Social network analysis of surgical team behaviors

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Overview

- Teamwork in high-risk medical environments
- Two models for teamwork
- Capturing adaptive team processes
- Case study in paediatric cardiac surgery
- Conclusions and recommendations

Surgical team behavior and patient outcome

- Previous research: good teamwork associated with shorter duration of operations, fewer adverse events and lower postoperative morbidity
- Effect sizes medium to large (Schmutz & Manser, 2013)

- Some serious incidents in the field of pediatric cardiac surgery have been attributed to poor team processes (Bristol, Winnipeg)

- Drawbacks of previous studies:
  - Link between team processes and patient outcome problematic
  - Observations of teamwork possibly influenced by hindsight bias: cause-and-effect reverse of what most people believe

Some surprising findings[1]

- No association between teamwork and outcome
  - Exception: correlation (inverted U-shape) between surgical cooperation and patient outcome
- No association between teamwork and non-routine events
  - Exception: during cardiopulmonary bypass, positive association between surgical decision making and non-routine events
- Mental and physical preparation beforehand was not predictive at all of patient outcome; questionnaire immediately afterwards on unexpected events and team processes only predicted 30% of the variance in 30-day postoperative outcome

[1] Schraagen et al. (2011). A prospective study of paediatric cardiac surgical microsystems: Assessing the relationships between non-routine events, teamwork and patient outcomes. Br Med J, 20, 599-603

Shared Cognition versus Interactive Team Cognition[1]

- Teamwork is only part of the many contributing factors determining patient outcome (next to complexity, individual technical skills, patient factors and ‘chance’)
- Teamwork is not a monolithic entity, a property that a team either has or does not have: it is highly context-dependent (e.g., depending on the phase of the surgical procedure)
- A team itself is not a monolithic entity: there are differences in the roles various team members play, depending on their specialty (surgeon, anaesthetist, perfusionist, nurse)

[1] Cooke, N.J. et al. (2013). Interactive team cognition. Cognitive Science, 37, 255-285

 

Team model 1	Team model 2
Static team entities (‘leadership’; ‘situation awareness’; ‘decision making’)	Dynamic team processes
Aggregation of individual knowledge	Analysis at the team level
Context-independent	Context-dependent
Better teamwork leads to patient safety (causal I-P-O model)	Better teamwork is an adaptive response whenever patient safety is endangered (emergent model)

Implications for theoretical frameworks and measurement tools

- Medical teams consist of heterogeneous team members, and their individual knowledge cannot be aggregated to arrive at shared cognition (Cooke et al., 2013)

- Team cognition should be measured and studied at the team level: Use metrics based on communication flow

- Take context into account when studying medical teamwork: team cognition emerges in response to environmental demands


Current study

- Used Social Network Analysis techniques to study communication and coordination at the team level
- Used complexity of the surgical procedure as important determinant for teamwork in a dynamic environment
- Differentiated between the successive phases in a surgical procedure in order to capture context-dependency
- Looked in particular at high-risk transitional processes at the intersection of two successive phases

Hypotheses

- Complex procedures will need more specialized knowledge and will lead to flatter communication structures than less complex procedures (Ahuja & Carley, 1999)

- High-risk phases during the procedure will result in restricted communication among fewer (more senior) team members (cf. Carley, 1992; Carley & Lin, 1995; Xiao et al., 2003)

- Exploratory: does Social Network Analysis capture important team processes?

Method

Live observations of 40 pediatric cardiac surgery cases in clinical setting

Multi-method

Trained human factors observers

Schraagen, J.M.C. et al., (2010). Assessing and improving teamwork in cardiac surgery. *Quality and Safety in Healthcare*, 19: e29, 1-6.

Example of filled out behavioral marker system

Time	Actor(s)	From actor	To actor	Notech observation	Category	Score	Epoch
12.50	S1-P1	S1	P1	Where are you now? (35 degrees)	SA1	3	4
12.50	P1-S1	P1	S1	35 degrees	SA1	3	4
12.50	S1-P1	S1	P1	Okay we are ready.	SA1	3	4
12.50	S1-A1	S1	A1	Can we come of HLM? (No we wait until we are some over 35.)	MS	4	4
12.50	A1-S1	A1	S1	No we wait until we are some over 35.	MS	4	4
12.52	S1-A1	S1	A1	Now?	SA1	3	4
12.52	A1-S1	A1	S1	Yes	C	3	4
12.53	A1-T1	A1	T1	HLM is stopped.	SA1	3	5
12.53	P1-S1	P1	S1	Lessen input? (Yes if you can stop filling.)	MS	3	5
12.53	S1-P1	S1	P1	Yes if you can stop filling.	MS	3	5
13.02	A1-P1	A1	P1	Protamine is in.	SA1	3	5
13.05	A3-S1	A3	S1	Arterial line is gone for a while	SA1	4	5

Process flow in PCS during the various epochs

Epoch	Process flow	Domain
1	Patient in surgical holding area.Pre-operative events and medication.Patient transported to OR	Transport to OR
2	Patient in OR. Induction of anesthesia, insertion of lines.Preparing for surgery	Pre-surgery/Anesth. induction
3	Incision. Desection. Canulation	Surgery/pre-bypass
4	Go on cardiopulmonary bypass. Identification of structure. Surgical repair	Surgery/bypass
5	Off CPB. Heparine reversed. Hemostasis	Surgery/post bypass
6	Chest closed. Prepare for move and update ICU. Team leaves with patient to ICU	Transport to ICU
7	Arrival at ICU'. Nurses take over. Anesthetist/surgeon inform ICU attending	Handoff

Focus of current study: Epochs 2 to 5

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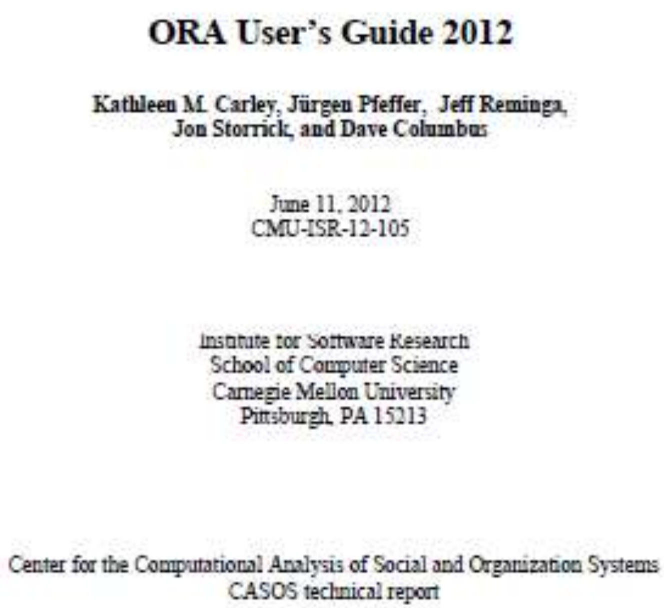
Example of epochs and critical transition periods

Epoch	2	3	4	5
Time (total)	8:15 – 9:51	9:52 – 10:27	10:28 – 12:33	12:34 – 13:40
Time (passage ½)	9:03 – 10:08	10:09 – 11:29	11:30 – 13:06	
Time (passage ¼)	9:27 – 9:59	10:18 – 10:58	12:01 – 12:49	

Social network analysis


ORA User's Guide 2012

Kathleen M. Carley, Jürgen Pfeffer, Jeff Reminga, Jon Storrick, and Dave Columbus

June 11, 2012
CMU-ISR-12-105

Institute for Software Research
School of Computer Science
Carnegie Mellon University
Pittsburgh, PA 15213

Center for the Computational Analysis of Social and Organization Systems
CASOS technical report

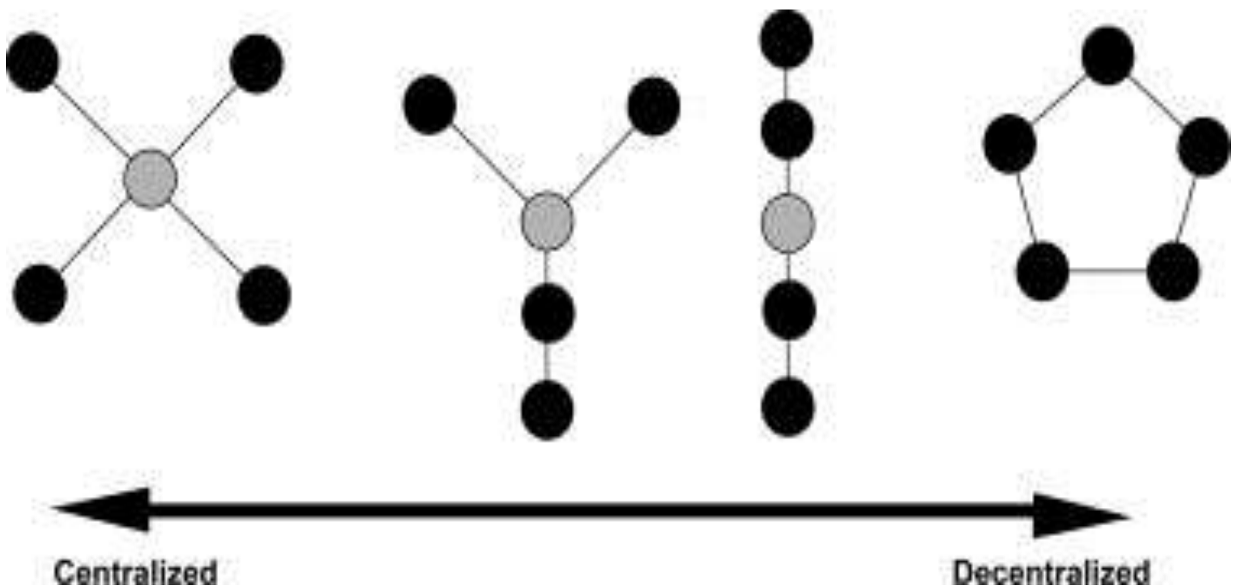
Calculated in ORA (CASOS, Carnegie-Mellon University, Carley et al.)

Compared to teamwork assessment tools:

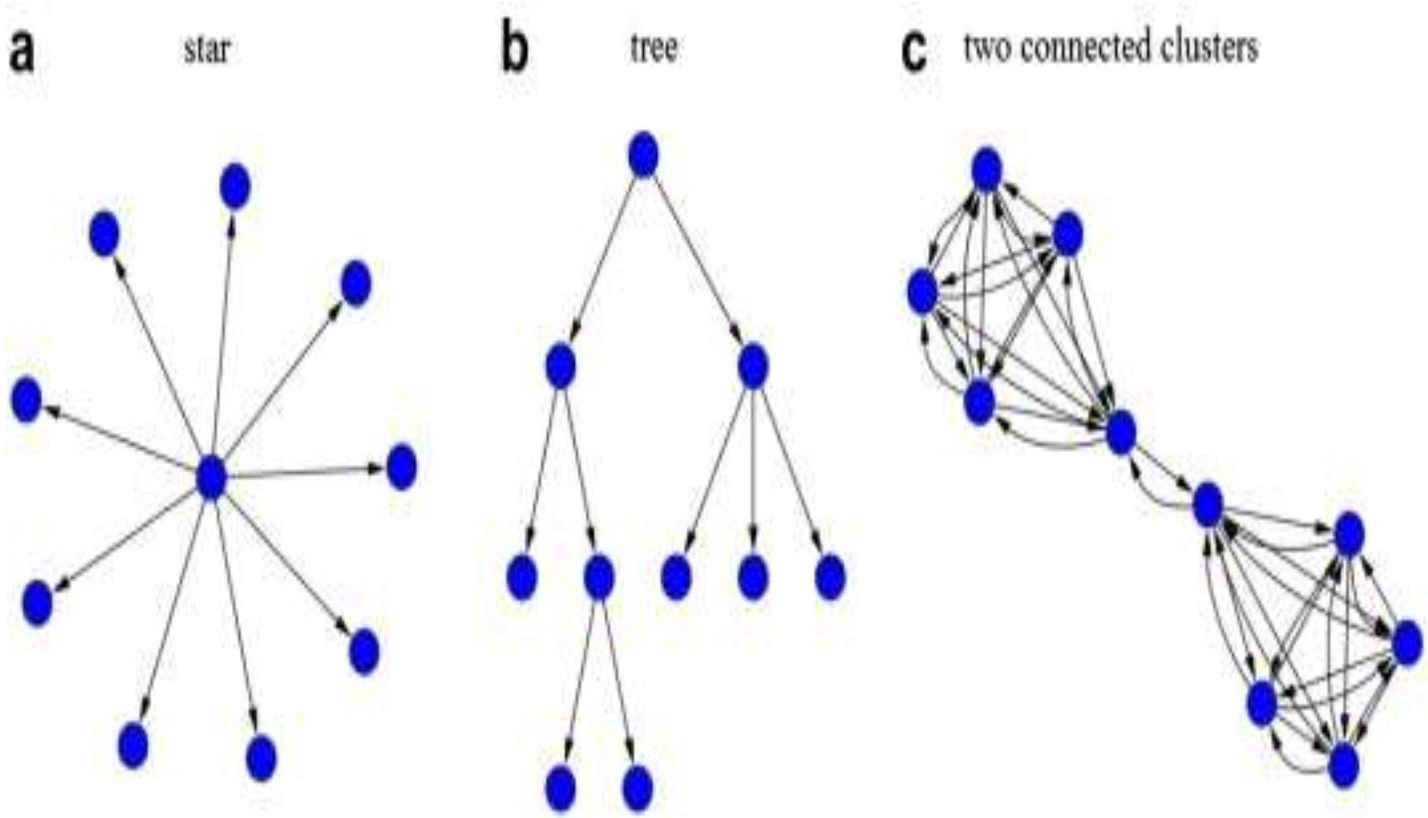
- Allows for more fine-grained analysis, adapted to specific crucial episodes during the surgical procedure
- Quantification across single procedures
- Analysis at the teamwork level

Examples of social network measures

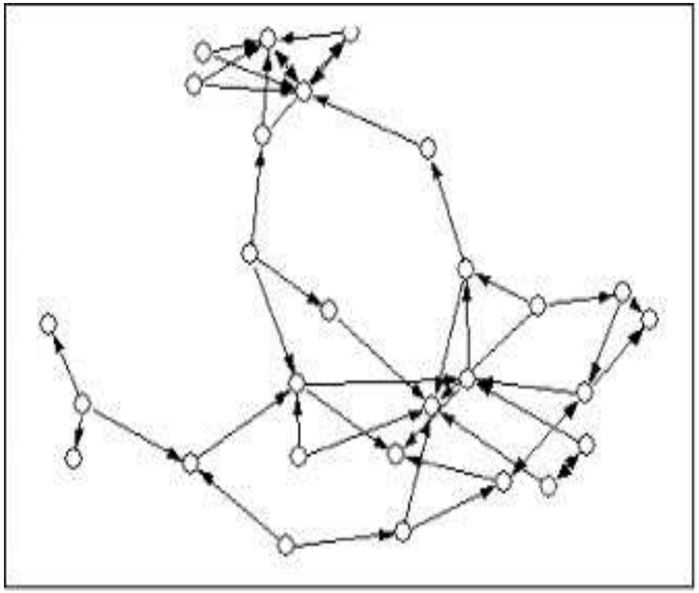
Degree centralization: number of individuals on which communication is based

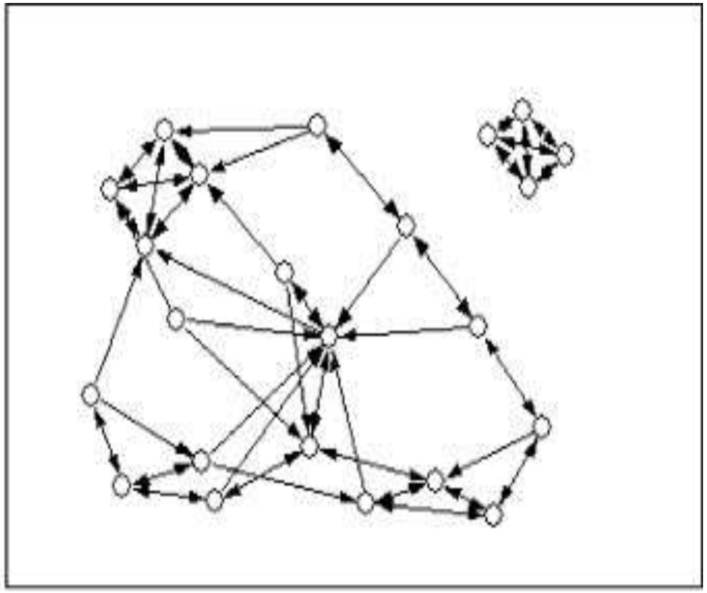


Hierarchical (tree) versus non-hierarchical (star)



Reciprocity

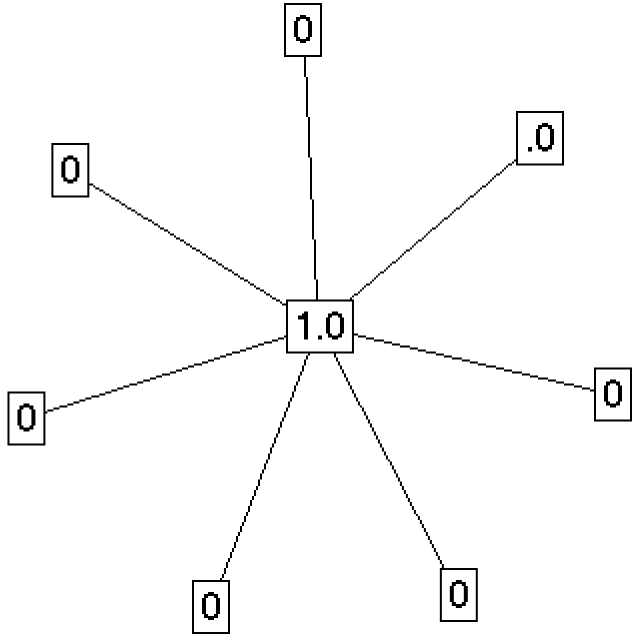


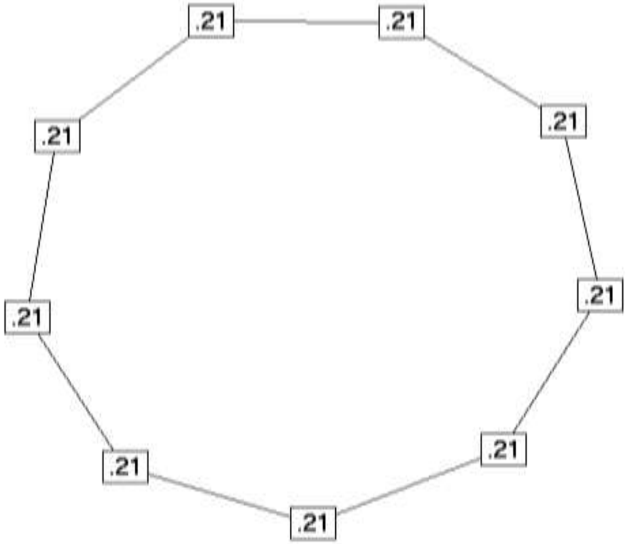


Low reciprocity

High reciprocity

Closeness centralization
Betweenness centralization



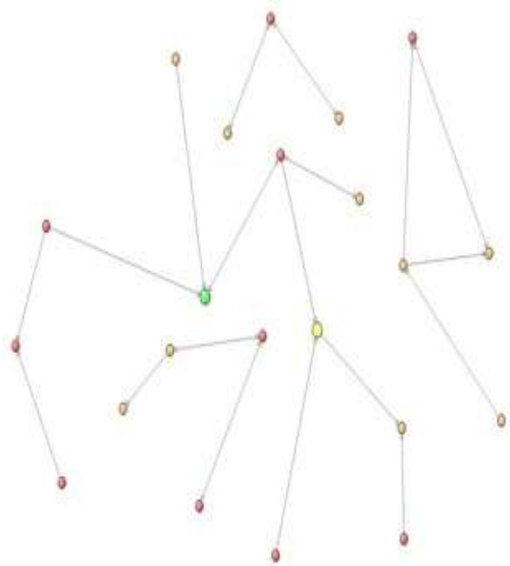


Betweenness centralization: 1
Closeness centralization: high

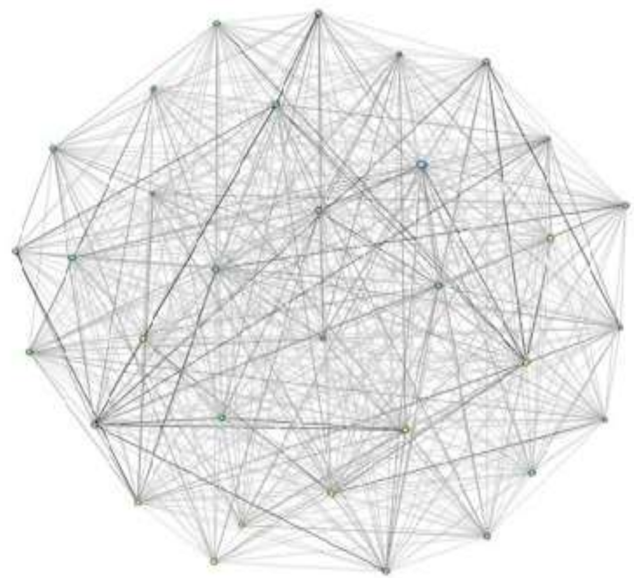
Betweenness centralization: 0
Closeness centralization: low


Density: higher level of information sharing in high-density networks

Low Density Network



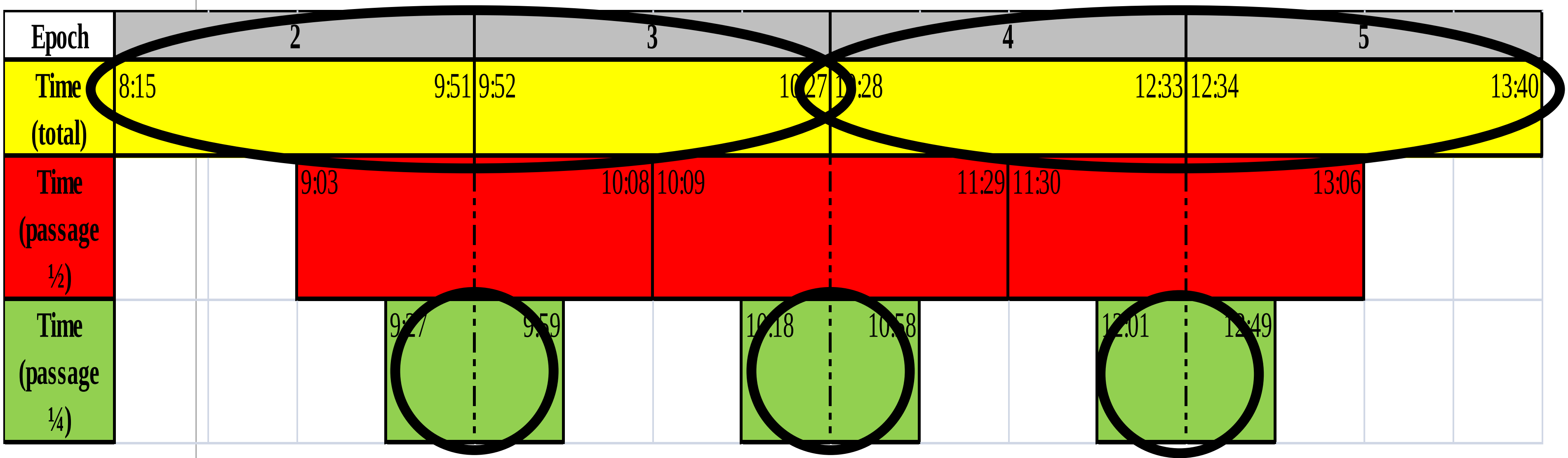
High Density Network



Results

During transitions:

* communication is based on fewer individuals
* information flow is faster



Differences between epochs

- CPB preparation (from epoch 2 to 3)
  - More connections to other highly-connected team members
- Going on CPB (from epoch 3 to 4):
  - Communication more based on a few individuals closer to transition
  - More connections to other highly-connected team members
  - More hierarchical communication patterns
- Going off CPB (from epoch 4 to 5)
  - Fewer hierarchical communication patterns
  - Denser networks

Results on complexity of procedures (median split)

More complex procedures:

- Have flatter communication structures, are less hierarchical
- Show higher levels of reciprocity

How do team members respond to NREs?

- Surgeon and anaesthetist respond to NREs in a differentiated manner, depending on:
  - Complexity of the procedure
  - Particular phase in the procedure

- Generally, NREs are responded to by lowering the centrality of the main actors, that is, the team as a whole becomes more dominant in comparison to single actors (surgeon, anaesthetist)

- However, only during the most critical phases of the most complex procedures, do single actors become more dominant as the number of NREs increases

Conclusions

- Teams adapt their communication patterns to:
  - Complexity of the procedure
  - Transitions between epochs
  - Criticality of epochs
  - Non-routine events

- Complexity and non-routine events are responded to with a **broadening** of communications, higher reciprocity and denser networks
- Transitions during critical epochs are responded to with **restricting** communication to key individuals

Recommendations

- Team research should move beyond general labels such as ‘leadership’ and ‘situation awareness’ and instead focus on adaptive team processes in context
- Social network analysis is able to characterize team processes at a fine-grained level
- This provides a solid basis for improving team communication processes and, ultimately, clinical performance