Unsure No
24	Update hospital patient records	Process	If the information in a patient record is found to be incomplete or incorrect, the record should be updated with correct information as soon as practicable.	Overall, how would you rate the updating of patient records, in terms of whether corrections and updates are recorded in a timely manner?	Very good Good Neither good nor poor Poor Very poor
25	Patient ID band is created	Process	The health service should have policies and protocols that reflect how it will meet	Overall, how would you rate	Very good
			accepted standards for identification bands, in terms of colour, size, comfort, usability, method for recording patient identifiers, information presentation and incorporation of new technologies to assist patient identification. Whether patient identifiers are printed or handwritten, the process of creating the ID band should be straightforward and result in an ID band that is legible and easy to read following exposure to the range of fluids and preparations the band may come into contact with.	the process of creating patient ID bands?	Good Neither good nor poor Poor Very poor
26	Details on ID band are confirmed with patient/family	Process	Before the ID band is attached to the patient by a clinician, that clinician should obtain verbal confirmation from the patient (or family/carer) of the patient identifiers included on the ID band. The UR number on the ID band should also be checked against the patient's medical record.	Is the correct process always used to confirm identify before attaching a patient ID band?	Yes Unsure No
27	ID band is attached to the patient	Process	Once the patient identifiers on the ID band have been confirmed, the ID band should be attached to the patient by the clinician caring for that patient. The clinician should check the band is securely fastened and the fit of the band should ensure the band is neither too tight to be comfortably worn, nor loose enough to fall off.	Are patient ID bands always fitted appropriately?	Yes Unsure No
28	Patients are wearing	Outcome	The patient ID band is an important mechanism to ensure patients are correctly	What proportion of patients	All
	correct, up-to-date ID band at all times		matched to all components of their intended care, including diagnostic, therapeutic and supportive components. The primary purpose of the ID band is to identify the patient wearing the band and therefore all patients should be wearing at least one ID band at all times and the details on any bands worn by patients should be correct, complete and up-to-date. These outcomes will be achieved through correct implementation of health service policies on creating, updating and attaching patient ID bands.	are wearing the appropriate number of correct, complete, up-to-date patient ID bands at all times during their stay in the health service?	More than half Half or less
29	Interim ID band is created for newborn	Process	Health service policies and protocols for creating identification bands that meet accepted standards should include reference to any special provisions that apply to newborns and the creation of newborn patient ID bands should conform to those protocols. The process of creating the interim newborn ID band should be straightforward and result in the correct number and format of ID band. Additionally, the process should be completed in a timely manner, to ensure that interim newborn ID bands can be attached prior to separation of the newborn from its mother.	Overall, how would you rate the process of creating interim ID bands for newborns?	Very good Good Neither good nor poor Poor Very poor
30	Details on interim ID band are checked with the mother or other family member	Process	Once the interim ID band has been created, but prior to attaching the band to the newborn, all details on the interim ID band should be checked with the mother or other family members. If any details are found to be incorrect, a new interim ID band should be created.	Are the details on the interim ID band always checked before the band is attached to the newborn?	Yes Unsure No
31	Interim ID bands are attached to newborn	Process	ID bands that include interim patient identifiers for the newborn should be attached to the newborn by an appropriate clinician prior to separation of the newborn from the mother. If the relevant health service policy stipulates that newborns should have two ID bands, both bands should be attached at the same time.	Is the correct number of interim ID bands attached to all newborns prior to separation from the mother?	Yes Unsure No
32	Interim ID bands are replaced by permanent ID bands	Process	Once the correct date of birth and gender of the newborn are known, the interim ID band should be replaced as soon as practicable with a permanent ID band that includes the updated information. Health service policies relating to newborns may stipulate a timeframe for this ID band replacement to occur (e.g. within the first 60 minutes after birth or before the newborn leaves the birthing suite). In the course of replacing the ID bands, the new bands should be checked against the existing bands before the existing bands are removed.	Is the correct procedure for replacing interim newborn ID bands with permanent ID bands always used?	Yes Unsure No
33	Temporary ID band attached to unidentifiable patient	Process	The temporary ID band should be attached to an unidentifiable patient by a clinician.	What proportion of unidentifiable patients have an appropriate temporary ID band attached?	All Some, but not all None
34	Patient is identified	Process	Although determination of a patient's true identity is often beyond the control of the health service, staff may be involved in obtaining information about the correct identity of the patient from a number of sources (the patient; other individuals accompanying the patient). Where staff receive information about a patient's identity, they should be aware of health service policies and protocols for disseminating that information and ensuring the patient record is updated.	Overall, how would you rate the health service in terms of determining the identity of unidentifiable patients?	Very good Good Neither good nor poor Poor Very poor
35	Update hospital records with correct details	Process	In circumstances where a patient record has been created with details that are known to be temporary or incomplete (for example, an unidentified patient or a newborn with interim patient identifiers), updates to patient identifiers should be made to the patient record as soon as practicable. For unidentified patients, this includes verified information about the patient's name, date of birth or address. For newborns, this includes correct date of birth and correct gender.	Overall, how would you rate the updating of temporary or incomplete patient records once correct patient identifier information has been obtained?	Very good Good Neither good nor poor Poor Very poor
36	Patient ID is confirmed prior to procedure, therapy or Investigation	Process	Prior to commencing any procedure, therapy or investigation, the patient's identity should be verbally confirmed with the patient (or carer/family). At the same time, the patient should be asked to confirm the nature of the procedure (and site of procedure, if relevant) and their consent for the procedure. If the procedure involves surgery, this confirmation process will take place during the 'Sign In' phase (according to the WHO Surgical Safety Checklist) prior to induction of anaesthesia. As part of this ID confirmation process, clinical staff should also confirm any known allergies or other relevant clinical alert information for the patient.	For what proportion of patients is the patient's identity confirmed prior to commencement of every procedure, therapy or investigation?	All More than half Half or less

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Node #	Node title	Type	Description This outcome reflects the organisation's offerts to correctly match each nations with the	Rating question How often are patients	Rating options
37	Patients are correctly matched with their intended care	Outcome	This outcome reflects the organisation's efforts to correctly match each patient with the care provided, through routine conscientious confirmation of the identity of each patient.	correctly matched with their intended care?	Always Most of the time Less than half the time
38	A second ID band is	Process	Where health services have a policy requiring a second ID band be attached to a patient	What proportion of patients	All
	attached prior to		undergoing particular procedures (e.g. surgery), the second ID band should be attached	have a second ID band	More than half
	procedure, therapy or		to the patient during their preparation for the procedure. The second band should be	attached prior to procedures	Half or less
	investigation		checked against the existing band before being attached.	for which the health service requires a second ID band?	
39	Patient ID is confirmed	Process	For some procedures, therapies or investigations, it may be appropriate to re-confirm	For what proportion of	All
	during the procedure		the identity of the patient at various stages of the procedure. For example, in the case	relevant procedures is the	More than half
			of surgery, during the 'Time Out' phase (according to the WHO Surgical Safety	patient's identity confirmed in	Half or less
			Checklist), members of the surgical team should verbally confirm the patient's name, site and procedure prior to commencing the surgery.	the course of the procedure?	
40	Second ID band is removed	Process	Where health services have a policy requiring a second ID band be attached to a patient	What proportion of relevant	All
	prior to discharge from		undergoing particular procedures (e.g. surgery), the second ID band should be removed	patients have their second ID	Most
	treatment area		from the patient after the procedure has been completed. The second band should be removed prior to the patient leaving the treatment area.	band removed prior to departure from the treatment	About half Less than half
			removed prior to the patient leaving the treatment area.	area?	None
41	Accurate records of	Output	Records of procedures, therapies and investigations conducted on patients should	Do the records of procedures,	Yes
	procedures, therapies and		include a minimum of three approved patient identifiers. This outcome will be achieved	therapies and investigations	Unsure
	investigations of patients		through correct implementation of patient identification protocols prior to, during and at the completion of procedures, therapies and investigations.	conducted on patients always include a minimum of three	No
			at the completion of procedures, therapies and investigations.	patient identifiers?	
42	Patient ID band is matched	Process	When a patient is having clinical samples taken, the attending clinicians must ensure the	Are clinical samples taken from	Yes
	to sample collection		request form is matched with the sample, which is then further checked against the	patients always checked	Unsure
	request forms		patient ID band.	against the request form and the patient ID band, to ensure	No
				the correct labelling of	
				specimens?	
43	Patients are correctly	Outcome	This outcome reflects the organisation's efforts to correctly match each patient with	How often are patients	Always
	matched with their clinical samples		their clinical samples, through routine conscientious confirmation of the identity of each patient and appropriate labelling of samples.	correctly matched with their clinical samples?	Most of the time Less than half the time
44	Patient identity (including	Process	During clinical handover, a patient's identity should always be confirmed using a	Is patient identity always	Yes
	alerts) is confirmed at		minimum of three identifiers, even if the clinician knows the patient. The patient should	confirmed during clinical	Unsure
	clinical handover		be asked to state their name and DOB and staff then check the UR number on the ID	handover?	No
45	Patient identity is	Process	band with the medical record. Whenever a patient is transferred from one part of the health service to another, or	Is patient identity always	Yes
43	confirmed at transfer or	1100033	discharged from the health service, their identity should be confirmed using a minimum	confirmed during transfer and	Unsure
	discharge		of three identifiers, as part of a structured transfer or discharge process.	discharge processes?	No
46	Clinical staff know the	Outcome	The risk of introducing mismatches between a given patient and components of their	Do clinical staff know the	Yes
	correct clinical information for patients in their care		care is highest at those points in the patient journey where care is transferred between one clinician and another. Therefore, this outcome reflects the efforts of the	correct clinical information for all patients in their care?	Unsure No
	Tor patients in their care		organisation to minimise these risks by confirming patient identity during all clinical	an patients in their care.	110
			handover, transfer and discharge processes.		
47	Monitoring of patient	Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of	To what extent are patient ID	Patient ID processes are
47	Monitoring of patient identification processes	Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of patient identification. This might include direct observation of ID-related processes;	To what extent are patient ID and procedure matching processes monitored?	Patient ID processes are closely and regularly monitored
47	I	Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of	and procedure matching	closely and regularly
47	I	Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of patient identification. This might include direct observation of ID-related processes; collecting feedback from clinicians, patients (and/or their carers/next-of-kin); regular	and procedure matching	closely and regularly monitored Monitoring is generally good, but could be improved
47	I	Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of patient identification. This might include direct observation of ID-related processes; collecting feedback from clinicians, patients (and/or their carers/next-of-kin); regular	and procedure matching	closely and regularly monitored Monitoring is generally good, but could be improved Monitoring needs significant
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	identification processes	Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of patient identification. This might include direct observation of ID-related processes; collecting feedback from clinicians, patients (and/or their carers/next-of-kin); regular review of documentation.	and procedure matching	closely and regularly monitored Monitoring is generally good, but could be improved Monitoring needs significant improvement There is no monitoring of patient ID processes
47	identification processes Patient mismatching events	Process Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of patient identification. This might include direct observation of ID-related processes; collecting feedback from clinicians, patients (and/or their carers/next-of-kin); regular review of documentation. The organisation should have systems in place for reporting adverse incidents and near	and procedure matching processes monitored? To what extent are incidents	closely and regularly monitored Monitoring is generally good, but could be improved Monitoring needs significant improvement There is no monitoring of patient ID processes Incidents and near misses
	identification processes		handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of patient identification. This might include direct observation of ID-related processes; collecting feedback from clinicians, patients (and/or their carers/next-of-kin); regular review of documentation. The organisation should have systems in place for reporting adverse incidents and near misses relating to patient ID and procedure matching. This is unlikely to be a separate	and procedure matching processes monitored? To what extent are incidents and near misses relating to	closely and regularly monitored Monitoring is generally good, but could be improved Monitoring needs significant improvement There is no monitoring of patient ID processes Incidents and near misses are always reported
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48	Patient mismatching events are reported Underlying issues are	Process	handover, transfer and discharge processes. The organisation should have mechanisms for monitoring the various processes of patient identification. This might include direct observation of ID-related processes; collecting feedback from clinicians, patients (and/or their carers/next-of-kin); regular review of documentation. The organisation should have systems in place for reporting adverse incidents and near misses relating to patient ID and procedure matching. This is unlikely to be a separate system from that used for reporting other incidents and near misses, but there should be provision in the reporting system for noting when an incident relates to patient identification. While incidents are most likely to be reported when an expected output or outcome is not achieved, it is also important to record incidents relating to flawed processes, as this can focus attention on issues before they become adverse incidents involving patient harm. Once data has been collected through monitoring activities and incident reporting	and procedure matching processes monitored? To what extent are incidents and near misses relating to patient ID reported? How would you rate the	closely and regularly monitored Monitoring is generally good, but could be improved Monitoring needs significant improvement There is no monitoring of patient ID processes Incidents and near misses are always reported Incidents are always reported, but near misses are not always reported Incidents and near misses are not always reported Incidents and near misses are rarely reported Don't know The process is thorough and
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Appendix S1.4



Appendix S1.4

This figure displays a portion of the MEERQAT process map used for Standard 5 MEER assessment sessions, which is shown in its entirety in Appendix S1.2. Each node has a coloured left-side edge indicating its type: green for objectives, purple for outcomes, pink for outputs, blue for processes and gold for inputs. The red number next to each node corresponds to the *Node* # in Appendix S1.3. The figure also displays an open rating panel for the node highlighted by the yellow halo, superimposed on the map image. The rating process entails three sequential steps: 1) polling participants for their initial views on how the node should be rated, including capturing comments; 2) entering a group consensus rating for the node; 3) deciding whether to flag the node for action plan tasks. The open rating panel shown in the figure is displaying the second step in the rating process. A comment made by participants during the discussion is shown in the callout at the top right hand corner of the figure. The corresponding card added to the action plan is also shown. The icon displayed in the top right corner of each node in the map signifies the group consensus rating: a purple check mark denotes an above-average consensus rating, an orange hazard icon denotes an average or below-average consensus rating and n/a denotes a node that was identified as not applicable to the group completing the assessment.

MEER intervention survey - analysis of reliability and inter-item consistency of survey responses

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Introduction

This R notebook checks for the reliability and inter-item consistency of survey responses for the MEER trial at the Epworth hospital.

The analysis focusses on the first seven questionnaire items reported in Table 2 of the paper ("Staff opinions on the MEER approach and its impact") as listed below:

- Q1: I have enjoyed the team-based discussions
- Q2: I like the process of reviewing the standards using the map-based graphical representations in the MEERQAT tool
- Q3: I have felt comfortable expressing my views and opinions in the team-based discussions
- Q4: I have found hearing the different perspectives amongst my colleagues to be worthwhile
- Q5: I have learnt new information about the national quality standards
- Q6: I have learnt new information about specific Epworth policies and protocols
- Q7: I have enjoyed the opportunity to reflect on my own clinical practice

The responses were collected in three surveys following the initial baseline survey, i.e. at 2.5 months (survey 2), 5 months (survey 3) and 10 months (survey 4) after the start of the MEER trial.

The responses for each survey question were based on a 5 point Likert scale, ranging from a least favourable (1) to a most favourable (5) response.

A single missing Likert rating for question 5 from a respondent was filled with the mode value (4) for question 5.

Load libraries

```
library("readxl")
library(psych)
library(ggplot2)
library(dplyr)
library(FSA)
library(lemon)
knit_print.data.frame <- lemon_print</pre>
```

Read in the data file for the questionairre Likert ratings

```
Data <- read.csv("Survey data BMJOQ Cronbach.csv")
headTail(Data) # display head and tail of the data file
```

	pin	survey	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	7	S2	4	4	4	4	4	3	4
2	1011	S2	3	3	2	3	3	4	4
3	1062	S2	4	4	3	4	4	4	4
4	1012	S2	4	3	4	5	4	4	4
		NA							
95	1037	S4	5	5	5	5	4	4	5
96	2068	S4	5	3	4	4	4	4	5
97	1059	S4	5	5	5	5	5	5	5
98	1070	S4	5	4	5	4	5	4	5

Check the data

##

Max.

:5.0

Max.

:5.000

```
str(Data)
                    98 obs. of 9 variables:
## 'data.frame':
   $ pin
            : int 7 1011 1062 1012 2036 1028 2050 2104 1017 1020 ...
   $ survey: Factor w/ 3 levels "S2", "S3", "S4": 1 1 1 1 1 1 1 1 1 1 1 ...
                  4 3 4 4 4 4 4 4 4 4 . . .
##
   $ Q1
            : num
##
   $ Q2
            : num
                   4 3 4 3 4 4 3 4 4 4 ...
##
   $ Q3
                  4 2 3 4 5 4 4 4 4 4 ...
            : num
   $ Q4
            : num 4 3 4 5 5 5 4 4 4 4 ...
##
                  4 3 4 4 4 4 4 4 4 4 ...
   $ Q5
            : num
            : num 3 4 4 4 4 5 4 4 4 4 ...
##
   $ 06
            : num 444445444 ...
   $ Q7
summary(Data)
##
        pin
                   survey
                                 Q1
                                                  Q2
                                                                  QЗ
##
   Min.
          :
               7
                   S2:28
                                  :3.000
                                                   :2.000
                                                                   :2.000
                           Min.
                                           Min.
                                                            Min.
   1st Qu.:1036
##
                   S3:39
                           1st Qu.:4.000
                                           1st Qu.:4.000
                                                            1st Qu.:4.000
   Median:1079
                   S4:31
                           Median :4.000
                                           Median :4.000
                                                            Median :4.000
##
   Mean
         :1408
                                  :4.327
                           Mean
                                           Mean
                                                   :4.102
                                                            Mean
                                                                   :4.316
##
   3rd Qu.:2030
                           3rd Qu.:5.000
                                           3rd Qu.:5.000
                                                            3rd Qu.:5.000
##
   Max.
           :3035
                           Max.
                                  :5.000
                                           Max.
                                                   :5.000
                                                            Max.
                                                                   :5.000
##
          Q4
                        Q5
                                         Q6
                                                         Q7
           :3.0
##
                         :2.000
                                         :2.000
                                                          :3.000
   Min.
                  Min.
                                  Min.
                                                   Min.
   1st Qu.:4.0
##
                  1st Qu.:4.000
                                  1st Qu.:4.000
                                                   1st Qu.:4.000
##
   Median:5.0
                  Median :4.000
                                  Median :4.000
                                                   Median :4.000
##
   Mean
           :4.5
                  Mean
                        :4.255
                                  Mean
                                        :4.235
                                                   Mean
                                                          :4.316
##
   3rd Qu.:5.0
                  3rd Qu.:5.000
                                  3rd Qu.:5.000
                                                   3rd Qu.:5.000
```

:5.000

Max.

:5.000

Max.

Get Likert rating counts

```
xtabs( ~ survey + Q1, data = Data)
##
        Q1
## survey 3 4 5
      S2 3 14 11
##
##
      S3 3 24 12
##
      S4 3 10 18
xtabs( ~ survey + Q2, data = Data)
##
        Q2
## survey 2 3 4 5
      S2 1 5 13 9
##
##
      S3 1 6 22 10
##
      S4 1 4 14 12
xtabs( ~ survey + Q3, data = Data)
##
        QЗ
## survey 2 3 4 5
      S2 1 1 14 12
      S3 0 3 23 13
##
      S4 1 3 10 17
##
xtabs( ~ survey + Q4, data = Data)
##
        Q4
## survey 3 4 5
      S2 1 11 16
##
      S3 0 21 18
      S4 1 13 17
##
xtabs( ~ survey + Q5, data = Data)
        Q5
##
## survey 2 3 4 5
      S2 1 3 15 9
      S3 0 2 25 12
##
      S4 0 1 18 12
xtabs( ~ survey + Q6, data = Data)
##
        Q6
## survey 2 3 4 5
      S2 2 3 17 6
##
##
      S3 0 1 24 14
      S4 0 1 18 12
xtabs( ~ survey + Q7, data = Data)
##
       Q7
## survey 3 4 5
      S2 3 16 9
##
      S3 2 25 12
##
      S4 2 12 17
##
```

RELIABILITY AND INTER-ITEM CONSISTENCY ANALYSES

```
# For convenience, put just the question data into a separate dataframe, d questions = c('Q1', 'Q2', 'Q4', 'Q5', 'Q6', 'Q7') d <- Data[,questions]
```

Calculate average inter-item correlation

Calculate the average inter-item (i.e. inter-question) correlation for Q1-Q7 using the corrr package.

```
library(corrr)
d %>% correlate()
```

```
## # A tibble: 7 x 8
    rowname
                01
                       Q2
                              QЗ
                                            Q5
                                                  Q6
                                                         07
##
    <chr>
             <dbl>
                    <dbl>
                          <dbl>
                                  <dbl>
                                         <dbl>
                                                <dbl>
                                                       <dbl>
## 1 Q1
                    0.690 0.530 0.536
                                        0.416
                                               0.189 0.452
            NΑ
## 2 Q2
             0.690 NA
                           0.402 0.471
                                        0.360
                                               0.161 0.354
## 3 Q3
             0.530 0.402 NA
                                  0.641
                                        0.363
                                               0.271
                                                      0.446
## 4 Q4
             0.536
                    0.471
                          0.641 NA
                                         0.418 0.342
                                                      0.458
## 5 Q5
             0.416
                    0.360 0.363 0.418 NA
                                                0.712 0.615
## 6 Q6
             0.189
                    0.161 0.271
                                 0.342
                                        0.712 NA
                                                      0.635
             0.452
                    0.354
                           0.446 0.458 0.615 0.635 NA
## 7 Q7
```

Obtain the average correlation of each item (question) with all others by computing the means for each column (excluding the rowname column):

```
inter_item <- d %>% correlate() %>% select(-rowname) %>% colMeans(na.rm = TRUE)
##
```

```
## Correlation method: 'pearson'
## Missing treated using: 'pairwise.complete.obs'
```

```
inter_item
```

```
## Q1 Q2 Q3 Q4 Q5 Q6 Q7
## 0.4688252 0.4062839 0.4421260 0.4777339 0.4808158 0.3853014 0.4935205
```

We can see that Q1, Q4, Q5 and Q7 are more strongly correlated with the other items on average than Q6. However, most items correlate with the others in a reasonably restricted range around .4 to .5.

To obtain the overall average inter-item correlation, we calculate the mean() of these values:

```
mean(inter_item)
```

[1] 0.4506581

Calculate Cronbach's alpha for questionnaire items

Cronbach's alpha is one of the most widely reported measures of internal consistency and shall be implemented using the alpha() function from the R psych package. This function takes a data frame where each column is a questionnaire item and each row is a survey respondent.

Cronbach's alpha will be checked for the following questionnaire groupings:

- All questions (Q1 Q7)
- Questions relating to team-based aspects of MEER (Q1, Q3, Q4)
- Questions relating to learning aspects of MEER (Q5, Q6, Q7)

Also, the consistency of Cronbach's alpha will be checked acrosss the three surveys: S1 (2.5 months), S2 (5 months) and S3 (10 months).

Cronbach's alpha across all questionairre items

```
psych::alpha(d)$total$std.alpha

## [1] 0.8516875
```

Cronbach's alpha for team based items: Q1, Q3, Q4

```
dTB <- d[c('Q1','Q3','Q4')]
psych::alpha(dTB)$total$std.alpha
```

[1] 0.7982847

Cronbach's alpha for learning items: Q5, Q6, Q7

```
dL <- d[c('Q5','Q6','Q7')]
psych::alpha(dL)$total$std.alpha</pre>
```

[1] 0.8503299

Cronbach's alpha across all questionairre items, calculated separately for surveys 2, 3, 4

```
Survey 2
```

```
S2 <- Data[Data$survey == 'S2', questions]
psych::alpha(S2)$total$std.alpha

## [1] 0.8487798

Survey 3

S3 <- Data[Data$survey == 'S3', questions]
psych::alpha(S3)$total$std.alpha

## [1] 0.8363949

Survey 4

S4 <- Data[Data$survey == 'S4', questions]
```

[1] 0.8723361

psych::alpha(S4)\$total\$std.alpha

CONCLUSIONS

Average inter-item correlations

The calculations on average inter-item correlation between the seven questionairre items (Q1 - Q7) showed that almost all items correlate with the others in a reasonably restricted range of 0.4 to 0.5, indicating good consistency in inter-item correlation.

Items Q1, Q4, Q5 and Q7 are more strongly correlated with the other items on average than Q6.

Cronbach alpha analyses

Rule of thumb guidelines for interpreting Cronbach alpha (α) for Likert scale questions are indicated in the table below:

Cronbach's alpha	Internal consistency
α ≥ 0.9	Excellent
0.9 > α ≥ 0.8	Good
0.8 > α ≥ 0.7	Acceptable
0.7 > α ≥ 0.6	Questionable
0.6 > α ≥ 0.5	Poor
0.5 > α	Unacceptable

On this basis, the seven questionairre items showed good internal consistency ($\alpha = 0.85$) as a tool for assessing general approval of the MEER approach.

This good consistency was maintained when the Likert rating data was segregated for each survey ($\alpha = 0.85$ for survey 2, $\alpha = 0.84$ for survey 3, $\alpha = 0.87$ for survey 4), indicating that the questionnaire items were stable over time (2.5, 5, 10 months after trial commencement), and for different groups of respondents.

Cronbach alpha was also calculated for questionairre items subdivided by two smaller topic groups:

- Questions relating to respondents' experience of team-based aspects of MEER (Q1, Q3, Q4)
- Questions relating to respondents' experience of learning aspects of MEER (Q5, Q6, Q7)

The learning topic subgroup showed good internal consistency ($\alpha = 0.85$) and the team-based topic subgroup showed borderline good/acceptable internal consistency ($\alpha = 0.80$).

Overall, it is concluded that these analyses validate the survey questions as an appropriate tool for gauging the approval of respondents to the MEER approach.

Process control charts and ITS analysis of Epworth MEER trial

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Introduction

This notebook file provides R code and results for process control charts (u-charts) and Interrupted Time Series (ITS) analyses of an intervention trial at the Epworth Richmond hospital in Melbourne which was applied to two units at the Epworth hospital in Richmond, 4 Gray (4G) and Emergency (ED), from Jan 2018 to Oct 2018.

The intervention was the application of a quality improvement approach called MEER. The effectiveness of the MEER intervention was gauged by its influence on reported adverse adverse incidents at the Epworth Richmond hospital as recorded by an electronic reporting system called RiskMan.

The RiskMan incidents analysed in this study can be categorised according to which of five National Safety and Quality Health Standards (NSQHS) they pertain to. In this study we consider only incidents related to **standard 5** where incidents for all units across the hospital were logged independently by the hospital records section. Incident reports for all other standards were generally self-reported and hence subject to confounding.

Monthly aggregated RiskMan incident counts for this analysis are imported from Std5 monthly culps.csv which span the first 10 months (Jan - Oct) in 2017 and 2018 for standard 5 incidents. The 2017 data is the baseline, and the 2018 data is the intervention.

The RiskMan counts in the data file are grouped by unit, year and month.

The unit groupings are:

- 4G
- ED
- 4G & ED
- Other Epworth Richmond units

Patient activity levels were obtained for each unit grouping in order to calculate incident rates. The activity level for all units except ED was taken as the monthly **bed occupancy** count. The activity levels for ED are recorded on the different metric of **patient attendances**.

In order to combine the ED and 4G data, we need to adjust the attendance activity levels of ED to make them equivalent to bed occupancy activity levels. We do this by multiplying the ED activity levels by a scalar, f =0.836, which makes the mean incident rate of ED during the baseline period (Jan-Oct 2017) equal to the mean incident rate for all other units (including 4G) in the same period.

f is calculated as follows

$$f = \frac{\sum_{incidents_{ED}}{incidents_{other+4G}} \times \frac{\sum_{activity_{other+4G}}{\sum_{activity_{ED}}} \quad \text{for data from Jan-Oct 2017}$$

The activity field for the ED and ED+4G records in the input .csv file has been adjusted for f as follows:

```
ED: activity_{ED} \times f
ED+4G: activity_{ED} \times f + activity_{4G}
```

References

The ITS analysis was conducted using segmented regression analysis based on the methodology described in the following paper:

Interrupted time series regression for the evaluation of public health interventions: a tutorial, *International Journal of Epidemiology 2016* J. Lopez Bernal, S. Cummins, A. Gasparrini

The process control charts were developed using the R qicharts2 package. U-charts for incident rates are provided.

Load R packages

```
library(qicharts2)
library(ggplot2)
library(ggpubr)
library(tidyverse)
library(zeallot)
library(foreign) ; library(tsModel) ; library("lmtest") ; library("Epi")
library(MASS)
library(car) # for qqp
```

Useful functions

Import .csv data file for standard 5 incident counts

The file includes the following fields:

- unit = unit or group of units that the incidents have been attributed to
- year = year of monthly incident count
- month = month of monthly incident count
- time = elapsed time in months since the start of the study
- culprount = count of incidents per month attributed to a unit or group of units (the outcome)
- MEER = MEER sessions (the intervention) coded 0 before intervention, 1 after
- activity = patient activity levels in the unit

Read in the standard 5 data and add field for incident rate:

```
# Read in the data
data5 <- read.csv("Std5 monthly culps.csv")

# Add a column for monthly incident rate per 1000 patients
data5$IR <- data5$culpcount / data5$activity * 1000.

# Factorize the ward and year columns
data5$year <- factor(data5$year, levels=c(2017,2018))
data5$unit <- as.factor(data5$unit)
data5$activity <- as.integer(data5$activity)</pre>
```

Display the data

knitr::kable(data5, format="markdown")

unit	year	month	culpcount	MEER	time	activity	IR
4G	2017	1	5	0	1	1351	3.7009623
4G	2017	2	6	0	2	928	6.4655172
4G	2017	3	1	0	3	1110	0.9009009
4G	2017	4	2	0	4	1055	1.8957346
4G	2017	5	4	0	5	1238	3.2310178
4G	2017	6	2	0	6	1054	1.8975332
4G	2017	7	4	0	7	1211	3.3030553
4G	2017	8	3	0	8	1174	2.5553663
4G	2017	9	5	0	9	1232	4.0584416
4G	2017	10	4	0	10	1103	3.6264733
4G	2018	1	1	1	13	1054	0.9487666
4G	2018	2	3	1	14	949	3.1612223
4G	2018	3	2	1	15	1007	1.9860973
4G	2018	4	1	1	16	1044	0.9578544
4G	2018	5	4	1	17	1034	3.8684720
4G	2018	6	1	1	18	950	1.0526316
4G	2018	7	3	1	19	1120	2.6785714
4G	2018	8	1	1	20	1166	0.8576329
4G	2018	9	2	1	21	1053	1.8993352
4G	2018	10	6	1	22	1084	5.5350554
ED	2017	1	13	0	1	1875	6.9315182
ED	2017	2	18	0	2	1796	10.0170979
ED	2017	3	23	0	3	1999	11.5046797
ED	2017	4	13	0	4	1952	6.6585304
ED	2017	5	17	0	5	2071	8.2083429
ED	2017	6	17	0	6	1968	8.6370589
ED	2017	7	25	0	7	2109	11.8510964
ED	2017	8	29	0	8	2208	13.1283065
ED	2017	9	46	0	9	2140	21.4909753
ED	2017	10	31	0	10	2117	14.6431454
ED	2018	1	14	1	13	1884	7.4282987
ED	2018	2	9	1	14	1803	4.9899816
ED	2018	3	16	1	15	2046	7.8169812
ED	2018	4	15	1	16	2003	7.4874011
ED	2018	5	13	1	17	2081	6.2467177
ED	2018	6	13	1	18	1843	7.0509188
ED	2018	7	24	1	19	1948	12.3190393
ED	2018	8	11	1	20	2003	5.4907608
ED	2018	9	16	1	21	1888	8.4707022
ED	2018	10	14	1	22	1976	7.0827965
4G & ED	2017	1	18	0	1	3226	5.5796652
4G & ED	2017	2	24	0	$\frac{2}{3}$	2725	8.8073394
4G & ED	2017	3	24	0		3109	7.7195240
4G & ED	2017	4	15	0	4	3007	4.9883605
4G & ED 4G & ED	2017	5 6	21 19	0	5 6	3309	$6.3463282 \\ 6.2872270$
4G & ED 4G & ED	2017	6 7	19 29	0		3022	8.7323095
4G & ED 4G & ED	$2017 \\ 2017$	8	$\frac{29}{32}$	$0 \\ 0$	7 8	3321	9.4590600
4G & ED 4G & ED		9	52 51	0	9	3383	9.4590600 15.1245552
4G & ED	2017	9	91	U	9	3372	10.1240002

unit	year	month	culpcount	MEER	time	activity	IR
4G & ED	2017	10	35	0	10	3220	10.8695652
4G & ED	2018	1	15	1	13	2939	5.1037768
4G & ED	2018	2	12	1	14	2753	4.3588812
4G & ED	2018	3	18	1	15	3054	5.8939096
4G & ED	2018	4	16	1	16	3047	5.2510666
4G & ED	2018	5	17	1	17	3115	5.4574639
4G & ED	2018	6	14	1	18	2794	5.0107373
4G & ED	2018	7	27	1	19	3068	8.8005215
4G & ED	2018	8	12	1	20	3169	3.7866835
4G & ED	2018	9	18	1	21	2942	6.1182869
4G & ED	2018	10	20	1	22	3061	6.5338125
Other	2017	1	41	0	1	10430	3.9309684
Other	2017	2	57	0	2	11951	4.7694754
Other	2017	3	76	0	3	13536	5.6146572
Other	2017	4	58	0	4	11669	4.9704345
Other	2017	5	62	0	5	14326	4.3277956
Other	2017	6	60	0	6	13213	4.5409824
Other	2017	7	62	0	7	13503	4.5915722
Other	2017	8	91	0	8	15547	5.8532193
Other	2017	9	62	0	9	14923	4.1546606
Other	2017	10	86	0	10	14979	5.7413713
Other	2018	1	42	1	13	12213	3.4389585
Other	2018	2	74	1	14	13254	5.5832202
Other	2018	3	78	1	15	14244	5.4759899
Other	2018	4	65	1	16	13545	4.7988188
Other	2018	5	85	1	17	14718	5.7752412
Other	2018	6	68	1	18	13798	4.9282505
Other	2018	7	79	1	19	15050	5.2491694
Other	2018	8	79	1	20	15908	4.9660548
Other	2018	9	62	1	21	14632	4.2372881
Other	2018	10	85	1	22	15493	5.4863487

Summarise the data

```
str(data5)
## 'data.frame':
                      80 obs. of 8 variables:
              : Factor w/ 4 levels "4G","4G & ED",..: 1 1 1 1 1 1 1 1 1 1 ...

: Factor w/ 2 levels "2017","2018": 1 1 1 1 1 1 1 1 1 ...

: int 1 2 3 4 5 6 7 8 9 10 ...
## $ unit
    $ year
##
   $ month
   $ culpcount: int 5 6 1 2 4 2 4 3 5 4 ...
## $ MEER : int 0 0 0 0 0 0 0 0 0 0 ...

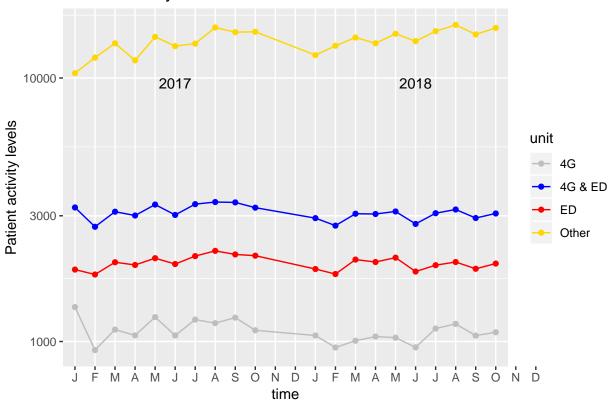
## $ time : int 1 2 3 4 5 6 7 8 9 10 ...

## $ activity : int 1351 928 1110 1055 1238 1054 1211 1174 1232 1103 ...
   $ IR
                : num 3.701 6.466 0.901 1.896 3.231 ...
summary(data5)
                                                                        MEER
          unit
                     year
                                  month
                                                  culpcount
                              Min. : 1.0
                                             Min. : 1.00
##
          :20
                   2017:40
                                                                  Min. :0.0
                                                                  1st Qu.:0.0
##
    4G & ED:20
                              1st Qu.: 3.0
                                               1st Qu.: 8.25
                   2018:40
##
    ED
          :20
                              Median: 5.5
                                                Median :17.50
                                                                  Median:0.5
                              Mean : 5.5
##
    Other:20
                                               Mean :28.07
                                                                  Mean :0.5
                              3rd Qu.: 8.0
                                               3rd Qu.:43.00
                                                                  3rd Qu.:1.0
##
##
                              Max. :10.0
                                               Max. :91.00
                                                                  Max. :1.0
##
                                               IR
         time
                          activity
                      Min. : 928
1st Qu.: 1685
                                               : 0.8576
   Min. : 1.00
                                       \mathtt{Min}.
##
    1st Qu.: 5.75
                                         1st Qu.: 4.0266
                      Median: 2466
                                        Median : 5.4812
##
   Median :11.50
   Mean :11.50
                                        Mean : 6.0087
                      Mean : 5002
                      3rd Qu.: 5145
                                         3rd Qu.: 7.1692
##
    3rd Qu.:17.25
## Max. :22.00
                      Max. :15908 Max. :21.4910
```

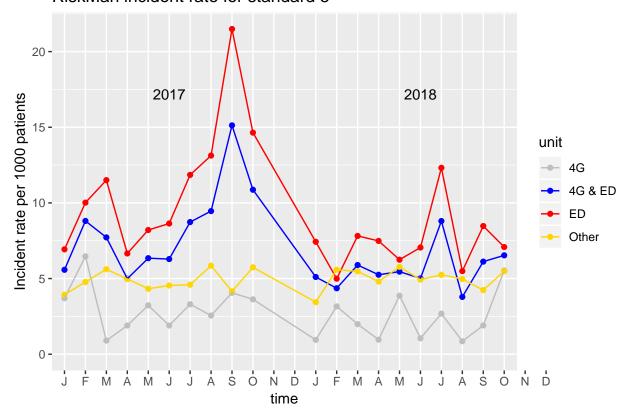
View the data

Plot patient activity levels

Patient activity levels



Plot RiskMan incident rates for standard 5 RiskMan incident rate for standard 5

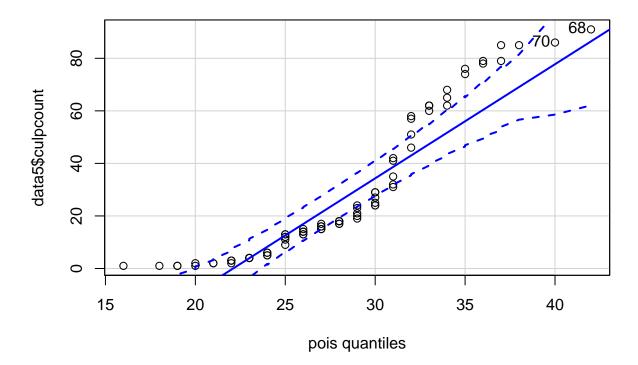


Probablity distributions for the culpcount data

The culpcount data fits within the confidence intervals (dashed lines) of the negative binomial distribution, but not for the Poisson distribution.

Poisson distribution

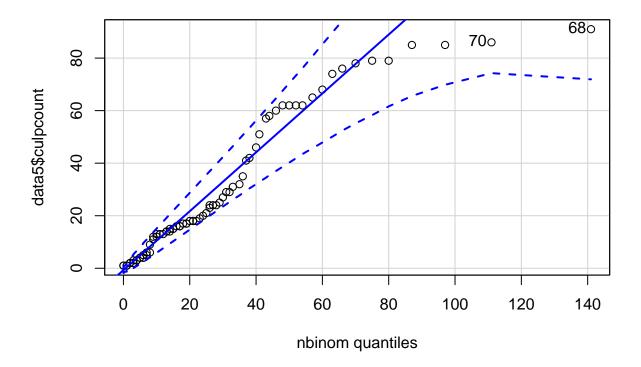
```
poisson <- fitdistr(data5$culpcount, "Poisson")
qqp(data5$culpcount, dist="pois", lambda=poisson$estimate)</pre>
```



[1] 68 70

Negative binomial distribution

```
nbinom <- fitdistr(data5$culpcount, "Negative Binomial")
qqp(data5$culpcount, dist="nbinom", size = nbinom$estimate[[1]], mu = nbinom$estimate[[2]])</pre>
```



[1] 68 70

CHART AND ANALYSIS FUNCTIONS

Process control chart

```
controlChart <- function(chartType,dataAll,u,cpart,ctitle=NULL,showdev=TRUE) {</pre>
  # This is a function for enhancing the qicharts2 control charts
  # assertion checks for chartType, cpart and showdev
if (!(chartType %in% c('u','c','i'))) {stop("chartType must be 'c', 'u' or 'i'")}
if (!(cpart %in% c('freeze','part'))) {stop("cpart must be 'freeze' or 'part'")}
if (typeof(showdev) != "logical") {stop("showdev must be TRUE or FALSE")}
  # get the dataframe slice for the unit
  df <- filter(dataAll, unit==u)</pre>
  # set up chart variables
  if (chartType=='c') {
    metric <- "counts"
ylabel <- "Incident counts"
    ymult <- 1}
  else if (chartType %in% c('u','i')) {
    metric <- "rates"</pre>
    ylabel <- "Incidents per 1,000 patients"</pre>
    ymult <- 1000}
  # create chart title if not provided
  if (is.null(ctitle)) {
    if (u=="Other" | u=="4G & ED") {s <- "s"} else {s <- ""}
    ctitle <- str_c(chartType, "-chart of monthly RiskMan incident ",metric," for ",stand," in ",u," unit",s)
  #Part labels
  if (u=="Other") {
    partlabels <- c('2017 (Baseline)', '2018')</pre>
  } else {
   partlabels <- c('2017 (Baseline)', '2018 (MEER intervention)')
  # chart partitioning
  lastmonth <- 10  # last recorded month is October
if (cpart=='freeze') {</pre>
    freeze1 <- lastmonth
    part1 <- NULL
  } else if (cpart=='part') {
    freeze1 <- NULL
    part1 <- lastmonth
  # create control chart
  cc <- qic(x=time, y=culpcount, n=activity,</pre>
                         = df,
              data
                        = chartType,
              chart
              freeze = freeze1,
              part = part1,
              part.labels = partlabels,
              multiply = ymult,
                      = ctitle,
= ylabel,
              title
              vlab
                        = 'Month')
              xlab
  # Copy the control chart data into variables
  ud <- cc$data
  y <- ud$y cl <- ud$cl
  # create control lines for +/- 1 \& 2 sigma limits
  ud$ucl1 = cl + (ud$ucl - cl) / 3.
  ud$ucl2 = cl + (ud$ucl - cl) / 1.5
  ud$lcl1 = cl + (ud$lcl - cl) / 3.
  ud$1c12 = c1 + (ud$1c1 - c1) / 1.5
```

```
# create color vector for y points
  ud$pcol <- 'black'
  ud$pcol[(y > ud$ucl1) | (y < ud$lcl1)] <- 'pink'
  ud$pcol[(y > ud$ucl2) | (y < ud$lcl2)] <- 'gold'
  ud$pcol[(y > ud$ucl) | (y < ud$lcl)] <- 'red'
  # create extra ggplot layers
  cp <- geom_point(colour = ud$pcol, fill = "black", size = 2.5)
cp2 <- geom_point(colour = "black", fill = "black", size = 2.5)
lxy <- geom_line(colour = "cornflowerblue")</pre>
  11 <- geom_line(data=ud, mapping=aes(y=ucl1), colour="white", size=1)</pre>
  12 <- geom_line(data=ud, mapping=aes(y=ucl2), colour="white", size=1)
  13 <- geom_line(data=ud,mapping=aes(y=lcl1),colour="white",size=1)
  14 <- geom_line(data=ud, mapping=aes(y=lcl2), colour="white", size=1)
  tit <- theme(plot.title = element_text(size=14,color='darkgreen',hjust=0.5))</pre>
  xl <- xlab('Time (month)\n')</pre>
  xl <- theme(axis.title.x=element_blank()) # remove x label</pre>
  bg <- theme(panel.background = element_rect(fill = 'grey98'))</pre>
  # Create the xticks and labels
  c(monthx,monthLet) %<-% monthTics(lastmonth)</pre>
  sc <- scale_x_discrete(labels=monthLet,limits=monthx)</pre>
  # Display the chart
  if (showdev) {
    ccnew \leftarrow cc + 11 + 12 + 13 + 14 + 1xy + cp + sc + ylim(0,NA) + tit + xl
  } else {
    ccnew <- cc + cp2 + sc + ylim(0,NA) + tit + xl+ bg
 return(ccnew)
}
```

Segmented regression model function

Segmented regression analyses comparing 2017 baseline with 2018 intervention period, using Poissom, quasiPoisson and negative binomial distributions to model the data

```
segreg <- function(dataAll, form, u) {
    # dataAll = dataframe containing all the data (i.e. data5)
    # form = the glm model formula (e.g. "poisson")
    # u = unit selected for the analysis (e.g. "4G & ED")

# Calculate incident rate ratio of unit relative to Other units
dataUnit <- filter(dataAll, unit==u)
dataOther <- filter(dataAll, unit=='Other')
dataUnit$IROther <- dataOther$IR
dataUnit$IRR <- dataUnit$IR / dataUnit$IROther

# Poisson regression analysis
modelP <- glm(form, family="poisson", dataUnit)

# quasi-Poisson regression analysis
modelqP <- glm(form, family="quasipoisson", dataUnit)

# negative binomial regression analysis
modelnb <- glm.nb(form, dataUnit)

return(list(dataUnit,modelP,modelqP,modelnb)) # return both the dataframe and models
}</pre>
```

Segmented regression full analysis function

```
segregfull <- function(dataAll, form, u, plotTitle=NULL) {
  # dataAll = dataframe containing all the data (i.e. data5)
  # form = the glm model formula
  # u = unit selected for the analysis (e.g. "4G & ED")</pre>
```

```
# lastmonth = last month for including the yearly data (generally set to 10 for Oct)
# Generate the Poisson and quasiPoisson models
c(dataUnit, modelP, modelqP, modelnb) %<-% segreg(dataAll, form, u)
cat('\n')
# Calculate predicted values from Poisson model (modelP)
lastmonth <- 10 # last recorded month is October
f <- 10 # number of x axis plot points per month
monthpts <- (f:(lastmonth*f)) / f
n <- length(monthpts) # number of x axis plot points per year
standardiser <- mean(dataUnit$activity/1000.) * mean(dataUnit$IROther)
datanew <- data.frame(activity=mean(dataUnit$activity),</pre>
                        IROther=mean(dataUnit$IROther),
                        MEER=rep(c(0,1), c(n,n)),
                        month=c(monthpts,monthpts)
                        time=c(monthpts, monthpts+12))
datanew$prednb <- predict(modelnb,type="response",datanew)/standardiser
pred2017 <- filter(datanew,time<=12)</pre>
pred2018 <- filter(datanew,time>=13)
# Create the incident rate ratio plot
c(monthx,monthLet) %<-% monthTics(lastmonth)</pre>
if (is.null(plotTitle)) {
 plotTitle <- paste('Incident rate ratio for',u,'vs Other for standard 5 up to Oct')
plt <- ggplot() +</pre>
  geom_point(dataUnit, mapping=aes(x=time,y=IRR,color=year)) +
  geom_line(pred2017, mapping=aes(x=time, y=prednb), color='blue', alpha=0.7) +
  geom_line(pred2018, mapping=aes(x=time, y=prednb), color='red', alpha=0.7) +
  scale_x_discrete(labels=monthLet,limits=monthx) +
  scale_colour_manual(values=c("blue", "red")) +
  ggtitle(plotTitle) +
  theme(plot.title = element_text(size=14,color='darkgreen',hjust=0.5)) +
  ylab('incident rate ratio') +
  xlab('Time (month)\n') +
  # theme(axis.title.x=element_blank()) + # remove x label
  ylim(0,NA) +
 annotate(geom="text", x=5.5, y=0.15, label="2017 (baseline)",color='blue') + annotate(geom="text", x=17.5, y=0.15, label="2018 (MEER intervention)",color='red') + theme(legend.position = "none")
return(plt)
```

ANALYSIS & FIGURES

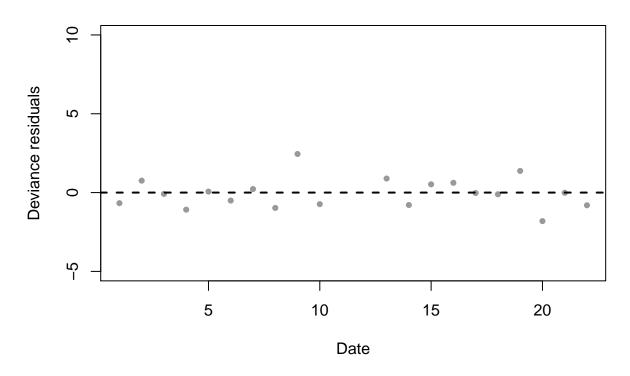
ED+4G vs Other

glm analyses

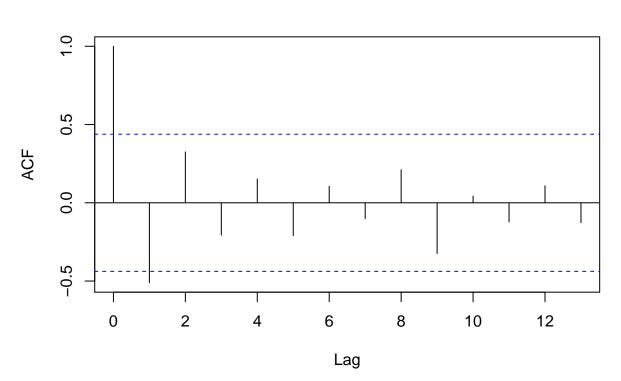
```
# Specify the regresion formula
form <- culpcount ~ offset(log(activity)) + offset(log(IROther)) + MEER + harmonic(month,1,12)
## *** POISSON analysis ***
##
## Call:
## glm(formula = form, family = "poisson", data = dataUnit)
##
## Deviance Residuals:
##
       Min
                 1Q
                      Median
                                    30
                                            Max
## -2.1253
            -0.8875
                    -0.0447
                               0.6778
##
## Coefficients:
                           Estimate Std. Error z value Pr(>|z|)
                            -6.34852
                                        0.06295 -100.849 < 2e-16 ***
## (Intercept)
## MEER
                           -0.42023
                                        0.09831
                                                 -4.274 1.92e-05 ***
## harmonic(month, 1, 12)1 -0.22396
                                        0.06222
                                                  -3.600 0.000319 ***
## harmonic(month, 1, 12)2 0.09478
                                        0.07940
                                                   1.194 0.232564
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## (Dispersion parameter for poisson family taken to be 1)
##
       Null deviance: 62.904 on 19 degrees of freedom
## Residual deviance: 28.815 on 16 degrees of freedom
## AIC: 134.01
## Number of Fisher Scoring iterations: 4
## *** QUASI-POISSON analysis ***
##
## Call:
## glm(formula = form, family = "quasipoisson", data = dataUnit)
##
## Deviance Residuals:
## Min 1Q Median
## -2.1253 -0.8875 -0.0447
                                    30
                                            Max
                               0.6778
                                         3.3505
## Coefficients:
##
                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)
                           -6.34852
                                        0.08694 -73.024 < 2e-16 ***
## MEER
                           -0.42023
                                        0.13577 -3.095 0.00695 **
## harmonic(month, 1, 12)1 -0.22396
## harmonic(month, 1, 12)2 0.09478
                                        0.08592
                                                -2.606 0.01909 *
                                                 0.864 0.40014
                                        0.10965
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for quasipoisson family taken to be 1.907246)
##
##
       Null deviance: 62.904 on 19 degrees of freedom
## Residual deviance: 28.815 on 16 degrees of freedom
## AIC: NA
## Number of Fisher Scoring iterations: 4
## *** NEGATIVE BINOMIAL analysis ***
##
## Call:
## glm.nb(formula = form, data = dataUnit, init.theta = 42.89001556,
##
       link = log)
##
```

```
## Deviance Residuals:
                           Median
##
                                           30
                                                     Max
        Min
                   10
## -1.80970 -0.74702 -0.05567
                                     0.54804
                                                 2.44944
##
## Coefficients:
                              Estimate Std. Error z value Pr(>|z|)
                                          0.08041 -78.906 < 2e-16 ***
0.12020 -3.452 0.000556 ***
## (Intercept)
                              -6.34502
## MEER
                              -0.41496
## harmonic(month, 1, 12)1 -0.22288
                                           0.07749 -2.876 0.004026 **
                                           0.09761 1.008 0.313443
## harmonic(month, 1, 12)2 0.09839
## -
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(42.89) family taken to be 1)
##
##
        Null deviance: 40.052 on 19 degrees of freedom
## Residual deviance: 17.896 on 16 degrees of freedom
## AIC: 133.17
## Number of Fisher Scoring iterations: 1
##
##
##
                   Theta: 42.9
##
              Std. Err.: 35.9
##
   2 x log-likelihood: -123.168
##
## Linear model coefficients
                                                                       P exp(Est.)
                               Estimate StdErr
## (Intercept)
                              -6.345019 0.080412 -78.906279 0.000000 0.001755
                              -0.414965 0.120200 -3.452275 0.000556 0.660364
## MEER
## harmonic(month, 1, 12)1 -0.222876 0.077492 -2.876129 0.004026 0.800214 ## harmonic(month, 1, 12)2 0.098389 0.097606 1.008024 0.313443 1.103392
                                  2.5%
                                           97.5%
## (Intercept)
                              0.001499 0.002055
## MEER
                              0.521757 0.835791
## harmonic(month, 1, 12)1 0.687457 0.931467 ## harmonic(month, 1, 12)2 0.911271 1.336018
```

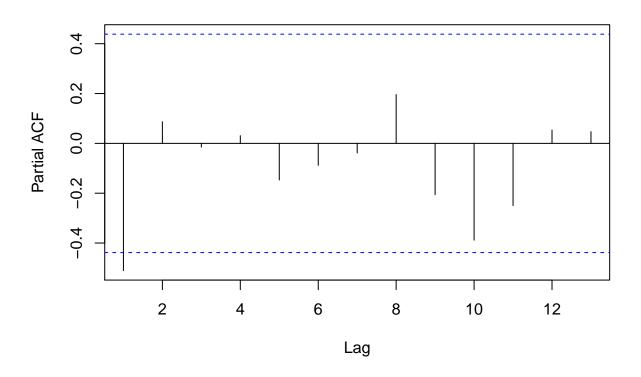
Residuals over time



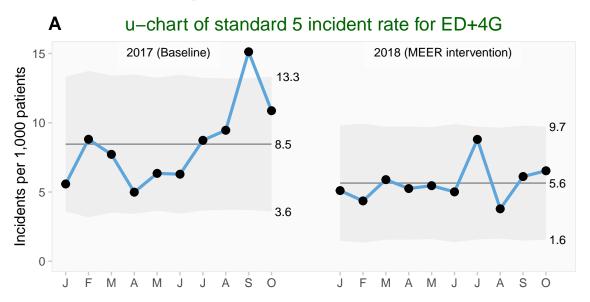
Series res



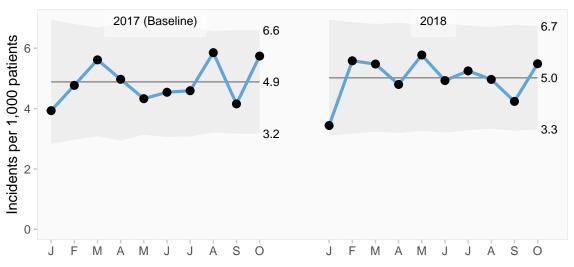
Series res



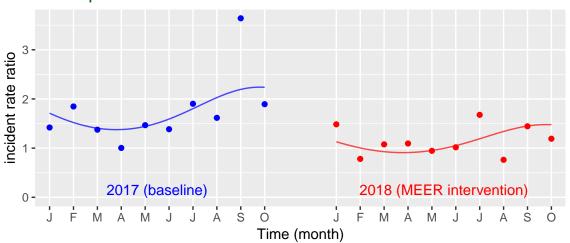
Generate u-charts and ITS plot



B u-chart of standard 5 incident rate for Other units



CITS plot of std 5 incident rate ratio for ED+4G vs Other units



Supplementary File #4

Additional Data on Participation in MEER Sessions and Surveys

Project participants

- 1. Participation in the MEER project involved two main activities:
 - Attending MEER sessions during the afternoon handover period when these sessions coincided with a rostered morning shift for the participant; and
 - Completing online surveys, including a baseline survey at the start of the project (i.e. before MEER sessions commenced) and three post-intervention surveys at the 2.5, 5 and 10 month timepoints.
- 2. Participation in all activities was voluntary, i.e. individuals who agreed to participate in the project could choose not to attend MEER sessions at any time and for any reason (or for no reason) and similarly could choose not to complete any of the surveys or not to answer questions within the surveys.
- 3. The Nurse Unit Managers (NUMs) of two units at Epworth Hospital Richmond (i.e. the ED and inpatient ward 4Gray) agreed to invite staff in their units to participate in the project. As Epworth is a private hospital, most medical professionals that work at the hospital are not actually hospital employees and therefore only nursing staff, ED medical staff and clerical staff were invited to participate in the project. ED and 4Gray staff that agreed to participate in the project were assigned a Participant Identification Number (PIN) that was needed to allow individuals to complete the online surveys.
- 4. ED and 4Gray nursing staff that did not wish to participate in the project, as well as medical practitioners and other clinical and non-clinical staff of the hospital who sometimes work in the participating units (pharmacists, physiotherapists, etc), were encouraged to attend MEER sessions and contribute to the team-based discussions but were not formally invited to participate in the project or allocated a PIN.
- 5. The following table summarises MEER session attendance records kept by the NUMs combined with data obtained from surveys:

Table SF3. 1 Staff participation	and MEER session attendance
----------------------------------	-----------------------------

Unit	Total staff on roster	No. of staff assigned a PIN	No. with PIN that attended at least one MEER session	No. with PIN that completed at least one survey	No. with <u>no</u> PIN that attended at least one MEER session
ED	81*	50	41	20	24
4Gray	60*	33	28	21	18
TOTAL	141*	83	69	41	42

^{*} These numbers are approximate as staff rosters are continually changing.

Key findings from this summary table:

- The proportion of staff on each roster that agreed to participate (i.e. were assigned a PIN) was 62% in the ED and 55% in 4Gray. Some of the staff that were <u>not</u> allocated a PIN would include those on permanent night shift, who knew they would never be able to attend the MEER sessions scheduled for the afternoon handover period.
- More staff attended MEER sessions than requested to formally participate. That is, 83
 individuals requested and were assigned a PIN, but a further 42 individuals participated
 in the MEER sessions without obtaining a PIN. Since they did not receive a PIN, they
 could not complete the survey. Of these 42 individuals, 27 attended more than a single

MEER session, even though they were not required to attend any sessions at all. It is not clear how to interpret this, other than concluding some people weren't interested in participating in a research project, but were happy to participate in the MEER sessions.

There were 14 individuals (= 83 – 69) across the two participating units that were assigned a PIN but never attended a MEER session. This may have simply reflected lack of opportunity, as the MEER sessions were always conducted on a particular day each week and any staff not rostered on the morning shift that day would be unlikely to make a special trip into the hospital to participate.

Analysis of survey participation

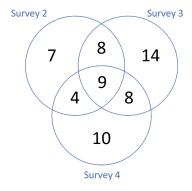
6. While all participants assigned a PIN were able to complete the baseline survey, project participants most likely would not have completed post-intervention surveys (conducted at 2.5 months, 5 months and 10 months) if they had not yet attended at least one MEER session. The following table summarises MEER session attendance records kept by NUMs showing the number of individuals with PINs who had attended at least one MEER session by the closing date of each survey.

Table SF3. 2 Attendance of participants at MEER sessions prior to conduct of post-intervention surveys

	Baseline survey	2.5-month survey	5-month survey	10-month survey
	(Survey #1)	(Survey #2)	(Survey #3)	(Survey #4)
No. of respondents	41	28	39	31
Respondents as a percentage of staff with PIN (n = 83)	49.4%	33.7%	47.0%	37.3%
No. of staff that had attended at least one MEER session by survey closing date	n/a	62	66	69
Respondents as a percentage of staff with PIN that had attended at least one MEER session by survey closing date	n/a	45.2%	59.1%	44.9%

From this summary table, it can be seen that of the 69 people who received a PIN and attended at least one MEER session, 62 had attended at least one MEER session by the time the 2.5-month survey was closed for responses and 66 had attended at least one MEER session by the time the 5-month survey was closed for responses. These figures provide a more realistic denominator for determining response rates in the post-intervention surveys.

7. Analysis of the PIN data collected in the three post-intervention surveys reveals information about which surveys were completed by project participants, as shown in the following Venn diagram.



8. One possible interpretation of this distribution of survey participation is that the seven individuals who completed the first post-intervention survey, but neither of the two remaining surveys, were negatively disposed to – or not engaged by – the MEER sessions and therefore decided not to participate further in the project. A similar interpretation could be applied to the 14 individuals that only completed the second survey. The 10 individuals that only completed the third survey may have only started attending MEER sessions late in the project and so may not have had an opportunity to complete more than one post-intervention survey.

To determine whether there were any differences in the "positivity" of respondents in their opinions of the MEER approach (as presented in Table 2, Rows A – G of the article), depending on which surveys participants answered, or the number of surveys answered, the ratings nominated for each of those seven statements were analysed in further detail.

The seven statements survey respondents were asked to rate were:

Q01: I have enjoyed the team-based discussions

Q02: I like the process of reviewing the standards using the map-based graphical representation in the MEERQAT tool

Q03: I have felt comfortable expressing my views and opinions in the team-based discussions

Q04: I have found hearing the different perspectives amongst my colleagues to be worthwhile

Q05: I have learnt new information about the national quality standards

Q06: I have learnt new information about specific Epworth policies and protocols

Q07: I have enjoyed the opportunity to reflect on my own clinical practice

Initially, the average ratings nominated by the various cohorts of respondents for each of the seven statements were calculated. In the following table, the comparison between those respondents that only completed the first survey at 2.5 months and those that completed multiple surveys is highlighted. Cells in the table highlighted in green are those having the higher average rating in the two-way comparison, while cells highlighted in pink are those having the lower average rating in the two-way comparison.

Table SF3. 3 Average ratings for each statement as nominated by each cohort of survey respondents

	Average rating nominated by respondents						
Respondent cohort	Q01	Q02	Q03	Q04	Q05	Q06	Q07
Overall responses (n = 60)	4.33	4.10	4.32	4.50	4.26	4.23	4.32
2.5-month responses (n = 28)	4.29	4.07	4.32	4.54	4.14	3.96	4.21
5-month responses (n = 39)	4.23	4.05	4.26	4.46	4.26	4.33	4.26
10-month responses (n = 31)	4.48	4.19	4.39	4.52	4.37	4.35	4.48
One survey completed (n = 31)	4.29	3.97	4.29	4.58	4.26	4.35	4.39
Two surveys completed (n = 20)	4.23	4.00	4.23	4.45	4.05	4.18	4.30
Three surveys completed (n = 9)	4.52	4.41	4.48	4.48	4.41	4.19	4.26
Multiple (i.e. 2 or 3) surveys completed (n = 29)	4.34	4.16	4.33	4.46	4.26	4.18	4.28
Only completed 2.5-month survey (n = 7)	4.00	4.00	4.57	4.71	4.00	4.00	4.29
Only completed 5-month survey (n = 14)	4.14	3.86	4.21	4.64	4.36	4.50	4.36
Only completed 10-month survey (n = 10)	4.70	4.10	4.20	4.40	4.30	4.40	4.50

Charts comparing these average ratings are presented on the following pages.

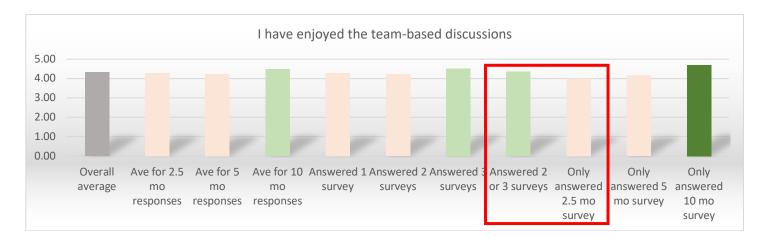
Respondent Views on MEER Session – Average ratings based on respondent profile

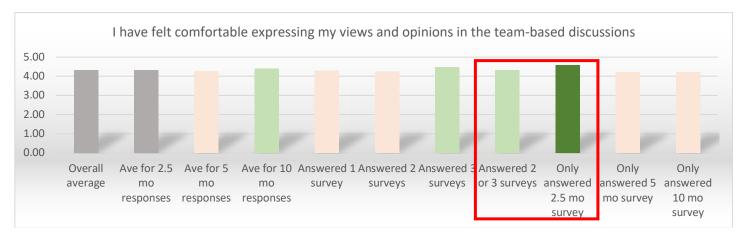
For each of the seven statements survey respondents were asked to rate, the following charts show the average rating for various cohorts of respondents, based on:

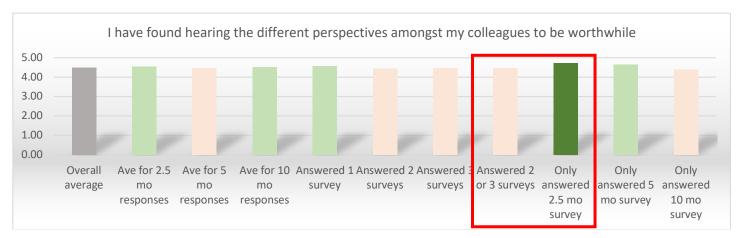
- All respondents for a particular post-intervention survey (All surveys, 2.5-month survey; 5-month survey; 10-month survey)
- Number of post-intervention surveys the respondent completed (1, 2, 3 or multiple i.e. 2 or 3 surveys)
- Respondents that only answered the 2.5-month survey, or only answered the 5-month survey or only answered the 10-month survey.
- The red rectangle highlights the comparison between respondents that only answered the first post-intervention survey at 2.5 months and those who answered multiple (i.e. 2 or 3) post-intervention surveys.

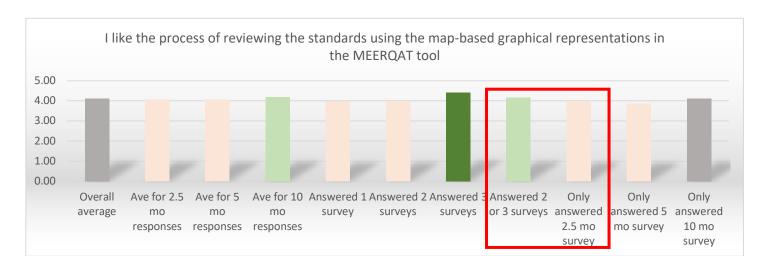
Key:

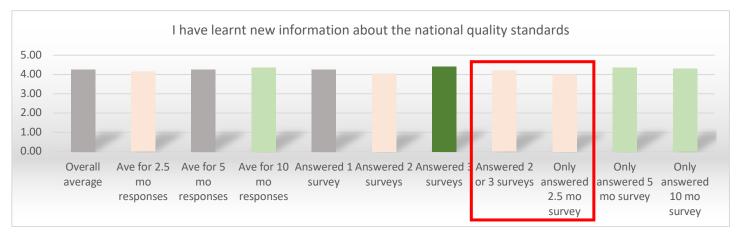
Signifies the average rating	Signifies the average rating	Signifies the average rating	Signifies the highest
for that cohort was equal to	for that cohort was below	for that cohort was above	average rating for that
the overall average for that	the overall average for that	the overall average for that	statement across all the
statement	statement	statement	various cohorts

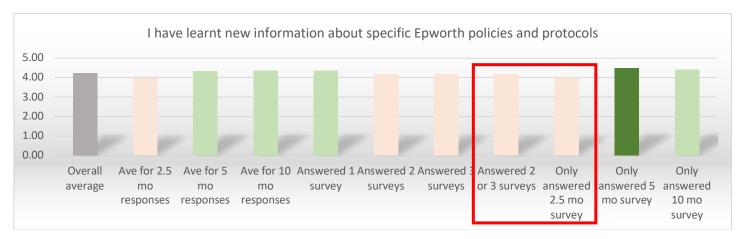


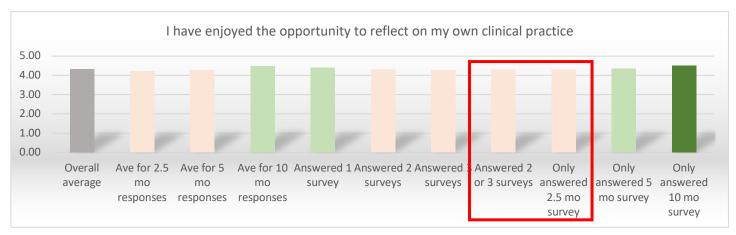












From this analysis, it is apparent there were differences, but no consistent patterns across the seven statements as to which cohorts – on average – rated their perceptions of the MEER intervention more or less positively. Most certainly, these results would suggest that the individuals that only completed the first post-intervention survey at 2.5 months were not, as a group, less positive about all aspects of their experiences than other participants that continued to answer surveys at the 5- and 10-month timepoints. It should also be noted the least positive averages in the table, which were in relation to the statement *I like the process of reviewing the standards using the map-based graphical representation in the MEERQAT tool*, were nevertheless approaching an average of 4, which is a positive response. Therefore, this analysis is effectively about the degree of positiveness, as opposed to positive *versus* negative.

- 9. To determine whether there were any statistically significant differences between the ratings nominated for these seven statements by the various cohorts of survey participants, differences in survey question responses were analysed by ordinal regression with Cumulative Link Models (CLM) or Cumulative Link Mixed Models (CLMM). This analysis is presented in the R notebook on the following pages.
- 10. In summary, the analyses revealed the following:
 - There were differences observed between respondents when the responses for the
 2.5-month, 5-month and 10-month surveys were compared (p < 0.01).
 - There was no significant difference overall between the 2.5-month and 5-month surveys (p > 0.1). However, when the comparison was done question by question, a significant difference was seen for Q06 (I have learnt new information about specific Epworth policies and protocols).
 - There was a significant difference overall between the 2.5-month and 10-month surveys (p < 0.01). When the comparison was done question by question, the only significant difference was seen for Q06 (I have learnt new information about specific Epworth policies and protocols).
 - There was a significant difference overall between the 5-month and 10-month surveys (p < 0.01). However, when the comparison was done question by question, no significant differences were found.
 - No significant difference was found between the responses of participants that only answered the 2.5-month survey and participants that responded to multiple (i.e. two or three) of the post-intervention surveys (p > 0.1). When the comparison was done question by question, no significant differences were found.
 - No significant difference was found between the responses of participants that only answered the 5-month survey and participants that responded to multiple (i.e. two or three) of the post-intervention surveys (p > 0.1). When the comparison was done question by question, no significant differences were found.

MEER intervention survey - analysis of differences between survey responses

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Introduction

This R notebook checks for differences between survey responses which were conducted after the initial baseline survey, i.e. at 2.5 months (survey 2), 5 months (survey 3) and 10 months (survey 4) after the start of the MEER trial at the Epworth hospital.

The analysis focusses on the first seven questions reported in Table 2 of the paper ("Staff opinions on the MEER approach and its impact") as listed below:

- Q1: I have enjoyed the team-based discussions
- Q2: I like the process of reviewing the standards using the map-based graphical representations in the MEERQAT tool
- Q3: I have felt comfortable expressing my views and opinions in the team-based discussions
- Q4: I have found hearing the different perspectives amongst my colleagues to be worthwhile
- Q5: I have learnt new information about the national quality standards
- Q6: I have learnt new information about specific Epworth policies and protocols
- Q7: I have enjoyed the opportunity to reflect on my own clinical practice

The responses for each survey question were based on a 5 point Likert scale, ranging from a least favourable (1) to a most favourable (5) response. The Likert scales are not assumed to necessarily represent equally spaced responses.

Each participant was identified by a unique pin for each survey.

Not all trial participants responded to each survey. A Venn diagram showing the numbers of survey respondents across the three surveys (2,3,4) is shown below:

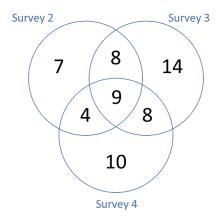


Figure 1: Venn diagram of survey respondents

The specific aim of the analyses is to address the following questions:

- 1. Do the ratings nominated by respondents differ between Survey 2, Survey 3 and Survey 4?
- 2. Do the ratings nominated by respondents who only completed Survey 2 differ from respondents who answered two or three of the post-intervention surveys?
- 3. Do the ratings nominated by respondents who only completed Survey 3 differ from respondents who answered two or three of the post-intervention surveys?

Differences in survey question responses were analysed by ordinal regression with Culumlative Link Models (CLM) or Cumulative Link Mixed Models (CLMM), using the R clm or clmm functions respectively.

Reference

Mangiafico (2016) "SUMMARY AND ANALYSIS OF EXTENSION EDUCATION PROGRAM EVALUATION IN R" see section on *Two-sample Paired Ordinal Test with CLMM* http://rcompanion.org/handbook/G_12.html

Load libraries

```
library("readxl")
library(psych)
library(ggplot2)
library(dplyr)
library(FSA)
library(lemon)
knit_print.data.frame <- lemon_print</pre>
```

Read in and process the Likert data file

```
# Read in the data for 5 scale Likert scores
Data <- read.csv("Survey data BMJOQ reshaped.csv")

# Create labelled variables for survey names (for plot axis labels)
survey_names = c("2.5 month survey","5 month survey","10 month survey")
Data$survey_names <- mapvalues(Data$survey, from=c(2,3,4), to=survey_names)
Data$survey_names <- factor(Data$survey_names, ordered=TRUE, levels=survey_names)

# factorize variables
Data$qn <- factor(Data$qn)
Data$num_surveys <- factor(Data$num_surveys)
Data$survey <- factor(Data$survey)
Data$Likert.f <- factor(Data$Likert, ordered = TRUE)</pre>
```

Display head and tail of the data

	pin	qn	num_surveys	survey	Likert	survey_names	Likert.f
1	7	Q01	1	2	4	2.5 month survey	4
2	1011	Q01	2	2	3	2.5 month survey	3
3	1062	Q01	2	2	4	2.5 month survey	4
4	1012	Q01	2	2	4	2.5 month survey	4
		NA	NA	NA		NA	NA
681	1037	Q07	2	4	5	10 month survey	5
682	2068	Q07	1	4	5	10 month survey	5
683	1059	Q07	2	4	5	10 month survey	5
684	1070	Q07	3	4	5	10 month survey	5

Check the data

```
str(Data)
                          684 obs. of 7 variables:
## 'data.frame':
    $ pin : int 7 1011 1062 1012 2036 1028 2050 2104 1017 1020 ... $ qn : Factor w/ 7 levels "Q01", "Q02", "Q03", ...: 1 1 1 1 1 1 1 1 1 1 1 ... $ num_surveys : Factor w/ 3 levels "1", "2", "3": 1 2 2 2 2 1 2 3 3 3 ... $ survey : Factor w/ 3 levels "2", "3", "4": 1 1 1 1 1 1 1 1 1 1 ... $ Likert : int 4 3 4 4 4 4 4 4 4 4 ...
##
##
    $ survey_names: Ord.factor w/ 3 levels "2.5 month survey"<..: 1 1 1 1 1 1 1 1 1 1 ...
                       : Ord.factor w/ 4 levels "2"<"3"<"4"<"5": 3 2 3 3 3 3 3 3 3 3 ...
     $ Likert.f
summary(Data)
           pin
                                     num_surveys survey
                                                                     Likert
                            qn
                         Q01:98
                                                                        :2.000
##
     Min.
                                     1:217
                                                     2:196
                                                                Min.
     1st Qu.:1036
                                                                1st Qu.:4.000
##
                         Q02:98
                                     2:278
                                                     3:272
##
     Median :1080
                         Q03:98
                                     3:189
                                                     4:216
                                                                Median :4.000
##
     Mean :1409
                         Q04:98
                                                                Mean :4.294
     3rd Qu.:2032
                         Q05:96
                                                                3rd Qu.:5.000
##
##
     Max. :3035
                         Q06:98
                                                                Max. :5.000
##
                         Q07:98
##
                  survey_names Likert.f
##
     2.5 month survey:196
                                    2: 8
##
     5 month survey :272
                                    3: 51
                                    4:357
     10 month survey :216
##
                                    5:268
##
##
##
```

Get Likert data counts

```
xtabs( ~ survey + Likert.f + num_surveys, data = Data)
\#\# , , num\_surveys = 1
##
##
         Likert.f
## survey 2 3 4 5
        2 2 7 18 22
##
        3 1 9 48 40
4 2 7 24 37
##
##
##
\#\# , , num\_surveys = 2
##
        Likert.f
## survey 2 3 4 5
## 2 3 8 51 22
##
        3 0 5 78 28
##
        4 0 7 39 37
##
## , , num_surveys = 3
##
##
        Likert.f
## survey 2 3 4 5
        2 0 4 31 28
##
        3 0 3 37 23
##
        4 0 1 31 31
```

Summarize data treating Likert ratings as numeric

```
Summarize(Likert ~ num_surveys + survey, data=Data, digits=3)
  num_surveys survey
                                     sd min Q1 median Q3 max
                         n mean
         1 2 49 4.224 0.848 2 4
## 1
                                                   4 5.0 5
                     2 84 4.095 0.705
2 63 4.381 0.607
                                         2 4
3 4
## 2
                                                    4 5.0
                                                            5
                                                   4 5.0
## 3
              3
                                                            5
## 4
                     3 98 4.296 0.677
                                                   4 5.0
## 5
              2
                     3 111 4.207 0.507
                                          3 4
                                                    4 4.5
                                                            5
                     3 63 4.317 0.563
                                         3 4
                                                            5
## 6
              3
                                                    4 5.0
## 7
                     4 70 4.371 0.783
              1
                                                    5 5.0
                                                            5
                                        3 4
## 8
              2
                     4 83 4.361 0.636
                                                    4 5.0
                                                            5
              3
                     4 63 4.476 0.535
                                                    4 5.0
Summarize(Likert ~ num_surveys, data=Data, digits=3)
    num_surveys n mean
                             sd min Q1 median Q3 max
             1 217 4.304 0.751 2 4
2 278 4.219 0.617 2 4
## 1
                                            4 5
                                                    5
## 2
                                             4 5
                                                    5
              3 189 4.392 0.570
                                                    5
Summarize(Likert ~ survey, data=Data, digits=3)
    survey n mean sd min Will
2 196 4.219 0.722 2 4
                        sd min Q1 median Q3 max
## 1
## 2
                                        4 5
                                               5
## 3
         4 216 4.398 0.660
                                               5
```

ANALYSIS OF QUESTIONS

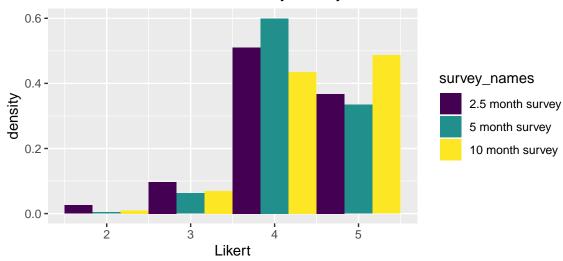
Load libraries for CLM and CLMM analysis

```
library(ordinal)
library(car)
library(RVAideMemoire)
```

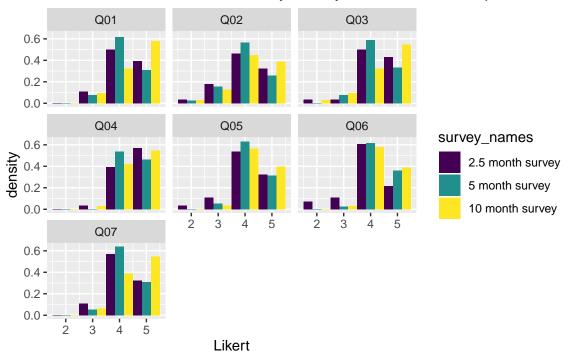
Question 1: Do the ratings nominated by respondents differ between Survey 2 (2.5 months), Survey 3 (5 months) and Survey 4 (10 months)?

Plot histograms of normalised counts of the Likert responses by survey number

NORMALISED Likert counts by survey number



NORMALISED Likert counts by survey number for each question



Test for differences in Likert ratings between all surveys (2,3,4) for all questions

Using the clmm function, Likert.f is the dependent variable, and survey is the independent variable. Question number, qn, is used as a blocking variable.

Test for differences in Likert ratings between survey 2 and survey 3 for all questions

Test for differences in Likert ratings between survey 2 and survey 4 for all questions

[1] 0.008616933

survey

Test for differences in Likert ratings between survey 3 and survey 4 for all questions

8.2366 1 0.004105 **

Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1

Test for differences between surveys by question

Using the clm function, Likert.f is the dependent variable, and survey is the independent variable.

Pr(>Chisq) is provided for each question for none, survey2, survey3, or survey4 data excluded.

```
##
## *** EXCLUDED SURVEY: none ***
## Q01 0.1455
## Q02 0.6389
## Q03 0.4139
## Q04 0.7385
## Q05 0.5284
## Q06 0.0653
## Q07 0.1208
##
## *** EXCLUDED SURVEY: 2 ***
## Q01 0.0528
## Q02 0.3438
## Q03 0.1927
## Q04 0.5652
## Q05 0.4424
## Q06 0.8455
## Q07 0.0717
##
## *** EXCLUDED SURVEY: 3 ***
## Q01 0.1989
## Q02 0.5344
## Q03 0.5528
## Q04 0.8742
## Q05 0.285
## Q06 0.0451
## Q07 0.085
##
## *** EXCLUDED SURVEY: 4 ***
## Q01 0.6455
## Q02 0.8376
## Q03 0.4803
## Q04 0.465
## Q05 0.6394
## Q06 0.0456
## Q07 0.834
```

Question 2: Do the ratings nominated by respondents who only completed Survey 2 differ from respondents who answered two or three of the post-intervention surveys?

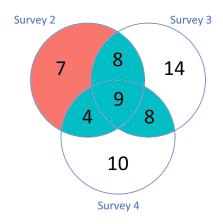


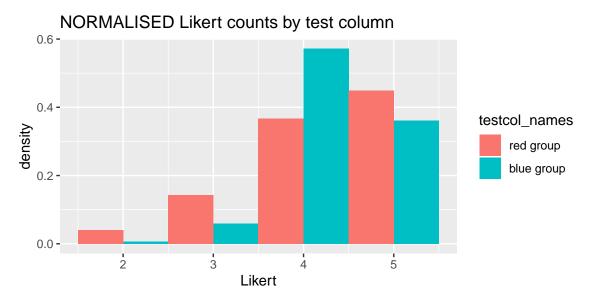
Figure 2: Venn diagram of test samples

Set up the data with testcol as the independent variable

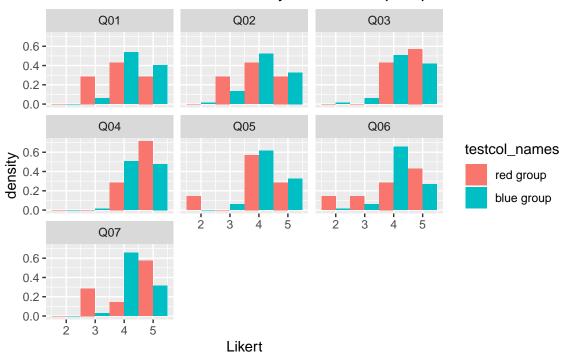
```
Data2 <- Data
Data2$testcol <- 2
Data2 <- Data2 %>%
  mutate(testcol = replace(testcol, survey==2 & num_surveys==1, 0)) %>%
  mutate(testcol = replace(testcol, num_surveys != 1, 1)) %>%
  filter(testcol != 2)

Data2$testcol <- factor(Data2$testcol)
testcol_names = c("red group", "blue group")
Data2$testcol_names <- mapvalues(Data2$testcol, from=c(0,1), to=testcol_names)</pre>
```

Plot the histograms



NORMALISED Likert counts by test column per question



Conduct test for all questions combined

Using the clmm function, Likert.f is the dependent variable, and testcol is the independent variable. testcol delineates between single responses for survey 2 (red group) and multiple survey (blue group) responses. Question number, qn, is used as a blocking variable.

Test for each question

Using the clm function, Likert.f is the dependent variable, and testcol is the independent variable. testcol delineates between single responses for survey 2 (red group) and multiple survey (blue group) responses. Analayses are conducted for each question separately.

Question 3: Do the ratings nominated by respondents who only completed Survey 3 differ from respondents who answered two or three of the post-intervention surveys?

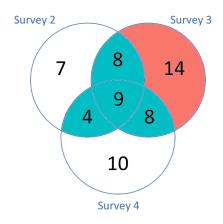
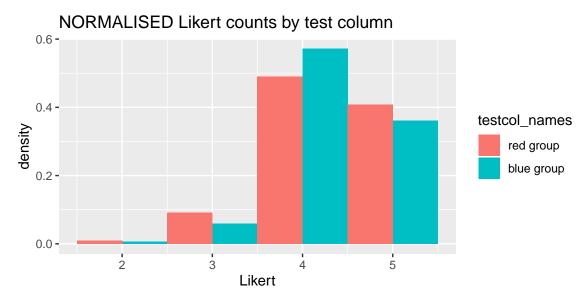


Figure 3: Venn diagram of test samples

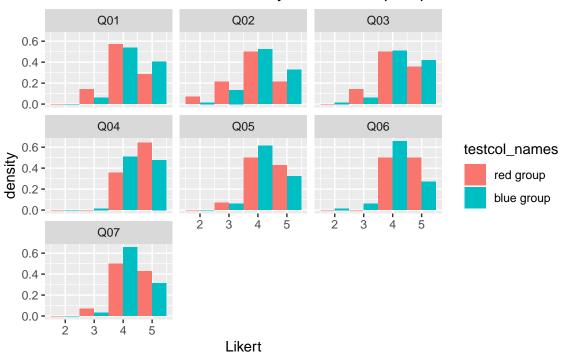
Set up the data with testcol as the independent variable

```
Data3 <- Data
Data3$testcol <- 2
Data3 <- Data3 %>%
    mutate(testcol = replace(testcol, survey==3 & num_surveys==1, 0)) %>%
    mutate(testcol = replace(testcol, num_surveys != 1, 1)) %>%
    filter(testcol != 2)
Data3$testcol <- factor(Data3$testcol)
testcol_names = c("red group", "blue group")
Data3$testcol_names <- mapvalues(Data3$testcol, from=c(0,1), to=testcol_names)</pre>
```

Plot the histograms



NORMALISED Likert counts by test column per question



Conduct test for all questions combined

Using the clmm function, Likert.f is the dependent variable, and testcol is the independent variable. testcol delineates between single responses for survey 3 (red group) and multiple survey (blue group) responses. Question number, qn, is used as a blocking variable.

Test for each question

Using the clm function, Likert.f is the dependent variable, and testcol is the independent variable. testcol delineates between single responses for survey 3 (red group) and multiple survey (blue group) responses. Analayses are conducted for each question separately.

MEER intervention survey - Paired two sample ordinal test

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Introduction

This R notebook provides an analysis of two survey questions which asked trial participants in the Epworth hospital 4G and ED wards about their **knowledge** of the NSQHS quality standards (3,4,5,6,10) and the effectiveness of the **implementation** of quality activities in their ward.

The survey questions were asked prior to the MEER intervention (*first*) and after they had participated in a MEER session (*last*).

Participants were asked to gauge their responses on a Likert scale as follows:

KNOWLEDGE question: How would you rate your own knowledge and understanding of the following standards?

- 0 This standard is not applicable to my work
- 1 I am not aware of this standard
- 2 I am aware of the standard, but am not at all familiar with the detail
- \bullet 3 I am familiar with the detail, but have limited understanding of its relevance to my work
- 4 I am familiar with the detail and understand its relevance to my work

IMPLEMENTATION Question: Overall, how would you rate the application of the following standards in your ward/unit?

- 0 Don't know
- 1 Very poor
- 2 Poor
- 3 Neither good nor poor
- 4 Good
- 5 Very good

Each participant was identified by a PIN and all first and last responses were paired.

The survey question responses were analysed as a two-way repeated ordinal regression with CLMM (Cumulative Link Mixed Models), using the R clmm function

Reference

Mangiafico (2016) "SUMMARY AND ANALYSIS OF EXTENSION EDUCATION PROGRAM EVALUATION IN R" see section on *Two-sample Paired Ordinal Test with CLMM* http://rcompanion.org/handbook/G 12.html

Load libraries

```
library("readxl")
library(psych)
library(ggplot2)
library(dplyr)
library(FSA)
library(lemon)
knit_print.data.frame <- lemon_print</pre>
```

Load the data

Knowledge

```
DataK <- read_excel("All survey data.xlsx", sheet = "knowldata")
DataK$Time <- factor(DataK$Time,levels=c("first","last"))
DataK$standard <- factor(DataK$standard)
DataK$Likert.f <- factor(DataK$Likert, ordered = TRUE)
headTail(DataK)

## standard Time PIN Likert Likert.f
## 1 3 first 1005 4 4</pre>
```

```
## 2
         3 first 1006
                         4
## 3
        3 first 1007
                        2
       3 first 1011
## 4
     <NA> <NA> ... ... 10 last 2042 4 10 last 2050 3
## 5
                             <NA>
## 6
                               3
## 7
       10 last 2063
## 8
                        4
                               4
    10 last 2105 4
## 9
                                 4
```

Implementation

```
DataI <- read_excel("All survey data.xlsx", sheet = "Impdata")
DataI$Time <- factor(DataI$Time,levels=c("first","last"))
DataI$standard <- factor(DataI$standard)
DataI$Likert.f <- factor(DataI$Likert, ordered = TRUE)
headTail(DataI)</pre>
```

```
standard Time PIN Likert Likert.f
## 1
     3 first 1005 3
                              3
                              4
## 2
        3 first 1006
                      4
                      2
                              2
## 3
        3 first 1007
        3 first 1011 4
## 4
                             4
     <NA> <NA> ... ...
10 last 2042 3
                          <NA>
## 5
                           3
## 6
       10 last 2050
                             4
## 7
                      4
## 8
       10 last 2063
                      5
                             5
      10 last 2105 5
                              5
## 9
```

Display the data

Knowledge

standard	Time	PIN	Likert	Likert.f
3	first	1005	4	4
3	first	1006	4	4
3	first	1007	2	2
3	first	1011	4	4
3	first	1012	4	4
3	first	1019	2	2
3	first	1020	2	2
3	first	1035	4	4
3	first	1036	4	4
3	first	1038	4	4
3	first	1044	4	4
3	first	1050	4	4
3	first	1057	4	4
3	first	1059	4	4
3	first	1062	4	4
3	first	1065	4	4
3	first	1070	2	2
3	first	1071	2	2
3	first	1072	3	3
3	first	1082	4	4
3	first	1100	4	4
3	first	2009	4	4
3	first	2020	4	4
3	first	2042	2	2
3	first	2050	4	4
3	first	2063	3	3
3	first	2105	4	4
3	last	1005	4	4
3	last	1006	4	4
3	last	1007	4	4
3	last	1011	4	4
3	last	1012	4	4
3	last	1019	4	4
3	last	1020	$\frac{2}{4}$	$\frac{2}{4}$
	last	1035		
3	last	1036	4	4
3	last	1038	$\frac{4}{4}$	4
3	last last	1044	$\frac{4}{4}$	4
3	last	$1050 \\ 1057$	3	3
3	last	1057 1059	3 4	3 4
3	last	1062	4	4
3	last	1062 1065	4	4
3	last	1000	4	4
3	last	1070	3	3
3	last	1071 1072	2	2
3	last	1072 1082	$\frac{2}{4}$	4
3	last	1002 1100	4	4
3	last	2009	4	4
J	1000	4009	4	4

standard	Time	PIN	Likert	Likert.f
3	last	2020	4	4
3	last	2042	4	4
3	last	2050	3	3
3	last	2063	4	4
3	last	2105	4	4
4	first	1005	4	4
4	first	1006	4	4
4	first	1007	4	4
4	first	1011	4	4
4	first	1012	4	4
4	first	1019	4	4
4	first	1020	2	2
4	first	1035	4	4
4	first	1036	4	4
4	first	1038	4	4
4	first	1044	4	4
4	first	1050	4	4
4	first	1057	4	4
4	first	1059	4	4
4	first	1062	4	4
4	first	1065	4	4
4	first	1070	3	3
$\overline{4}$	first	1071	$\overset{\circ}{2}$	$\overset{\circ}{2}$
$\overline{4}$	first	1072	3	3
$\overline{4}$	first	1082	4	4
$\overline{4}$	first	1100	4	$\overline{4}$
4	first	2009	4	4
4	first	2020	4	4
4	first	2042	2	2
4	first	2050	4	4
4	first	2063	4	4
4	first	2105	4	4
4	last	1005	4	4
4	last	1006	4	4
4	last	1007	4	4
4	last	1011	4	4
4	last	1012	4	4
4	last	1012	4	4
4	last	1020	2	2
4	last	1020 1035	$\frac{2}{4}$	4
4	last	1036	4	4
4	last	1038	4	4
4	last	1036 1044	4	4
4	last	1044 1050	4	4
4	last	1050 1057	4	4
4			4	4
4	last	1059	$\frac{4}{4}$	$\frac{4}{4}$
4	last	1062	$\frac{4}{4}$	4
4	last	1065	$\frac{4}{4}$	
	last	1070		4
4	last	1071	4	4
4	last	1072	3	3
4	last	1082	4	4

standard	Time	PIN	Likert	Likert.f
4	last	1100	4	4
4	last	2009	4	4
4	last	2020	4	4
4	last	2042	4	4
4	last	2050	3	3
4	last	2063	4	4
4	last	2105	4	4
5	first	1005	4	4
5	first	1006	4	4
5	first	1007	4	4
5	first	1011	4	4
5	first	1012	4	4
5	first	1019	4	4
5	first	1020	2	2
5	first	1035	$\overline{2}$	$\overline{2}$
5	first	1036	$\overline{4}$	$\overline{4}$
5	first	1038	4	4
5	first	1044	4	4
5	first	1050	4	4
5	first	1057	3	3
5	first	1057	4	4
5	first	1062	4	4
5	first	1062 1065	4	4
5	first	1000	3	3
5	first	1070	3	3
			3 3	
5	first	1072		3
5	first	1082	4	4
5	first	1100	4	4
5	first	2009	4	4
5	first	2020	4	4
5	first	2042	2	2
5	first	2050	4	4
5	first	2063	4	4
5	first	2105	4	4
5	last	1005	4	4
5	last	1006	4	4
5	last	1007	4	4
5	last	1011	4	4
5	last	1012	4	4
5	last	1019	4	4
5	last	1020	2	2
5	last	1035	4	4
5	last	1036	4	4
5	last	1038	4	4
5	last	1044	4	4
5	last	1050	4	4
5	last	1057	4	4
5	last	1059	4	4
5	last	1062	4	4
5	last	1065	4	4
5	last	1070	4	4
5	last	1071	4	4
9	1000	1011	-	±

standard	Time	PIN	Likert	Likert.f
5	last	1072	2	2
5	last	1082	4	4
5	last	1100	4	4
5	last	2009	4	4
5	last	2020	4	4
5	last	2042	4	4
5	last	2050	3	3
5	last	2063	4	4
5	last	2105	4	4
6	first	1005	4	4
6	first	1006	4	4
6	first	1007	4	4
6	first	1011	4	4
6	first	1012	4	4
6	first	1019	4	4
6	first	1020	2	2
6	first	1035	4	4
6	first	1036	4	4
6	first	1038	4	4
6	first	1044	4	4
6	first	1050	4	4
6	first	1057	3	3
6	first	1057	4	4
6	first	1062	3	3
6	first	1065	4	4
6	first	1000	3	3
6	first	1070	3	3
6			3 3	3
6	first	1072	3 4	3 4
	first	1082		
6	first	1100	4	4
6	first	2009	4	4
6	first	2020	4	4
6	first	2042	2	2
6	first	2050	4	4
6	first	2063	4	4
6	first	2105	4	4
6	last	1005	4	4
6	last	1006	4	4
6	last	1007	4	4
6	last	1011	4	4
6	last	1012	4	4
6	last	1019	4	4
6	last	1020	2	2
6	last	1035	4	4
6	last	1036	4	4
6	last	1038	4	4
6	last	1044	4	4
6	last	1050	4	4
6	last	1057	4	4
6	last	1059	4	4
6	last	1062	4	4
6	last	1065	4	4
-			-	_

standard	Time	PIN	Likert	Likert.f
6	last	1070	4	4
6	last	1071	4	4
6	last	1072	2	2
6	last	1082	4	4
6	last	1100	4	4
6	last	2009	4	4
6	last	2020	4	4
6	last	2042	4	4
6	last	2050	3	3
6	last	2063	4	4
6	last	2105	4	4
10	first	1005	4	4
10	first	1006	4	4
10	first	1007	4	4
10	first	1011	4	4
10	first	1012	4	4
10	first	1019	3	3
10	first	1020	2	$\overset{\circ}{2}$
10	first	1035	$\frac{2}{2}$	2
10	first	1036	4	4
10	first	1038	4	4
10	first	1044	4	4
10	first	1044 1050	4	4
10	first	1050 1057	4	4
10	first	1057 1059	4	4
	first	1062	3	3
10				
10	first	1065	4	4
10	first	1070	3	3
10	first	1071	3	3
10	first	1072	3	3
10	first	1082	4	4
10	first	1100	4	4
10	first	2009	4	4
10	first	2020	4	4
10	first	2042	2	2
10	first	2050	4	4
10	first	2063	4	4
10	first	2105	4	4
10	last	1005	4	4
10	last	1006	4	4
10	last	1007	4	4
10	last	1011	4	4
10	last	1012	4	4
10	last	1019	4	4
10	last	1020	2	2
10	last	1035	4	4
10	last	1036	4	4
10	last	1038	3	3
10	last	1044	4	4
10	last	1050	4	4
10	last	1057	3	3
10	last	1059	4	4
10	10000	1000	- I	1

standard	Time	PIN	Likert	Likert.f
10	last	1062	4	4
10	last	1065	4	4
10	last	1070	4	4
10	last	1071	4	4
10	last	1072	2	2
10	last	1082	4	4
10	last	1100	4	4
10	last	2009	4	4
10	last	2020	4	4
10	last	2042	4	4
10	last	2050	3	3
10	last	2063	4	4
10	last	2105	4	4

Implementation

standard	Time	PIN	Likert	Likert.f
3	first	1005	3	3
3	first	1006	4	4
3	first	1007	2	2
3	first	1011	4	4
3	first	1012	3	3
3	first	1018	3	3
3	first	1019	4	4
3	first	1020	3	3
3	first	1035	4	4
3	first	1036	2	2
3	first	1038	5	5
3	first	1043	4	4
3	first	1044	4	4
3	first	1050	2	2
3	first	1057	5	5
3	first	1059	4	4
3	first	1062	$\overline{4}$	$\overline{4}$
3	first	1065	3	3
3	first	1070	3	3
3	first	1071	4	4
3	first	1072	4	4
3	first	1082	5	5
3	first	1086	4	4
3	first	1100	5	5
3	first	2009	$\frac{3}{4}$	4
3	first	2020	4	4
3	first	2020	4	4
3	first	2024 2042	3	3
3	first	2042 2050	3	3
3	first	2063	3 4	3 4
3	first	2003 2105	5	5
3		1005	4	4
3	last			
3 3	last	1006	4	4
ა 3	last	1007	4	4
	last	1011	4	4
3	last	1012	5	5
3	last	1018	4	4
3	last	1019	4	4
3	last	1020	4	4
3	last	1035	4	4
3	last	1036	2	2
3	last	1038	5	5
3	last	1043	4	4
3	last	1044	4	4
3	last	1050	4	4
3	last	1057	4	4
3	last	1059	4	4
3	last	1062	4	4
3	last	1065	4	4
3	last	1070	4	4
3	last	1071	4	4

-				
standard	Time	PIN	Likert	Likert.f
3	last	1072	5	5
3	last	1082	5	5
3	last	1086	4	4
3	last	1100	4	4
3	last	2009	4	4
3	last	2020	5	5
3	last	2024	5	5
3	last	2042	5	5
3	last	2050	4	4
3	last	2063	4	4
3	last	2105	5	5
4	first	1005	4	4
4	first	1006	4	4
4	first	1007	3	3
4	first	1011	4	4
4	first	1012	$\overline{4}$	4
4	first	1018	3	3
4	first	1019	5	5
4	first	1020	3	3
4	first	1020	4	4
4	first	1036	2	2
4	first	1038	5	5
4	first	1033	5	5
4	first	1043 1044	$\frac{3}{4}$	4
4	first	1044 1050	3	3
			5 5	5 5
4	first	1057		
4	first	1059	4	4
4	first	1062	4	4
4	first	1065	4	4
4	first	1070	4	4
4	first	1071	4	4
4	first	1072	2	2
4	first	1082	5	5
4	first	1086	4	4
4	first	1100	4	4
4	first	2009	3	3
4	first	2020	4	4
4	first	2024	3	3
4	first	2042	3	3
4	first	2050	4	4
4	first	2063	3	3
4	first	2105	4	4
4	last	1005	4	4
4	last	1006	4	4
4	last	1007	4	4
4	last	1011	4	4
4	last	1012	5	5
4	last	1018	4	4
4	last	1019	5	5
4	last	1020	4	4
4	last	1035	5	5
4	last	1036	3	3
*	10000	1000	0	3

standard	Time	PIN	Likert	Likert.f
4	last	1038	5	5
4	last	1043	4	4
4	last	1044	4	4
4	last	1050	4	4
4	last	1057	3	3
4	last	1059	4	4
4	last	1062	4	4
4	last	1065	4	4
4	last	1070	4	4
4	last	1071	4	4
4	last	1072	4	4
4	last	1082	4	4
4	last	1086	4	4
4	last	1100	4	4
$\overline{4}$	last	2009	$\overline{4}$	$\overline{4}$
4	last	2020	5	5
4	last	2024	4	4
4	last	2042	2	2
4	last	2050	4	4
4	last	2063	4	4
4	last	2105	4	4
5	first	1005	3	3
5	first	1005 1006	4	4
5	first	1007	4	4
5	first	1007	4	4
5	first	1012	4	4
5	first	1018	3	3
5	first	1019	5	5
5	first	1020	3	3
5	first	1035	4	4
5	first	1036	2	2
5	first	1038	5	5
5	first	1043	5	5
5	first	1044	4	4
5	first	1050	4	4
5	first	1057	5	5
5	first	1059	3	3
5	first	1062	4	4
5	first	1065	4	4
5	first	1070	4	4
5	first	1071	4	4
5	first	1072	3	3
5	first	1082	4	4
5	first	1086	5	5
5	first	1100	4	4
5	first	2009	3	3
5	first	2020	4	4
5	first	2024	5	5
5	first	2042	3	3
5	first	2050	4	4
5	first	2063	3	3
5	first	2105	5	5
3	11100	2100	9	9

standard	Time	PIN	Likert	Likert.f
5	last	1005	4	4
5	last	1006	4	4
5	last	1007	5	5
5	last	1011	4	4
5	last	1012	5	5
5	last	1018	4	4
5	last	1019	5	5
5	last	1020	4	4
5	last	1035	4	4
5	last	1036	3	3
5	last	1038	4	4
5	last	1043	5	5
5	last	1044	4	4
5	last	1050	4	4
5	last	1057	4	4
5	last	1059	4	4
5	last	1062	3	3
5	last	1065	4	4
5	last	1070	4	4
5	last	1071	5	5
5	last	1072	4	4
5	last	1082	5	5
5	last	1086	5	5
5	last	1100	4	4
5	last	2009	4	4
5	last	2020	5	5
5	last	2024	5	5
5	last	2042	$\overset{\circ}{2}$	$\overset{\circ}{2}$
5	last	2050	$\overline{4}$	$\overline{4}$
5	last	2063	4	4
5	last	2105	4	4
6	first	1005	3	3
6	first	1006	4	4
6	first	1007	4	4
6	first	1011	4	4
6	first	1012	4	4
6	first	1018	3	3
6	first	1019	1	1
6	first	1020	3	3
6	first	1020 1035	4	4
6	first	1036	3	3
6	first	1038	5	5
6	first	1043	5	5
6	first	1044	4	4
6	first	1050	4	4
6	first	1050 1057	5	5
6	first	1057	$\frac{3}{4}$	4
6	first	1062	3	3
6	first	1062 1065	3	3
6	first	1000	3	3
6	first	1070 1071	3 4	3 4
6	first	$1071 \\ 1072$	$\frac{4}{3}$	3
U	mst	1012	9	J

standard	Time	PIN	Likert	Likert.f
6	first	1082	4	4
6	first	1086	4	4
6	first	1100	4	4
6	first	2009	4	4
6	first	2020	4	4
6	first	2024	5	5
6	first	2042	3	3
6	first	2050	5	5
6	first	2063	5	5
6	first	2105	5	5
6	last	1005	4	4
6	last	1006	4	4
6	last	1007	4	4
6	last	1011	4	4
6	last	1012	$\overline{4}$	4
6	last	1018	4	4
6	last	1019	4	4
6	last	1020	4	4
6	last	1035	4	4
6	last	1036	4	4
6	last	1038	4	4
6	last	1033	5	5
6	last	1043 1044	$\frac{3}{4}$	4
6	last	1044 1050	4	4
6	last	1050 1057	4	$\frac{4}{4}$
6	last	1059	4	4
6	last	1062	3	3
6	last	1065	4	4
6	last	1070	4	4
6	last	1071	5	5
6	last	1072	4	4
6	last	1082	4	4
6	last	1086	4	4
6	last	1100	4	4
6	last	2009	4	4
6	last	2020	5	5
6	last	2024	5	5
6	last	2042	5	5
6	last	2050	4	4
6	last	2063	5	5
6	last	2105	5	5
10	first	1005	3	3
10	first	1006	4	4
10	first	1007	4	4
10	first	1011	4	4
10	first	1012	4	4
10	first	1018	3	3
10	first	1019	3	3
10	first	1020	3	3
10	first	1035	3	3
10	first	1036	3	3
10	first	1038	5	5
-0	111.00	1000	9	9

standard	Time	PIN	Likert	Likert.f
10	first	1043	5	5
10	first	1044	4	4
10	first	1050	3	3
10	first	1057	5	5
10	first	1059	5	5
10	first	1062	2	2
10	first	1065	4	4
10	first	1070	3	3
10	first	1071	4	4
10	first	1072	3	3
10	first	1082	4	4
10	first	1086	4	4
10	first	1100	4	4
10	first	2009	4	4
10	first	2020	4	4
10	first	2024	4	4
10	first	2042	3	3
10	first	2050	5	5
10	first	2063	4	4
10	first	2105	4	4
10	last	1005	3	3
10	last	1006	4	4
10	last	1007	4	4
10	last	1011	4	$\overline{4}$
10	last	1012	5	5
10	last	1018	4	4
10	last	1019	4	4
10	last	1020	4	4
10	last	1035	4	4
10	last	1036	2	$\stackrel{1}{2}$
10	last	1038	4	4
10	last	1043	4	4
10	last	1044	4	4
10	last	1050	4	4
10	last	1057	4	4
10	last	1059	4	4
10	last	1062	4	4
10	last	1065	4	4
10	last	1070	4	4
10	last	1071	5	5
10	last	1072	4	4
10	last	1082	3	3
10	last	1082	4	4
10	last	1100	4	4
10	last	2009	5	5
10	last	2020	5	5
10		2020	5	5
10	last last	2024 2042	3	3
10	last	2042 2050	3 4	3 4
10	last	2063	5	5
10		2005 2105	5 5	5 5
10	last	2100	<u> </u>	<u> </u>

Check the data

Knowledge

```
str(DataK)
## Classes 'tbl_df', 'tbl' and 'data.frame': 270 obs. of 5 variables:
## $ standard: Factor w/ 5 levels "3","4","5","6",..: 1 1 1 1 1 1 1 1 1 1 1 ...
## $ Time : Factor w/ 2 levels "first","last": 1 1 1 1 1 1 1 1 1 ...
    $ PIN : num 1005 1006 1007 1011 1012 ...
$ Likert : num 4 4 2 4 4 2 2 4 4 4 ...
##
##
## $ Likert.f: Ord.factor w/ 3 levels "2"<"3"<"4": 3 3 1 3 3 1 1 3 3 3 ...
summary(DataK)
    standard
                   Time
                                     PIN
                                                      Likert
                                                                     Likert.f
    3:54
                first:135
                              Min. :1005
                                                 Min. :2.000
                                                                     2: 26
##
   4:54
                              1st Qu.:1020
                                                 1st Qu.:4.000
                                                                     3: 28
                last :135
##
   5:54
                              Median:1059
                                                 Median :4.000
                                                                     4:216
##
   6:54
                              Mean :1267
                                                 Mean :3.704
##
                              3rd Qu.:1100
                                                 3rd Qu.:4.000
    10:54
##
                              Max. :2105
                                                 Max. :4.000
Implementation
str(DataI)
## Classes 'tbl_df', 'tbl' and 'data.frame': 310 obs. of 5 variables:
    $ standard: Factor w/ 5 levels "3","4","5","6",..: 1 1 1 1 1 1 1 1 1 1 ...
$ Time : Factor w/ 2 levels "first","last": 1 1 1 1 1 1 1 1 1 1 ...
                 : num 1005 1006 1007 1011 1012 ...
   $ Likert : num 3 4 2 4 3 3 4 3 4 2 ...
$ Likert.f: Ord.factor w/ 5 levels "1"<"2"<"3"<"4"<..: 3 4 2 4 3 3 4 3 4 2 ...
##
summary(DataK)
     standard
                   Time
                                                      Likert
                                                                     Likert.f
                                      :1005
                                                        :2.000
    3:54
                                                                     2: 26
##
                first:135
                              Min.
                                                 Min.
##
    4:54
                last :135
                               1st Qu.:1020
                                                 1st Qu.:4.000
                                                                     3: 28
##
    5:54
                               Median:1059
                                                 Median :4.000
                                                                     4:216
##
   6:54
                               Mean :1267
                                                 Mean :3.704
##
    10:54
                               3rd Qu.:1100
                                                 3rd Qu.:4.000
                              Max. :2105
                                                 Max. :4.000
```

Get Likert data counts

Knowledge

```
xtabs( ~ Time + Likert.f + standard, data = DataK)
## , , standard = 3
##
##
             Likert.f
## Time 2 3 4
## first 6 2 19
## last 2 3 22
##
## , , standard = 4
##
## Likert.f
## Time 2 3 4
## first 3 2 22
## last 1 2 24
##
## , , standard = 5
##
## Likert.f
## Time 2 3 4
## first 3 4 20
## last 2 1 24
##
## , , standard = 6
##
## Likert.f
## Time 2 3 4
## first 2 5 20
## last 2 1 24
##
\#\# , , standard = 10
## Likert.f
## Time 2 3 4
## first 3 5 19
## last 2 3 22
```

```
xtabs( ~ Time + Likert.f + standard, data = DataI)
## , , standard = 3
##
##
            Likert.f
## Time 1 2 3 4 5 ## first 0 3 8 15 5
##
     last 0 1 0 22 8
##
## , , standard = 4
##
##
            Likert.f
## Time 1 2 3 4 5
## first 0 2 8 16 5
## last 0 1 2 23 5
##
## , , standard = 5
##
##
           Likert.f
## Time 1 2 3 4 5
## first 0 1 8 15 7
## last 0 1 2 19 9
\#\# , , standard = 6
##
##
           Likert.f
   Time 1 2 3 4 5 first 1 0 9 14 7 last 0 0 1 23 7
## Time
##
##
##
\#\# , , standard = 10
##
           Likert.f
   Time 1 2 3 4 5 first 0 1 10 15 5 last 0 1 3 20 7
## Time
##
```

Summarize data treating Likert scores as numeric

Knowledge

```
Summarize(Likert ~ standard + Time, data=DataK, digits=3)
       standard Time n mean
                                      sd min Q1 median Q3 max
          3 first 27 3.481 0.849 2 3.0
## 2
               4 first 27 3.704 0.669
                                           2 4.0
              5 first 27 3.630 0.688
## 4
             6 first 27 3.667 0.620
10 first 27 3.593 0.694
                                           2 3.5
## 5
                                           2 3.0
             3 last 27 3.741 0.594
                                           2 4.0
              4 last 27 3.852 0.456
5 last 27 3.815 0.557
                                           2 4.0
## 7
## 8
                                            2 4.0
             6 last 27 3.815 0.557
## 9
                                            2 4.0
             10 last 27 3.741 0.594
Summarize(Likert ~ Time, data=DataK, digits=3)
## Time n mean sd min Q1 median Q3 ma
## 1 first 135 3.615 0.702 2 3 4 4
## 2 last 135 3.793 0.548 2 4 4 4
                           sd min Q1 median Q3 max
Implementation
```

```
Summarize(Likert ~ standard + Time, data=DataI, digits=3)
      standard Time n mean
                                   sd min Q1 median Q3 max
          3 first 31 3.710 0.864 2 3
4 first 31 3.774 0.805 2 3
## 1
                                                   4 4.0
## 2
             4 first 31 3.774 0.805
                                                   4 4.0
                                                            5
## 3
             5 first 31 3.903 0.790
                                                   4 4.0
## 4
             6 first 31 3.839 0.898 1 3
                                                   4 4.0
            10 first 31 3.774 0.762
                                                   4 4.0
                                                            5
             3 last 31 4.194 0.601
## 6
                                                   4 4.5
## 7
             4 last 31 4.032 0.605
                                                   4 4.0
            5 last 31 4.161 0.688
6 last 31 4.194 0.477
## 8
                                                   4 5.0
## 9
                                        3 4
                                                   4 4.0
            10 last 31 4.065 0.680
                                                   4 4.0
Summarize(Likert ~ Time, data=DataI, digits=3)
                         sd min Q1 median Q3 max
      Time
             n mean
## 1 first 155 3.800 0.817 1 3 4 4 ## 2 last 155 4.129 0.611 2 4 4 4
                                                5
```

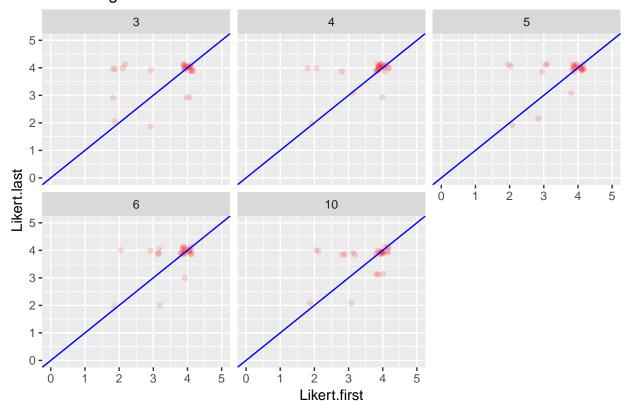
PLOT THE DATA

Paired scatter plots

Knowledge

```
DK1 <- filter(DataK, Time=='first')
DK2 <- filter(DataK, Time=='last')
DKm <- merge(DK1,DK2,by=c('standard','PIN'),suffixes = c('.first','.last'))
ggplot(DKm,mapping=aes(x=Likert.first, y=Likert.last)) +
  geom_jitter(width=0.2,height=0.15, alpha=0.15,color='red') +
  facet_wrap(~standard) +
  geom_abline(slope=1,color='blue') +
  xlim(0,5) + ylim(0,5) + ggtitle('Knowledge data')</pre>
```

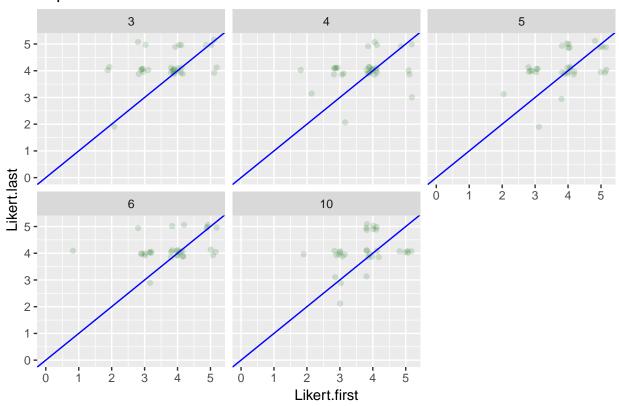
Knowledge data



Implentation

```
DK1 <- filter(DataI, Time=='first')
DK2 <- filter(DataI, Time=='last')
DKm <- merge(DK1,DK2,by=c('standard','PIN'),suffixes = c('.first','.last'))
ggplot(DKm,mapping=aes(x=Likert.first, y=Likert.last)) +
   geom_jitter(width=0.2,height=0.15, alpha=0.15,color='darkgreen') +
   facet_wrap(~standard) +
   geom_abline(slope=1,color='blue') +
   xlim(0,NA) + ylim(0,NA) + ggtitle('Implementation data')</pre>
```

Implementation data

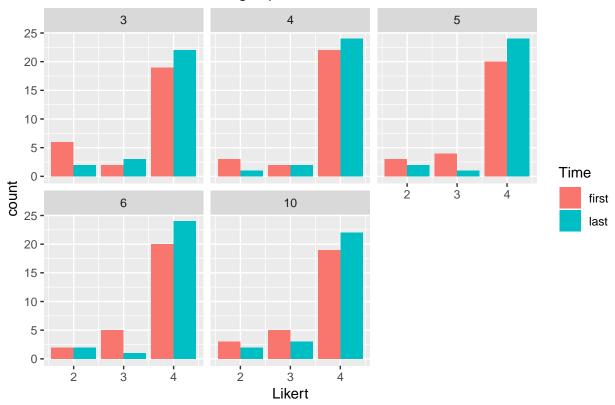


Histograms

${\bf Knowledge}$

```
ggplot(data = DataK) +
  geom_bar(mapping=aes(x=Likert, fill=Time), position='dodge') +
  facet_wrap(~standard) +
  ggtitle("Likert scores for Knowledge question for each standard")
```

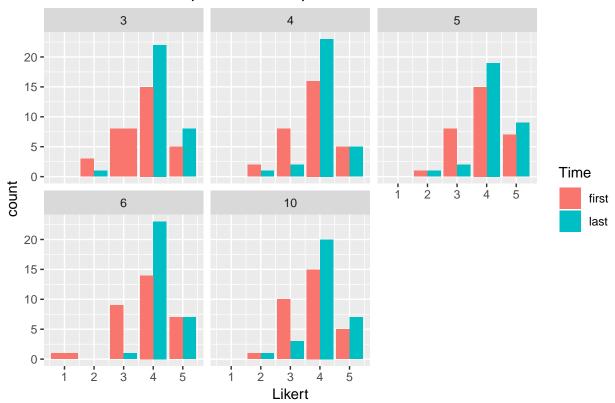
Likert scores for Knowledge question for each standard



Implementation

```
# Implementation data
ggplot(data = DataI) +
  geom_bar(mapping=aes(x=Likert, fill=Time), position='dodge') +
  facet_wrap(-standard) +
  ggtitle("Likert scores for Implementation question for each standard")
```

Likert scores for Implementation question for each standard



TWO WAY REPEATED ORDINAL REGRESSION

Using the clmm function, Likert.f is the dependent variable and standard and Time are the independent variables. The term Time:standard adds the interaction effect of these two independent variables to the model. PIN is used as a blocking variable, and is entered as a random variable.

Load libraries

```
library(ordinal)
library(car)
library(RVAideMemoire)
```

Define model and conduct analysis of deviance

Knowledge

```
modelK <- clmm(Likert.f ~ Time + standard + Time:standard + (1|PIN),</pre>
               data=DataK, threshold = "flexible")
anov <- Anova(modelK, type = "II")</pre>
print(anov)
## Analysis of Deviance Table (Type II tests)
##
## Response: Likert.f
##
                 LR Chisq Df Pr(>Chisq)
## Time
                  10.3209 1
                               0.001315 **
## standard
                   5.6175
                          4
                               0.229589
                  0.3739 4
## Time:standard
                               0.984561
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
```

Implementation

```
modelI <- clmm(Likert.f ~ Time + standard + Time:standard + (1|PIN),</pre>
               data=DataI, threshold = "flexible")
anov <- Anova(modelI, type = "II")</pre>
print(anov)
## Analysis of Deviance Table (Type II tests)
##
## Response: Likert.f
##
                LR Chisq Df Pr(>Chisq)
## Time
                  21.8667 1 2.923e-06 ***
                   2.6843 4
                                  0.612
## standard
## Time:standard
                          4
                                  0.892
                  1.1140
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
```