CENTER FOR HEALTHCARE ENGINEERING & PATIENT SAFETY
UNIVERSITY OF MICHIGAN

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The Impact of Communication, Coordination and OR Design on Surgical Patient Flow and Safety

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Project 1

How can Mobile Computing Improve Communication and Coordination on the Day of Surgery?

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Joint Research by

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Collaborative Partners

PALMETTO HEALTH

GHS GREENVILLE HEALTH SYSTEM

Project Background

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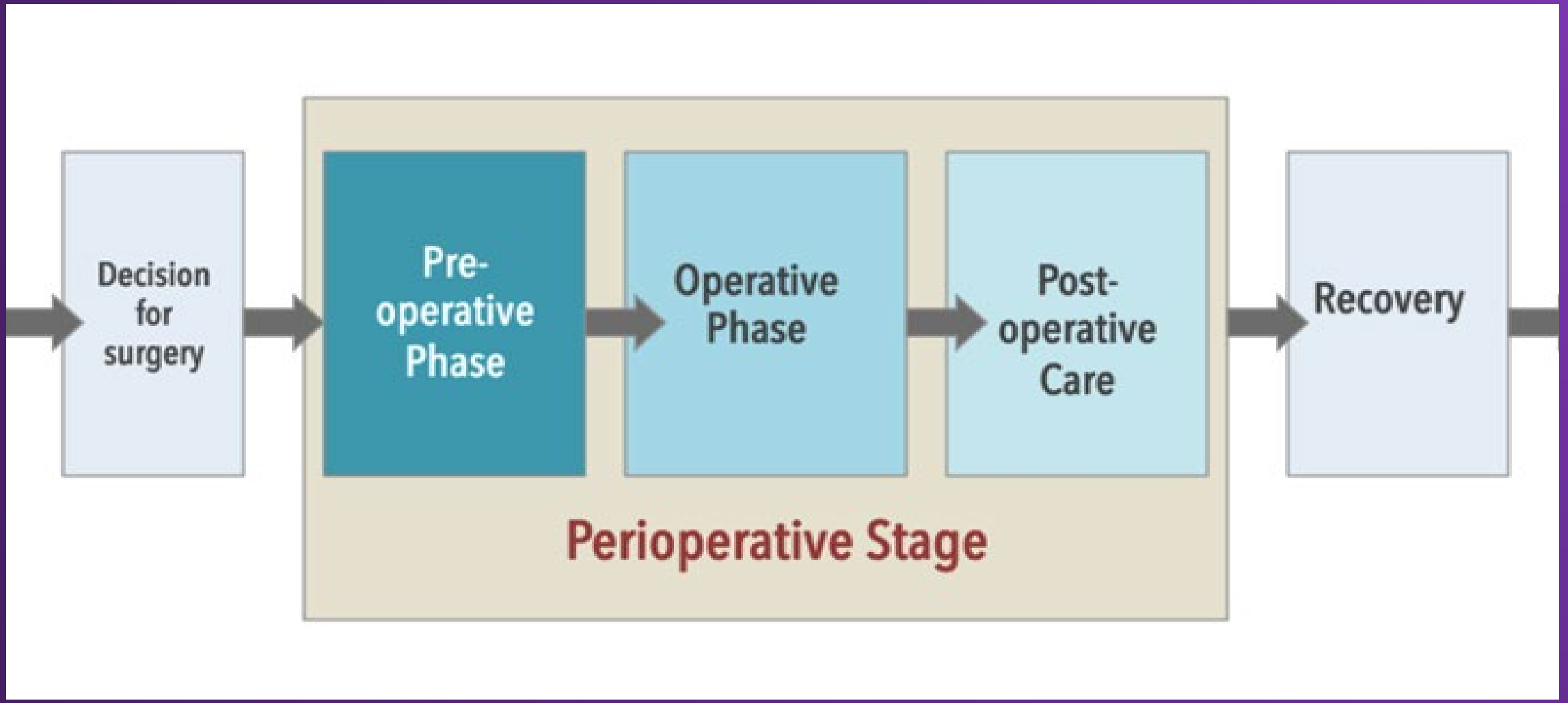
- Periop Mobile Learning System (PeriopMLS) includes mobile applications and research whose purpose is to improve coordination on the day of surgery by:
  - Improving individual workflows
  - Resolving system issues through data sharing and access
  - Changing staff behavior through improved learning

Research Questions

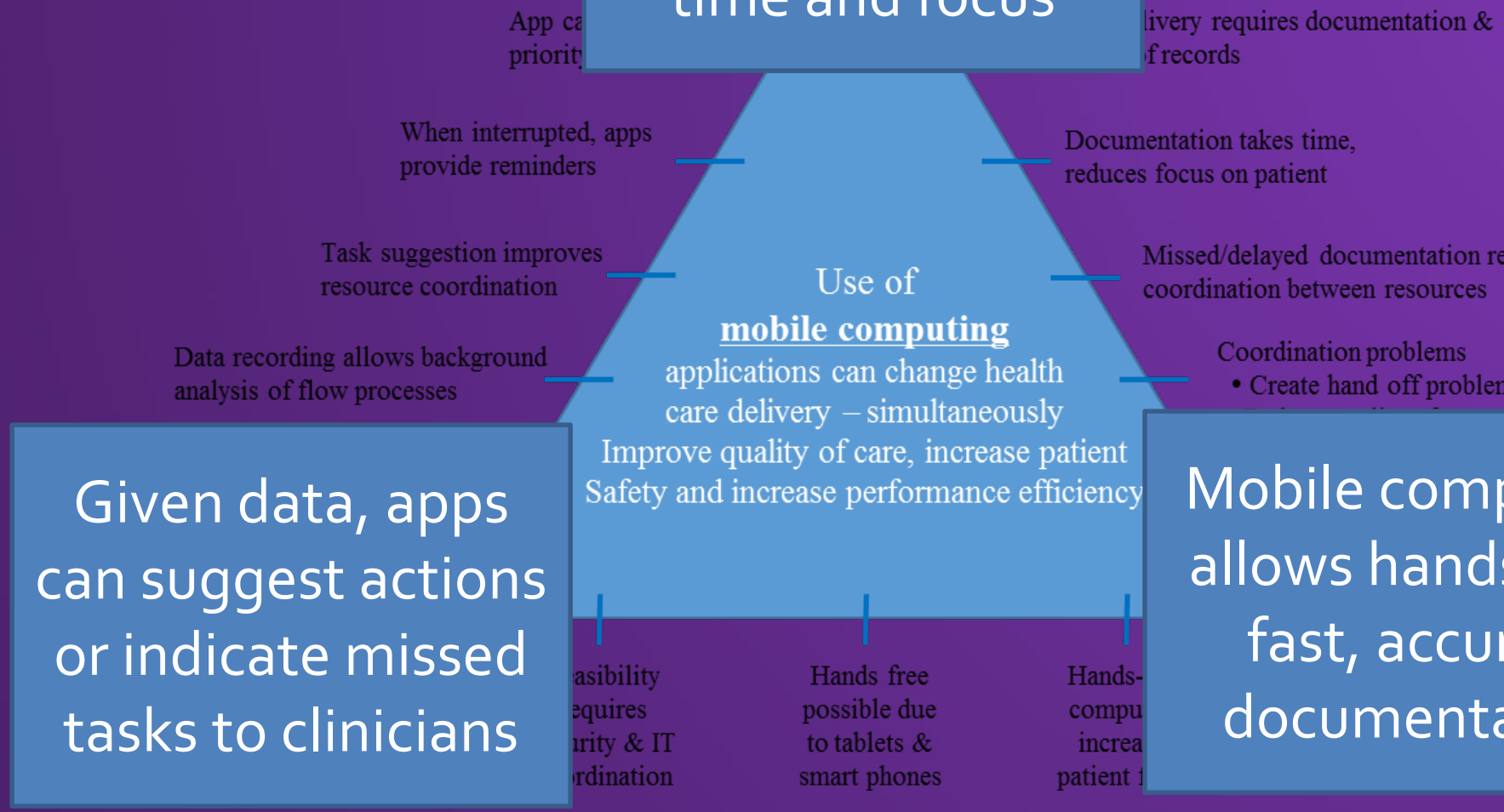
- Objective 1
  - How to use mobile devices in Perioperative Services (Periop) to increase communication and coordination?
- Objective 2
  - How to learn from data gathered using the mobile app?
- Objective 3
  - How to use training to obtain human change?

Periop View – Day of Surgery



Mobile Computing in Periop

Clinicians face competing priorities for their time and focus



Given data, apps can suggest actions or indicate missed tasks to clinicians

Mobile computing allows hands free, fast, accurate documentation

Steps of App Development Process

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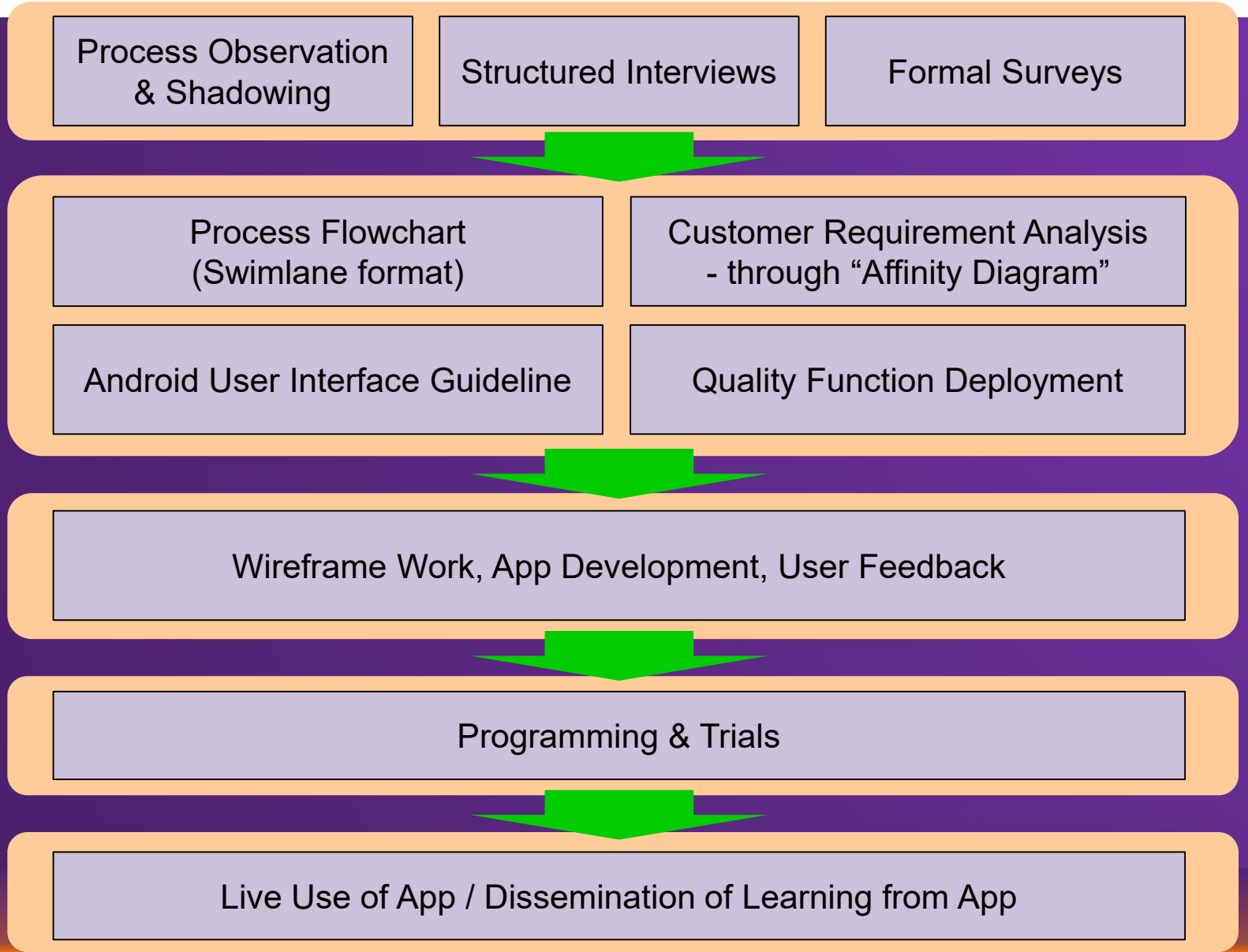

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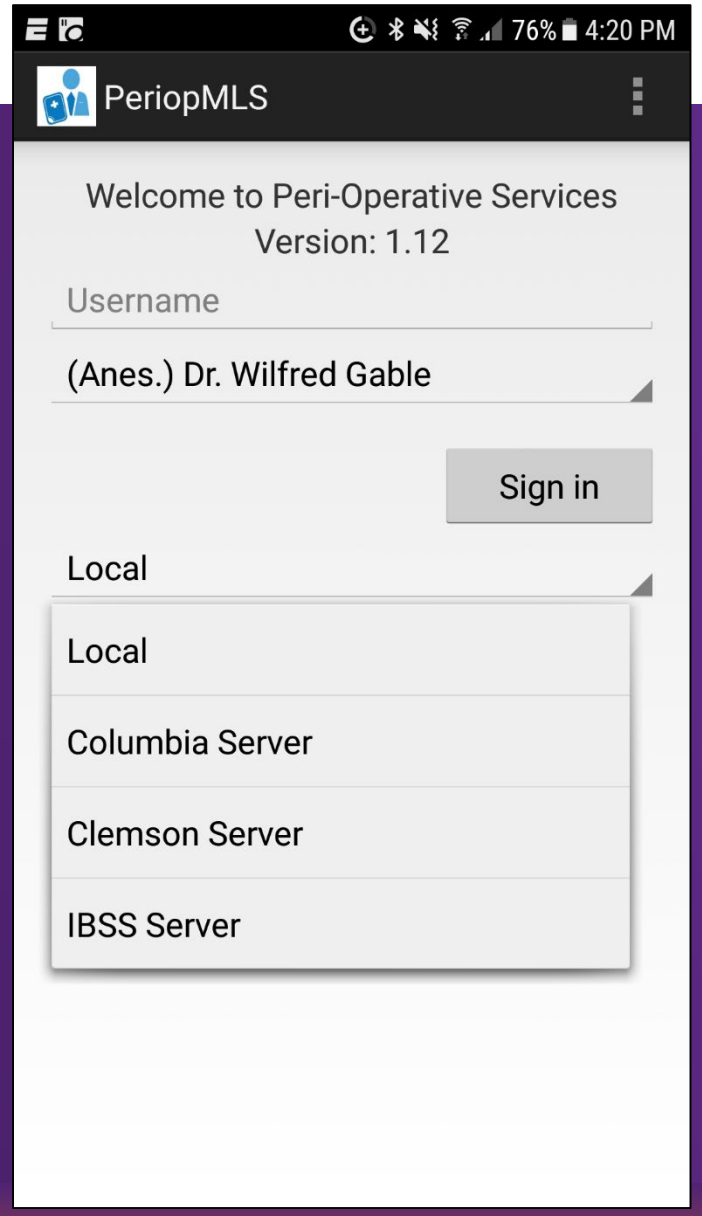
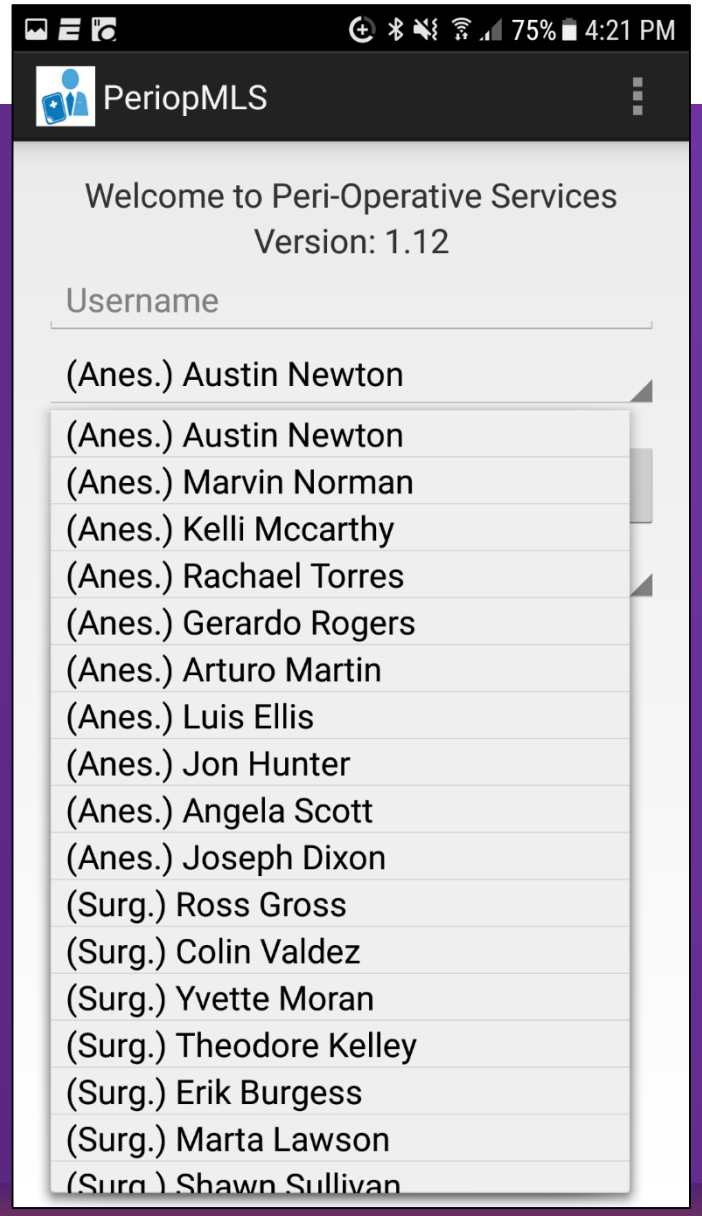
PERIOPMLS APP VIDEO

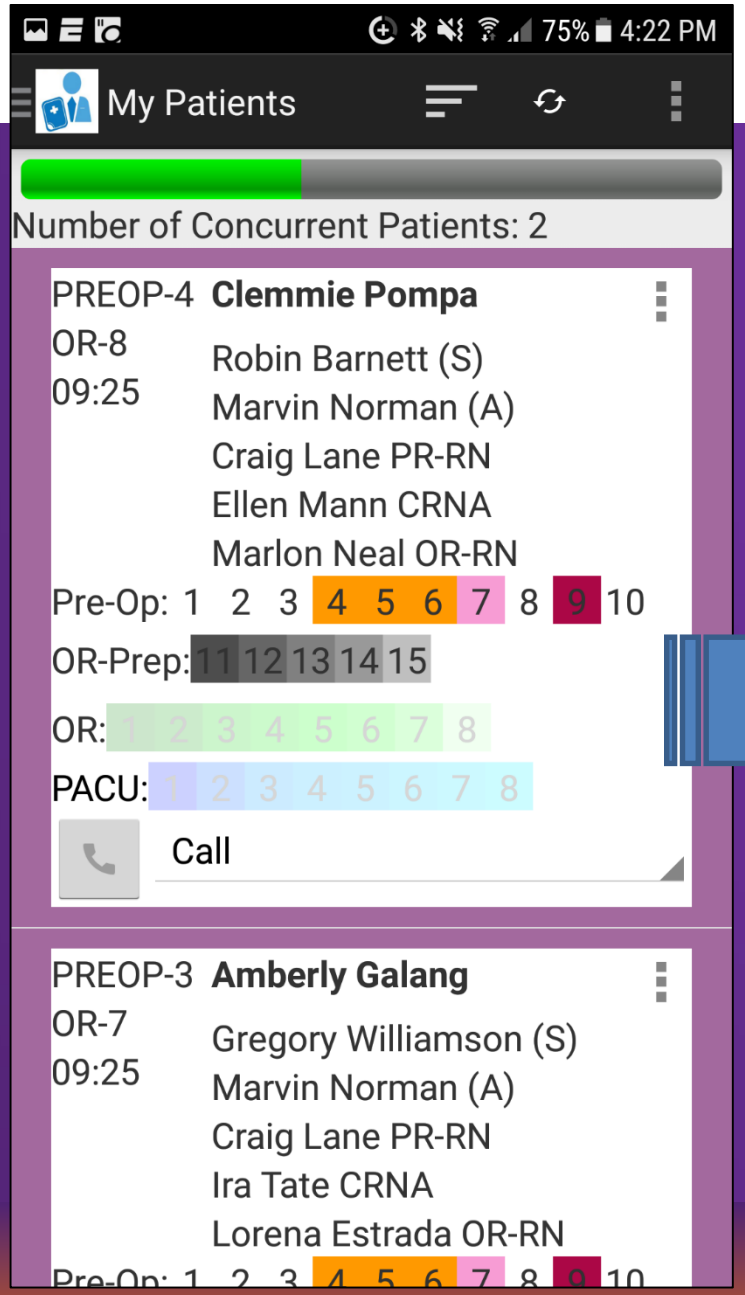
PERIOPMLS APP FUNCTIONS

PeriopMLS App – Login





PeriopMLS App – My Patients



PeriopMLS App – Preop Checklist

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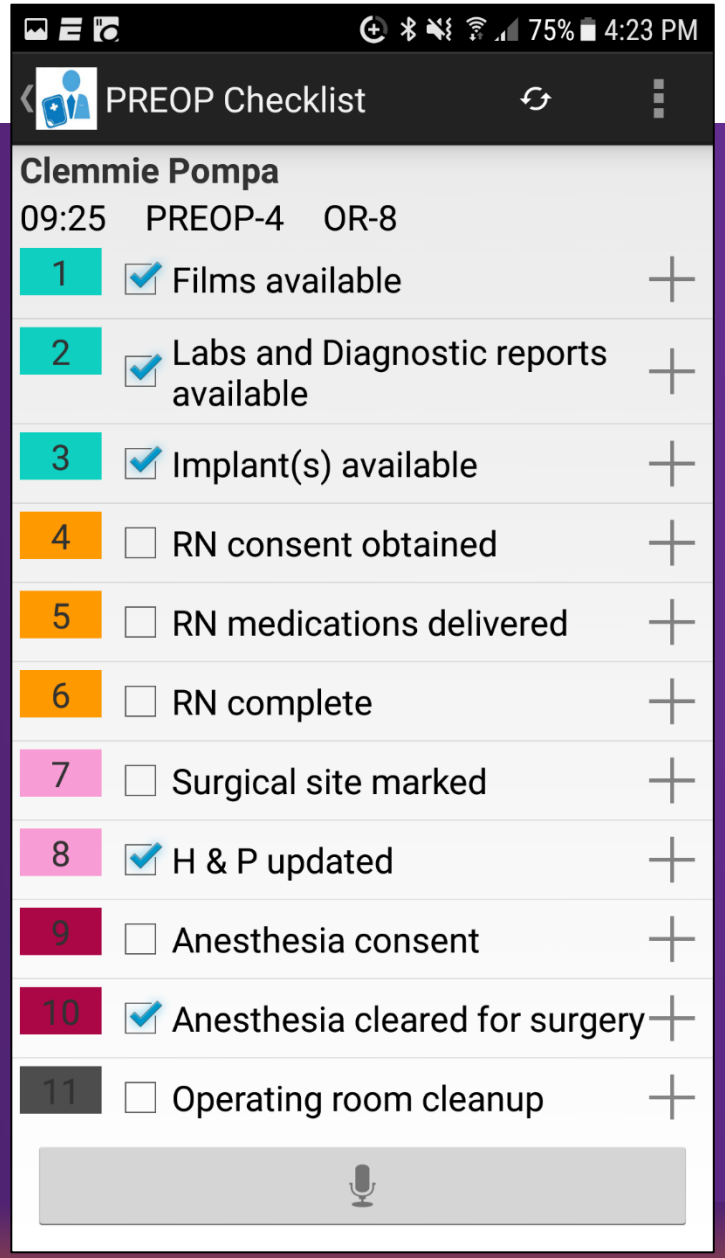

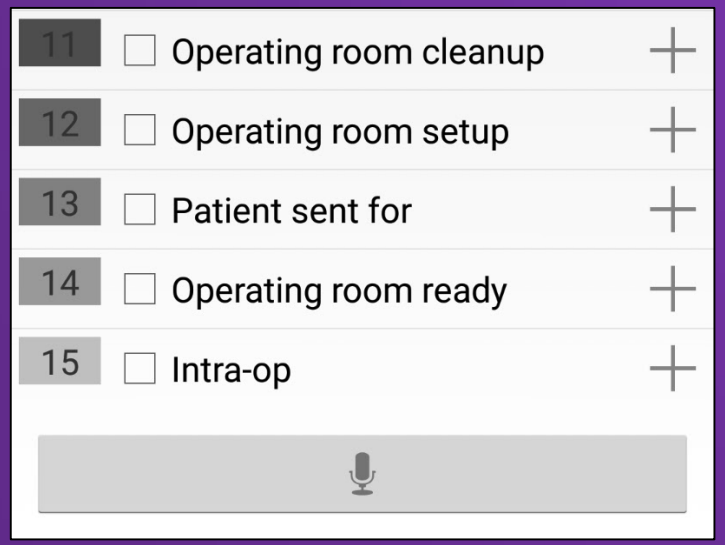

PeriopMLS App – OR / PACU Checklists

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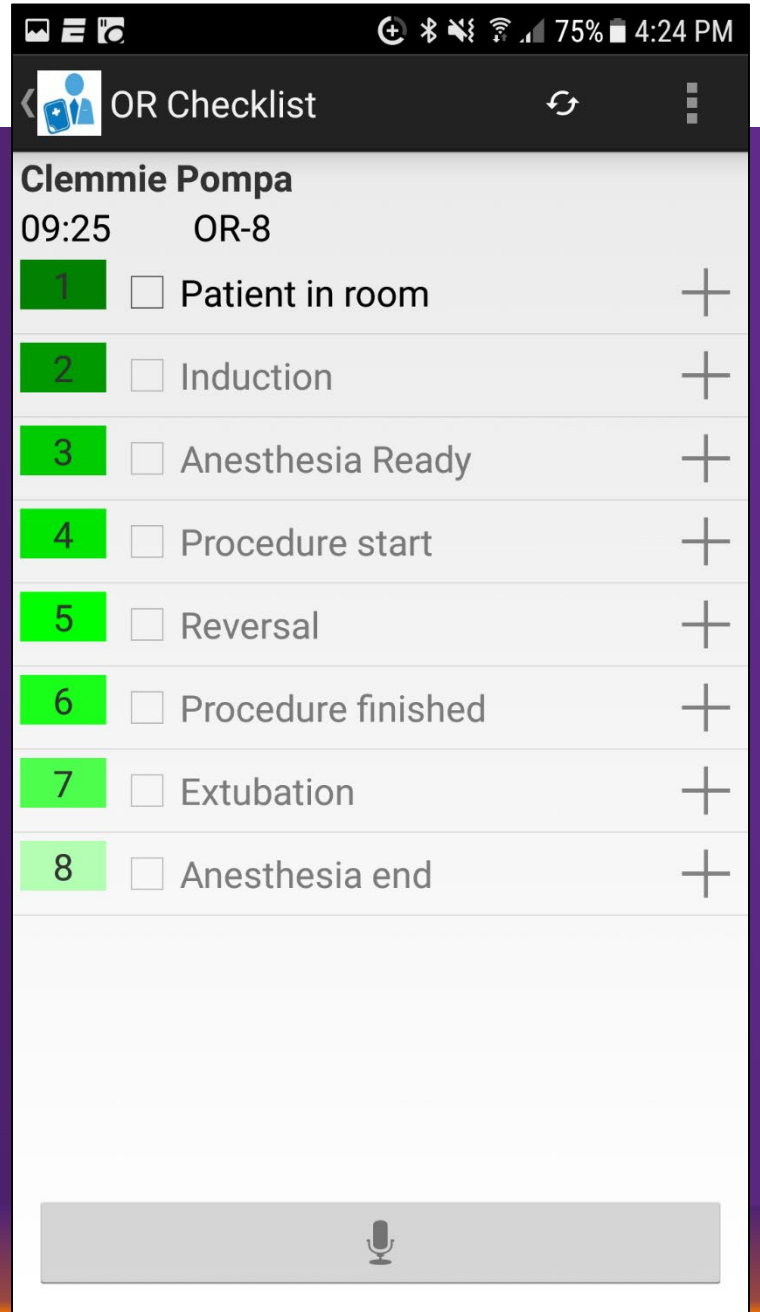

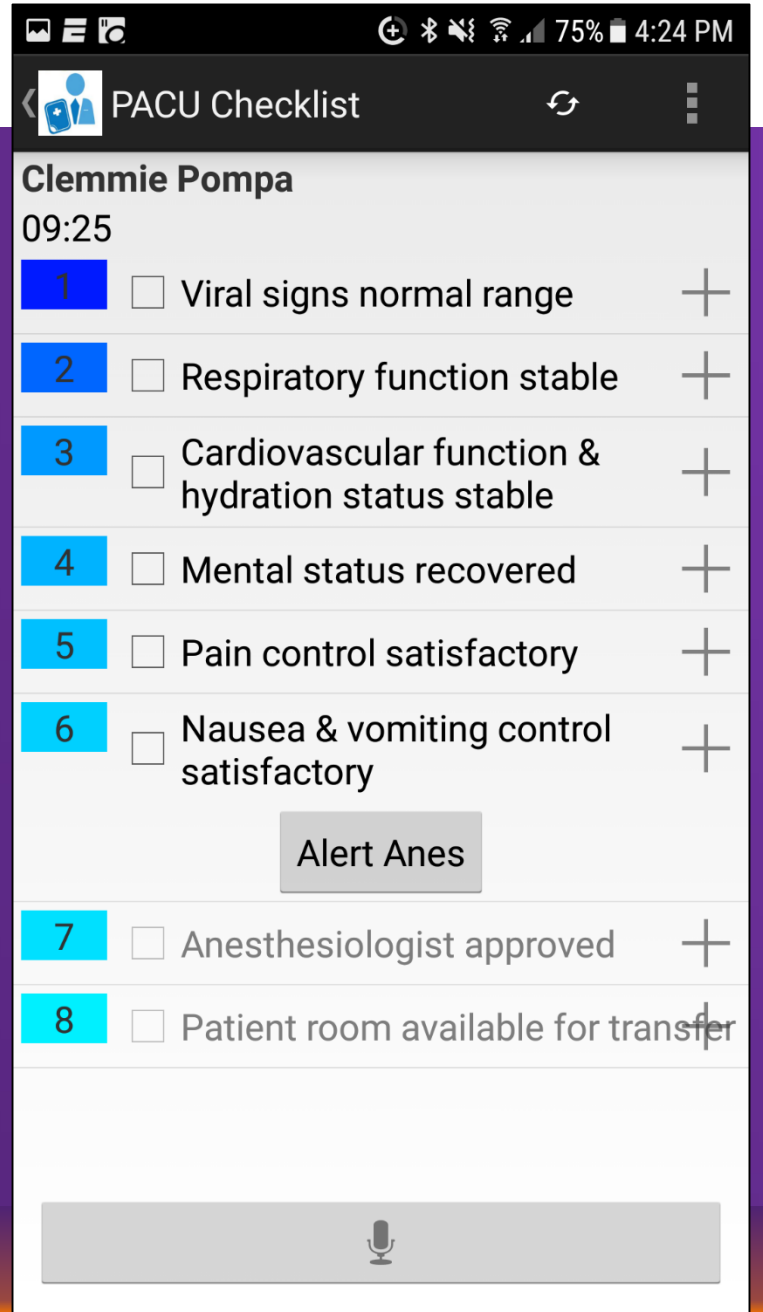

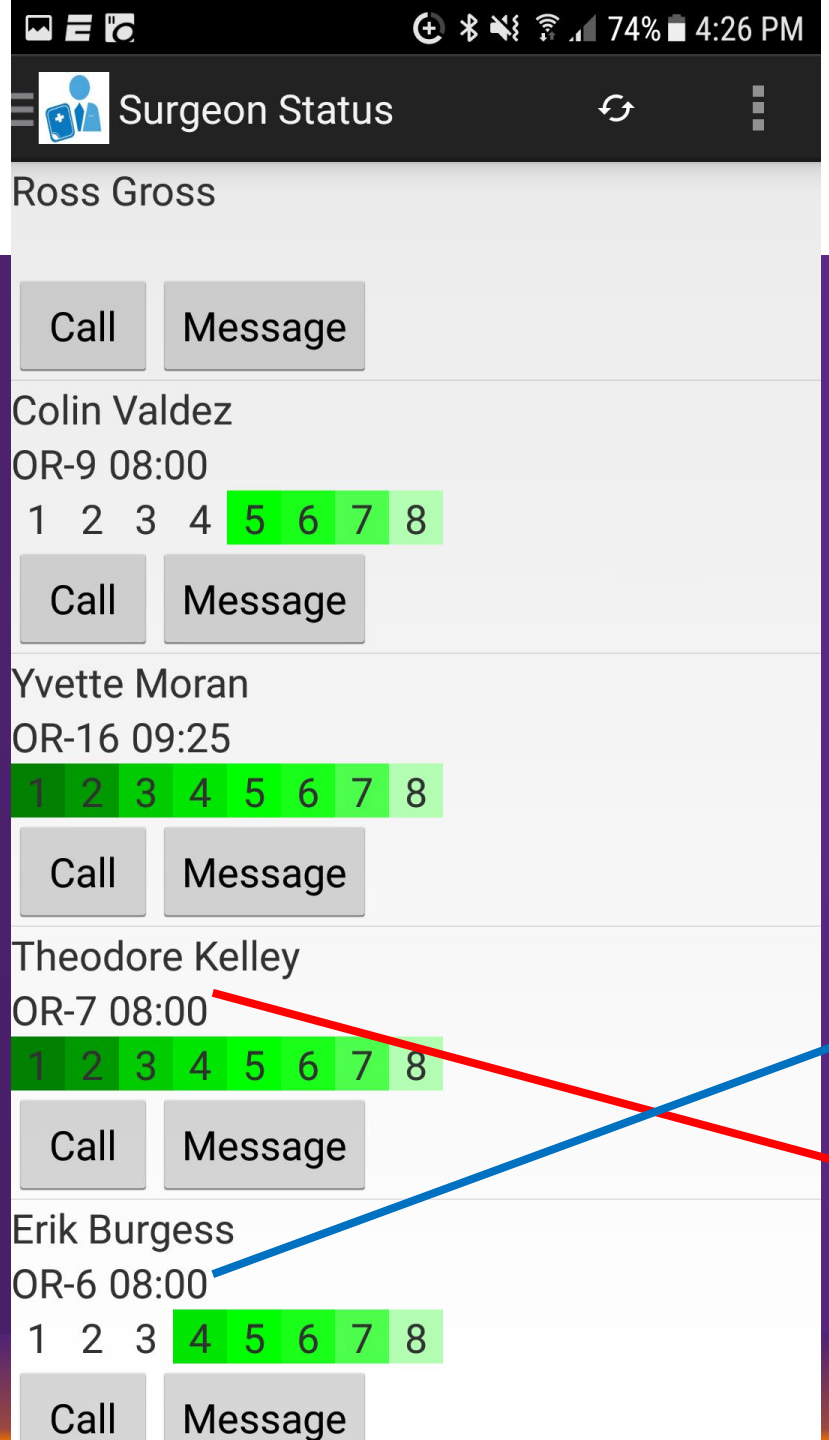

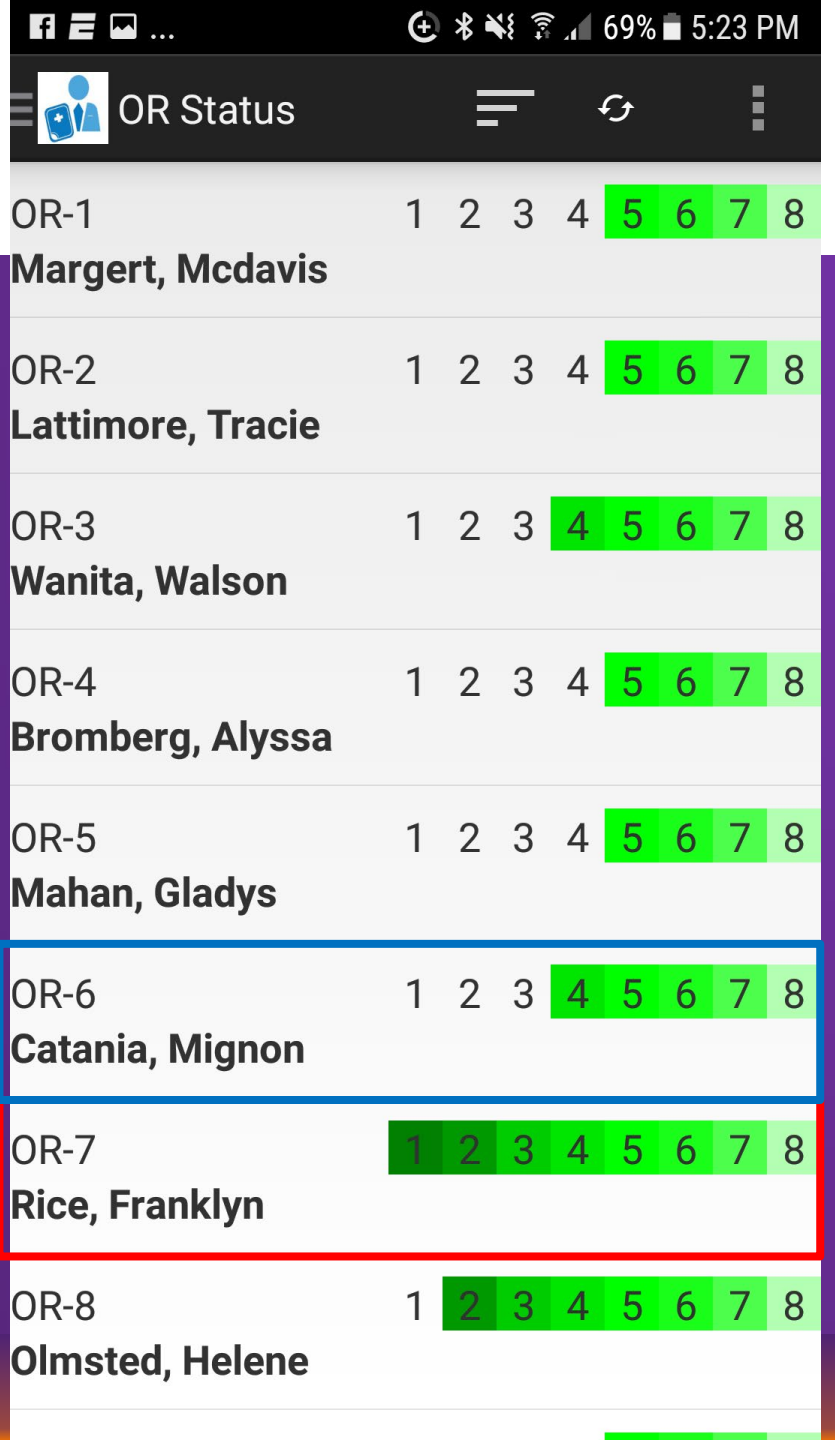

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Where do we go from here?

- Testing the app in a live environment is not an option for our healthcare partner
- Obtaining relevant feedback on app use and design is critical
- Create realistic scenarios that allow staff to
  - Feel as if they are experiencing an actual day of surgery
  - Comment on information being displayed on status boards
  - Communicate/coordinate with others through the proposed app
- The app should serve anesthesiologists, core managers, CRNAs, nurses, surgeons, …
- Employ a simulation model of the day of surgery…

Simulation-based Training / Mobile Computing

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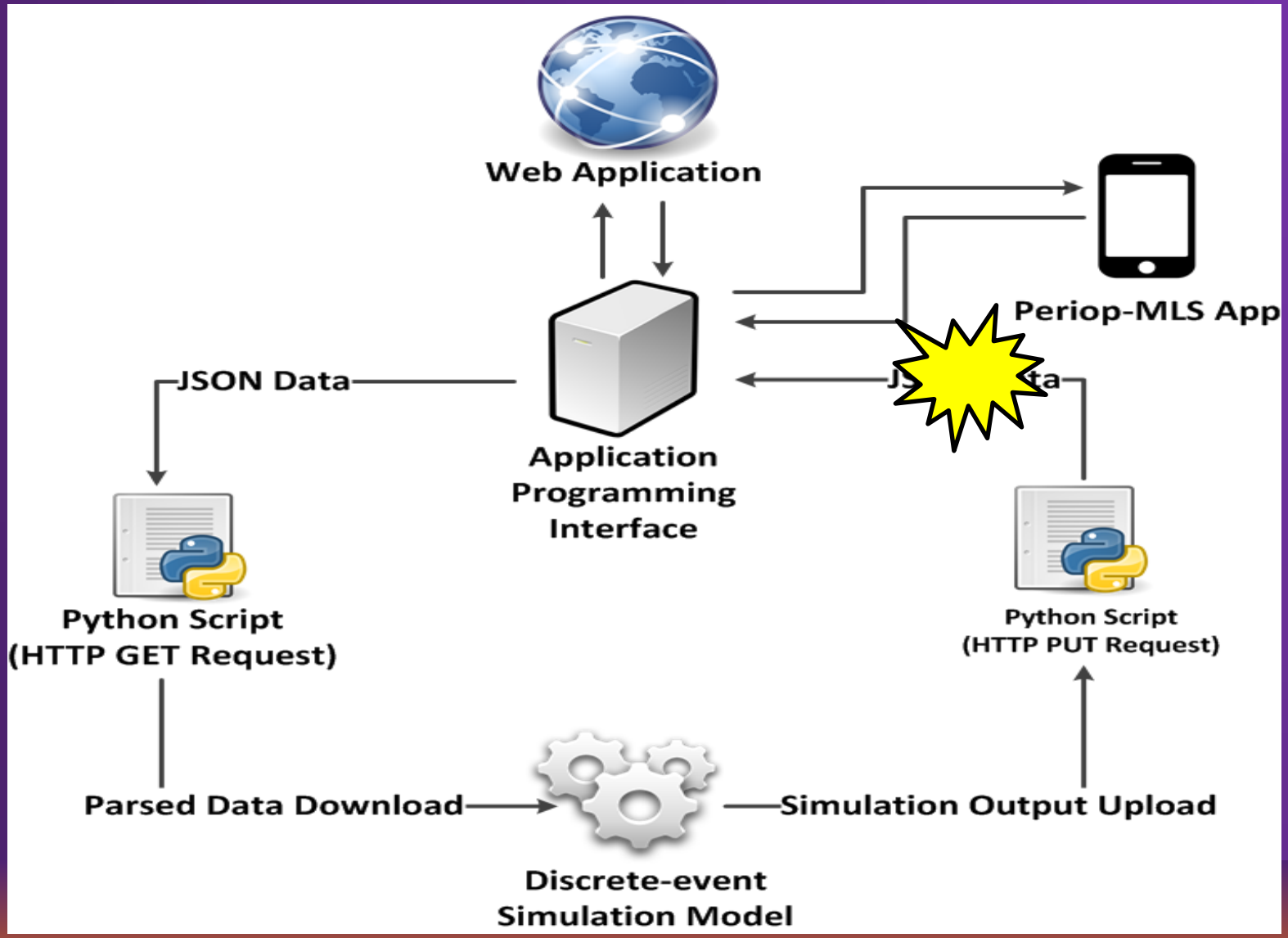
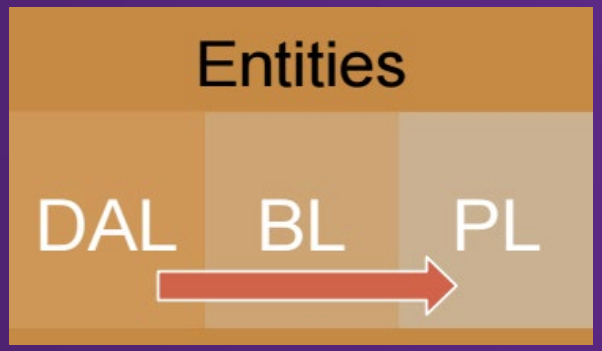
- Learn skills, gain knowledge and develop attitudes by emulating real-world interactive experiences [Lateef F., 2010]
- Deliver improved training to healthcare professionals, allowing them to better understand the effects of poor coordination and handoffs.
- Mobile computing allows multiple users to interact with the virtual system!

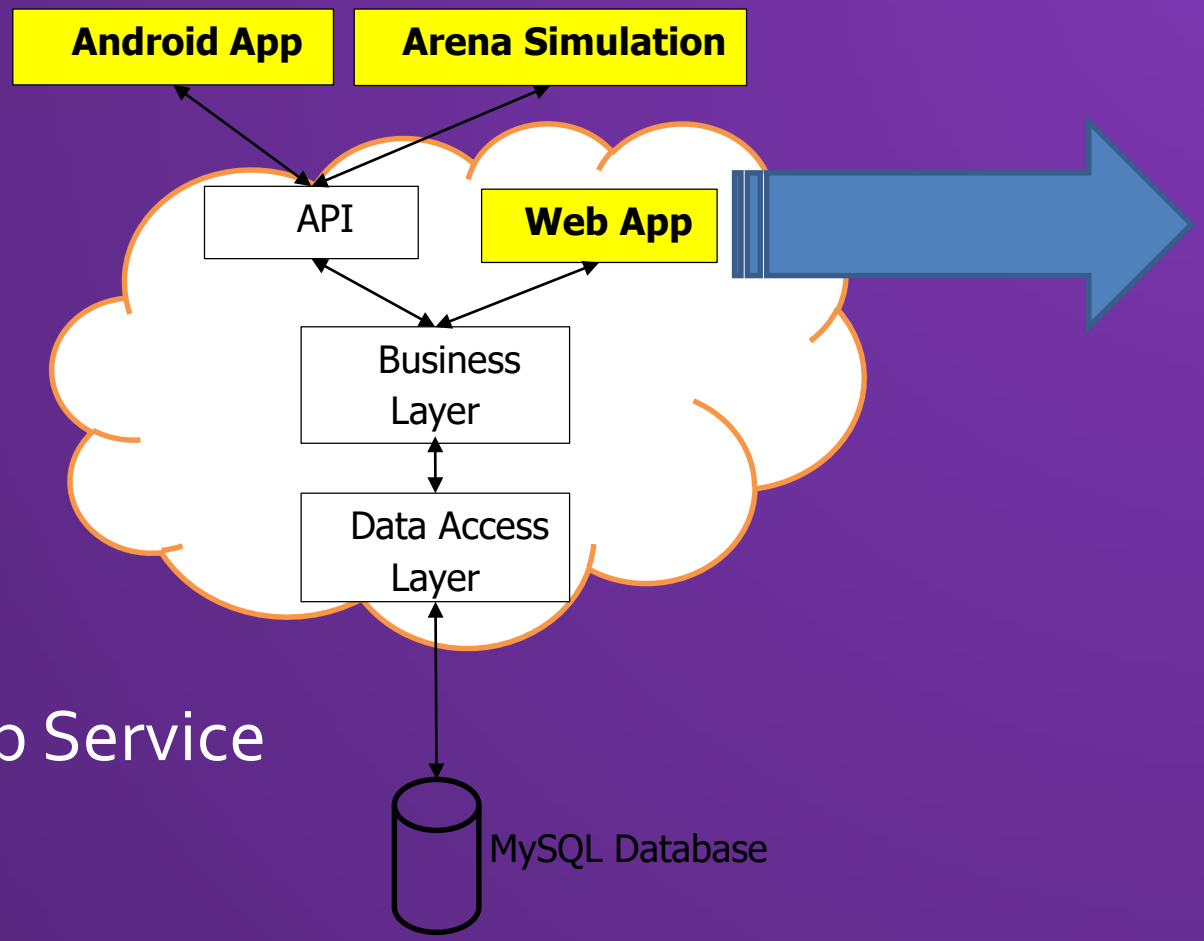
Simulating the Environment



An Improved Design…

- API and Web App are part of the same application
- Four-tier architecture





- Arena connects directly to the Web Service
  - Avoids read/write issues of text files
  - Avoids complex ADO.NET access to a database

Web Application

Periop MLS | Patient View | Phase View | Staff View | Hello Ross Gross | Log out

Patient Task List

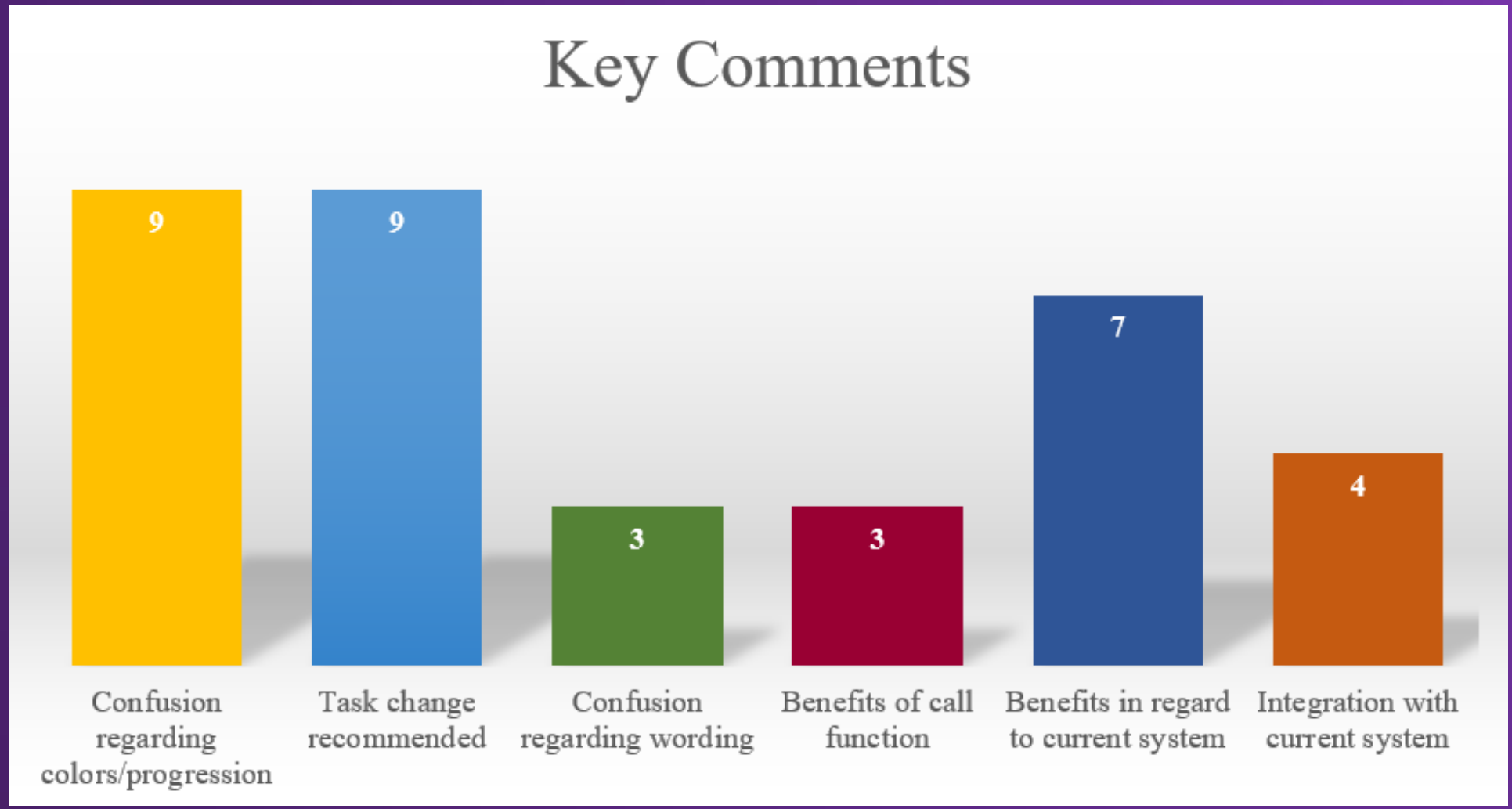
Active Patients

ID	Name	Type	Pre-Op		OR		PACU	SST	PIR	PST
1	Mcdavis Margert	AM	14		1			08:00	07:35	07:47
18	Lashawn Mercado	AM	18		1			09:25	N.A	N.A
2	Tracie Lattimore	AM	9		2			08:00	07:27	07:55
19	Elias Solt	AM	20		2			09:25	N.A	N.A
3	Walson Wanita	AM	5		3			08:00	07:16	N.A
20	Georgianna Sjogren	AM	19		3			09:25	N.A	N.A
4	Alyssa Bromberg	AM	1		4			08:00	07:18	07:39
21	Erna Clavette	AM	7		4			09:25	N.A	N.A
5	Gladys Mahan	AM	4		5			08:00	07:19	07:50
22	Carole Cureton	AM	21		5			09:25	N.A	N.A
6	Mignon Catania	AM	6		6			08:00	07:26	N.A
23	Dorthey Mahler	OP	5		6			09:25	N.A	N.A
7	Franklyn Rice	AM	8		7			08:00	N.A	N.A
24	Amberly Galang	OP	3		7			09:25	N.A	N.A
8	Helene Olmsted	AM	3		8			08:00	07:52	N.A
25	Clemmie Pompa	OP	4		8			09:25	N.A	N.A

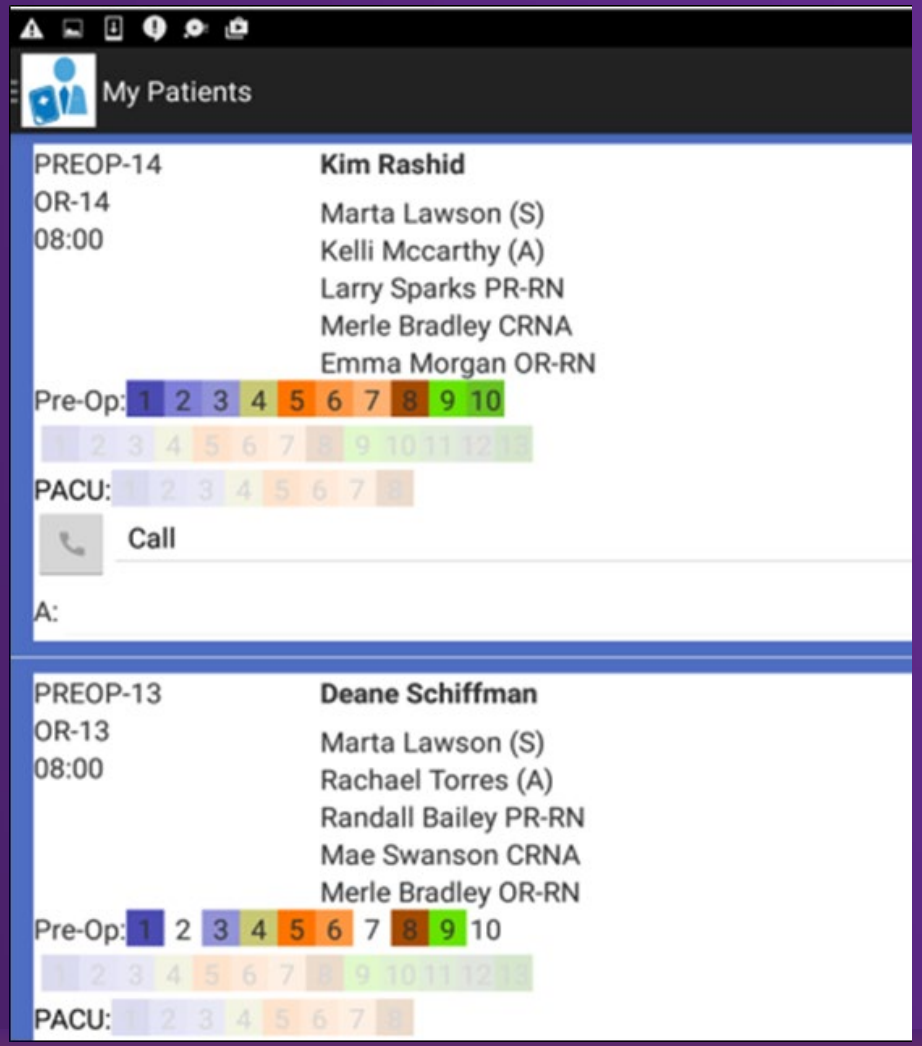
Sample Script – Preop RN

- Current simulated time is 6:00am
  - Craig Lane (Preop RN) is the assigned nurse for Preop rooms 3 and 4. Craig wants to know who his patients are, and which room each patient is in. He then wants to know the tasks to complete for his patients. Who else must complete tasks for the patient(s) before they are ready for the OR?
  - Patricia Kreiger is scheduled for surgery at 8:00am. Items done: consent form, films available, implants available, lab reports, and family members ready to talk. Craig Lane (Preop RN) must update these within the app
- Advance simulated time to 7:00am…
  - All Preop tasks for Patrica Kreiger (patient) are now finished; she is ready to be sent to the OR. However, Craig Lane (Preop RN) wants to know if the assigned OR is ready, who is the CRNA. Craig Lane needs to tell the CRNA that the patient is ready.
  - Notice the dashboard display for cases starting early/on-time/late. Can you determine which cases are in jeopardy of starting late?

Feedback from Staff…



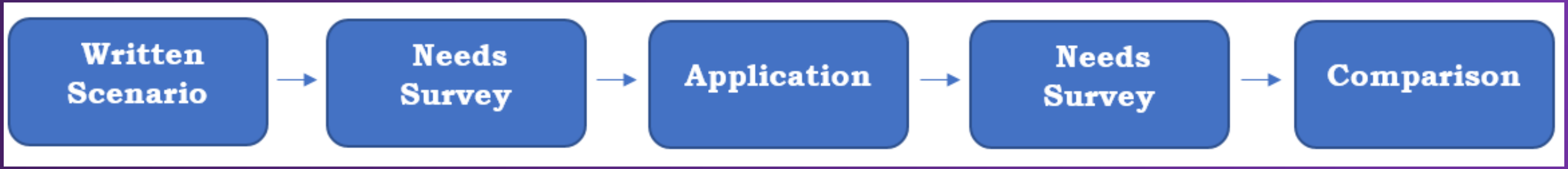
Changes made from feedback



User Testing

- Fall 2017 – Spring 2018
- Tabletop exercises integrating the mobile app, web-based visual dashboard, and discrete event simulation
- Specific scenarios designed to determine whether or not the mobile app provides for increased communication and coordination
  - Lab tests
  - Missing consent form
  - H&P updated

User Testing



Results

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"Very beneficial for lab communication"

"Notifications would eliminate guesswork."

Lab Test Survey Questions

Statement	Without App	With App	Difference
I am able to quickly obtain the information regarding the status of patient labs.	2.86	4.14	1.29
The lab status information is readily accessible to me throughout preoperative service.	3.07	4.07	1.00
I have the information I need to complete the patient lab tasks.	3.93	4.00	0.07
The ability to access information supports coordination to complete lab tasks.	3.21	4.07	0.86
Access to lab status information is user friendly.	3.14	4.14	1.00
I have access to patient event data in real time.	3.43	4.14	0.71
Presentation of lab status information is easy to read.	3.71	4.21	0.50
The access to lab status information supports coordination between users.	3.07	4.00	0.93
The access to lab status information supports communication between users.	3.07	4.14	1.07
Overall, I am satisfied with my access to lab status information.	2.71	4.07	1.36

"Seeing who's on the case cuts out three screens for me."

"Cuts down on calls. I really like this feature."

Takeaways

- Even the most experienced nurses don't know exactly when labs are completed
  - Nurses are checking as often as every 5 minutes for the results.
  - This causes unnecessary distraction from other tasks.
- Nurses can provide a voice for change in data management. This tool allows hospital staff a view of performance before rolling out changes in the actual system.
- Key concerns:
  - Notification fatigue
  - IT integration with other patient and hospital software

Did we accomplish our goals?

Three main goals:

- Improving individual workflows
- Resolving system issues through data sharing and access
- Changing staff behavior through education and learning

Contributions to literature…

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DIRECT APPLICATIONS

- Fredendall, Taaffe, Huynh, Greenstein, Vidal. "User-Centered Design for a Perioperative Mobile System Application," in prep.
- Uddin, Allen, Huynh, Vidal, Taaffe, Fredendall, Greenstein, 2018. "Improving Operating Room Performance via the Use of Mobile Applications," **mHealth**.
- Allen, Taaffe, Neilley, Busby, 2018. "First Case On-Time Starts Measured by Incision On-Time and No Grace Period: A Case Study of Perioperative Management at a Large Teaching Hospital," **Journal of Healthcare Management**.
- Uddin, Allen, Huynh, Vidal, Taaffe, Fredendall, Greenstein, 2017. "Effectiveness of a Countdown Timer in Reducing OR Turnover Time," **Journal of Mobile Technology in Medicine**.
- Taaffe, Fredendall, Huynh, Franklin, 2015. "Computer Simulation Shows the Effect of Communication on Day of Surgery Patient Flow," **AORN Journal**.

INDIRECT APPLICATIONS

- Taaffe, Pearce, Ritchie, 2018. "Using Kernel Density Estimation to Model Surgical Procedure Duration," **International Transactions in Operational Research**.
- Venkataraman, Fredendall, Taaffe, Huynh, Ritchie, 2018. "An Empirical Examination of Surgical Experience, Block Scheduling, and Costs in Perioperative Services," **Journal of Operations Management**.
- Taaffe, Fredendall, Weiss, 2018. "Managing Service-Specific and Shared Block Sizes when Setting Operating Room Capacity," **Quality Management Journal**.
- Zinouri, Taaffe, Neyens, 2018. "Modeling and Forecasting Daily Surgical Case Volume Using Time Series Analysis," **Health Systems**.

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Project 2

Influential Design Factors on Safety and Performance in the Operating Room?

"RIPCHD.OR" Project (Realizing Improved Patient Care through Human-Centered Design in Operating Rooms)

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Grant Organization

AHRQ

[Agency for Healthcare Research and Quality]

Sponsoring Organizations

CLEMSON UNIVERSITY

MUSC Medical University of South Carolina

A+H CENTER FOR HEALTH FACILITIES DESIGN & TESTING

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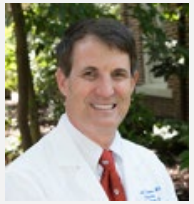

Scott Reeves, MD
Chair, Dept of Anesthesia & PeriOp

Dee San, RN, BSN, MBA
PeriOp Quality & Safety Manager

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Congestion in the operating room!

Research goal

- There is a lack of evidence on the impact of OR design on staff safety and efficiency related performance characteristics.
- Current design guidelines do not quantitatively address the impact of each guideline's setting on OR performance.
- We define a set of efficiency and safety metrics to evaluate performance of the layout.
- ***The goal of this research is to inform the OR design using simulation modeling and examine the relative impact of several room-specific or procedure-specific factors on safety and efficiency.***

Performance metrics

Performance metrics were chosen based on their ability to:

- Quantify system performance with respect to **density/occupancy** and **movement patterns**
- Be reliably tracked in a simulation model

Three performance measures were created:

- Total distance travelled (**TDT**)
  (Gurses et al., 2012; Neyens et al., 2018; W
- Total number of contacts (**TNC**)
  (Thiele et al., 2008; Fraid et al., 2002; Young & O'Regan, 2010; Lynch et al., 2009)
- Total number of transitions near the surgical area (**NTS**)
  (Ehrenwerth, 2011; Rostenberg & Barach, 2012)

Focus on "TNC Only" today!

Note: A contact is recorded when two subjects are within 0.6 meters of each other.

Questions

- Question 1: Can we use computer simulation to measure TNC?
- Question 2: Which factors have an impact on TNC?
- Question 3: What is the relative impact of each factor?

Methodology

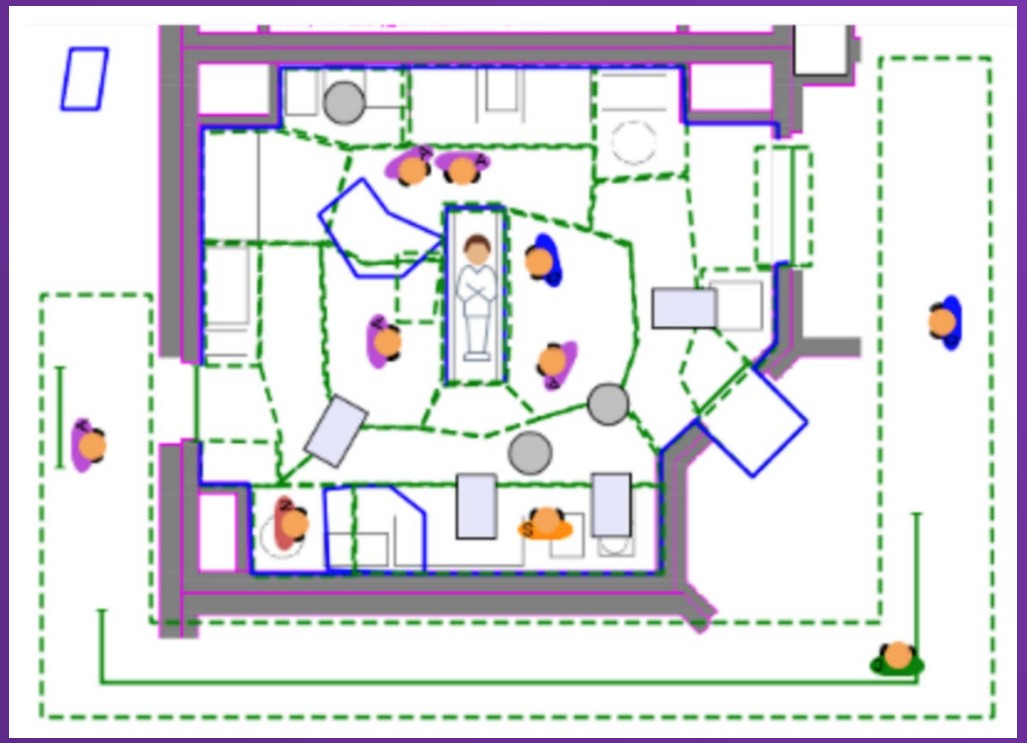
- Video coding of a series of actual surgeries
  - Recorded locations and activities of several key staff in the OR
  - Produced spreadsheets of all movements / activities

- Use agent-based simulation modeling as a decision making methodology

- Focus on five agent types:
  1. Circulating nurse (CN)
  2. Anesthesia team member
  3. Surgeon
  4. Resident
  5. Scrub nurse

Playback model

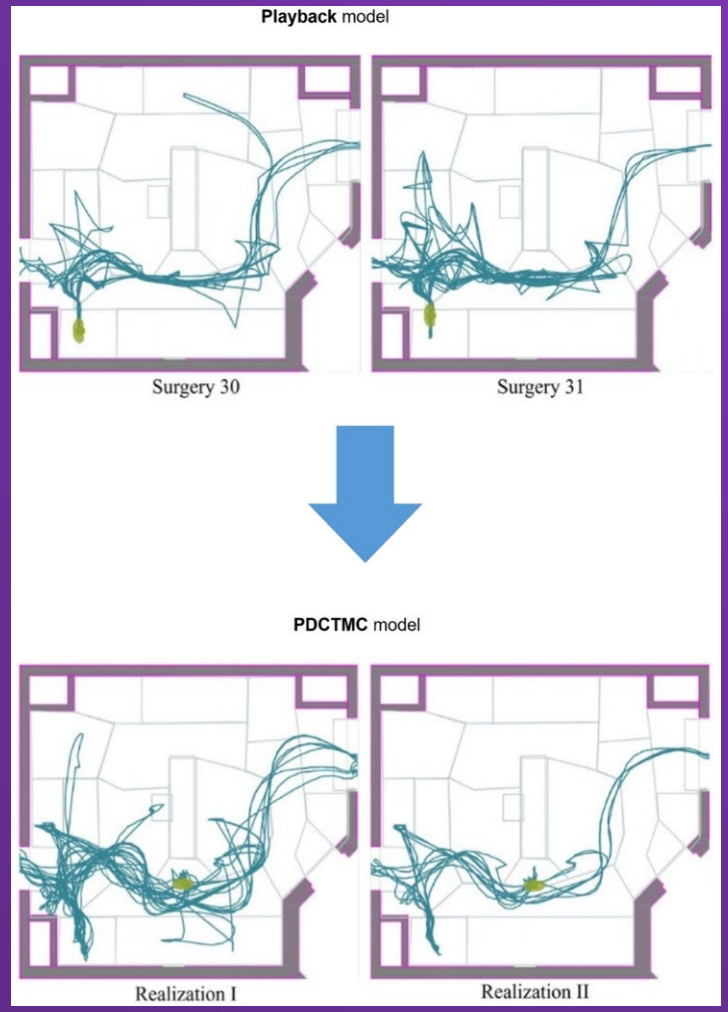
- The software reads data from excel spreadsheets and moves subjects accordingly
- Walls are used in directing the flow of traffic away from specific locations
- Each type has its own color to more easily distinguish between them



The randomized model

- ***Phase-dependent continuous time Markov chain***
  - Preparation, Intra-operative, Post-operative

- Data are used to determine a likelihood of moving between any two destination zones
  - Result – a set of probability transition matrices for each phase and each staff type
  - Dwell times per destination zone are also calculated



Probability Transitions – Intraoperative, Scrub Nurse

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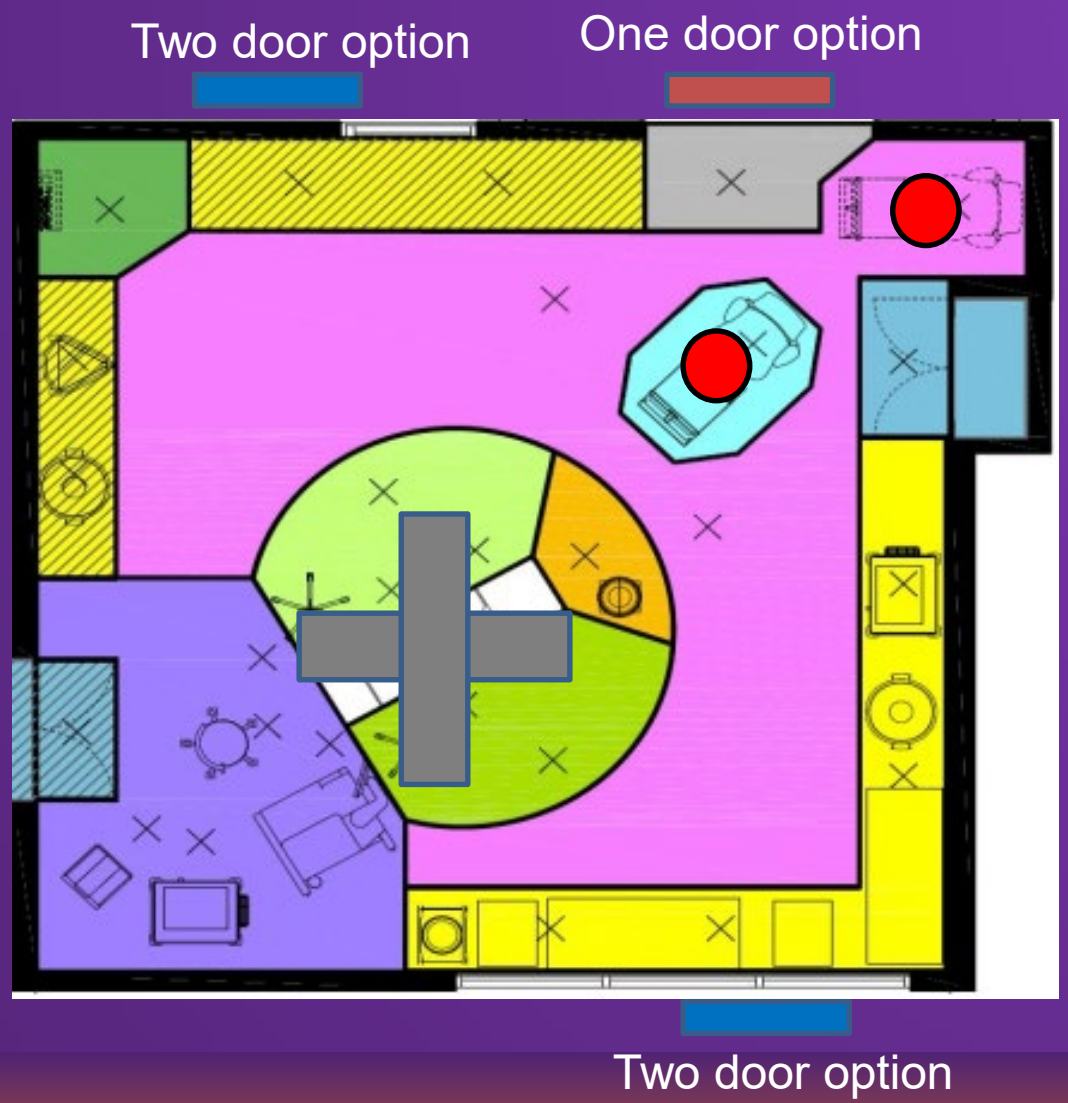
TO

FROM	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Zone 1	0.10	0.3	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0
Zone 2	0.30	0.2	0.0	0.0	0.0	0.2	0.0	0.1	0.2	0.0
Zone 3	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Zone 4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zone 5	0.5	0.1	0.0	0.0	0.3	0.1	0.0	0.0	0.1	0.0
Zone 6	0.3	0.2	0.0	0.0	0.2	0.1	0.0	0.2	0.1	0.0
Zone 7	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zone 8	0.1	0.4	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0
Zone 9	0.3	0.1	0.1	0.0	0.1	0.0	0.0	0.3	0.0	0.0
Zone 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
dwell time (seconds)	**14.0**	**89.4**	**8.1**	**5.0**	**80.3**	**34.2**	**9.6**	**39.6**	**11.5**	**19.1**

Zone-to-zone probability transitions and dwell times per zone

Potential design factors

- Number of staff
  - 5 vs. 7
- Procedure type
  - Pediatric vs. General
- Location of CN workstation
  - Wall vs. Foot of Table
- Table orientation
  - Angled, Vertical, Horizontal
- Room shape
  - Square vs. Rectangle
- Room size
  - Small vs. Medium
- Number of doors
  - 1 vs. 2



Experimental design

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Variable Name	Abbreviation	Level 1	Level 2	Level 3	Variable Type
Number of Staff	#Staff	five (n5)	seven (n7)	-	Independent/predictor
Surgery Type	surgType	pediatric (t2)	general (t1)	-	Independent/predictor
CNW Location	CNW	foot of table (f)	beside the wall (w)	-	Independent/predictor
Table Orientation	table	vertical (v)	angled (a)	Horizontal (h)	Independent/predictor
Shape	shape	rectangular (r)	square (s)	-	Independent/predictor
Size	size	small (s)	medium (m)	-	Independent/predictor
Number of Doors	door	one door (1d)	two doors (2d)	-	Independent/predictor
Total number of contacts	***TNC***	***192 scenarios modeled***			***Dependent/response***

Top/Bottom 10 scenarios (based on TNC metric)

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Ranked Scenario	size	shape	table	door	Surg Type	#Staff	CNW	TNC (per hour)	Confidence Interval
1	s	r	v	1d	t2	n7	f	68.4	(64.9-71.9)
2	s	r	v	2d	t2	n7	f	68.2	(64.7-71.8)
3	s	r	h	1d	t2	n7	f	67.7	(64.5-71)
4	s	r	a	1d	t2	n7	f	64.5	(61.5-67.5)
5	s	r	a	2d	t2	n7	f	60.6	(57.5-63.8)
6	s	s	a	1d	t2	n7	f	60.0	(57.2-62.7)
7	s	r	v	1d	t2	n7	w	59.9	(56.7-63.1)
8	s	s	h	1d	t2	n7	f	59.4	(56-62.9)
9	s	s	v	2d	t2	n7	f	59.3	(55.8-62.7)
10	s	s	v	1d	t2	n7	f	59.2	(56.6-61.9)

Ranked Scenario	size	shape	table	door	Surg Type	#Staff	CNW	TNC (per hour)	Confidence Interval
183	m	r	a	1d	t1	n5	w	12.2	(11.3-13)
184	m	s	a	1d	t1	n5	w	12.0	(11.1-12.9)
185	m	s	a	1d	t1	n5	f	11.9	(11.1-12.7)
186	m	s	h	2d	t1	n5	w	11.3	(10.6-12)
187	m	r	h	1d	t1	n5	w	11.1	(10.3-11.8)
188	m	r	v	1d	t1	n5	w	11.0	(10.2-11.8)
189	m	s	v	2d	t1	n5	w	10.9	(10.2-11.7)
190	m	s	h	1d	t1	n5	w	10.3	(9.65-10.09)
191	m	r	h	2d	t1	n5	w	10.2	(9.4-10.09)
192	m	r	a	2d	t1	n5	W	9.1	(8.23-9.91)

- For the highest 10 values of total number of contacts:
  - Room size is always small
  - Surgery type is always pediatric
  - Number of staff is always 7
  - CN workstation is typically located at the foot of the table
- For the lowest 10 values of total number of contacts:
  - Room size is always medium
  - Surgery type is always general
  - Number of staff is always 5
  - CN workstation is typically located beside the wall

Descriptive results: Density table of TNC ~ given factors

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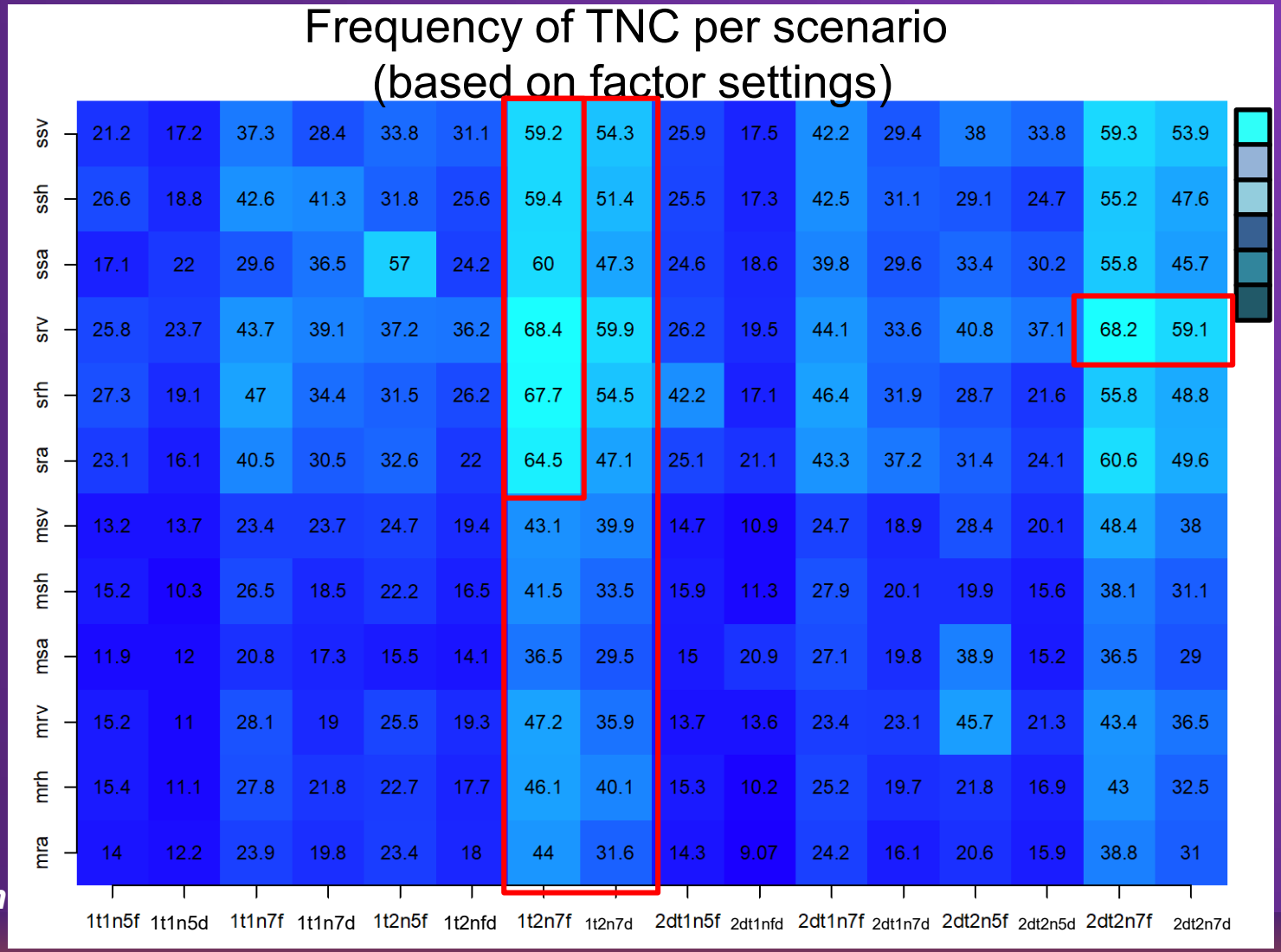
- Each square shows the **average TNC** for a single scenario (seven factors).
- The red rectangle represents
  - single door
  - pediatric surgery
  - 7 staff members
- Now consider a smaller rectangle
  - single door
  - pediatric surgery
  - 7 staff members
  - *CNW at foot of table*
  - *Small room size*
- Consider a third rectangle…now we have:
  - Pediatric surgery, 7 staff members, small room size, but…
  - Two doors instead of one
- What does all of this mean?
  - ***You cannot isolate one factor and claim it results in a higher TNC by itself…***



Predictive results: "Total # Contacts" Regression model

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predictor	coefficients	p-value
(Intercept)	12.00	<2e-16 ***
size-s	13.13	<2e-16 ***
shape-s	-1.50	<2e-16 ***
table-h	1.03	<2e-16 ***
table-v	3.37	<2e-16 ***
numberStaff-n7	16.37	<2e-16 ***
surgType-t2	13.00	<2e-16 ***
CNW-w	-6.99	<2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9.137 on 11324 degrees of freedom
Multiple R-squared: 0.667,Adjusted R-squared: 0.6668
F-statistic: 3240 on 7 and 11324 DF, p-value: < 2.2e-16

- TNC is negatively correlated with size.
- Number of staff appears to be positively related with TNC.
- CNW beside the wall has a negative relationship with TNC.
- Both horizontal / vertical table orientations result in positive relationships with TNC. Thus, an angled orientation might lead to fewer contacts than the other orientations

Answers?

- Question 1: Can we use computer simulation to measure TNC?
  - YES
- Question 2: Which factors have an impact on TNC?
  - SEVERAL, SOME AS EXPECTED, BUT OTHERS LIKE TABLE ORIENTATION LESS OBVIOUS
- Question 3: Can we identify a relative impact of each factor?
  - # STAFF, ROOM SIZE, LOCATION OF CN WORKSTATION, and SURGERY TYPE INFLUENCE TNC MORE THAN BED ORIENTATION AND ROOM SHAPE

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THANK YOU!

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