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PhysioEx: Visual Analysis of Physiological Event Streams

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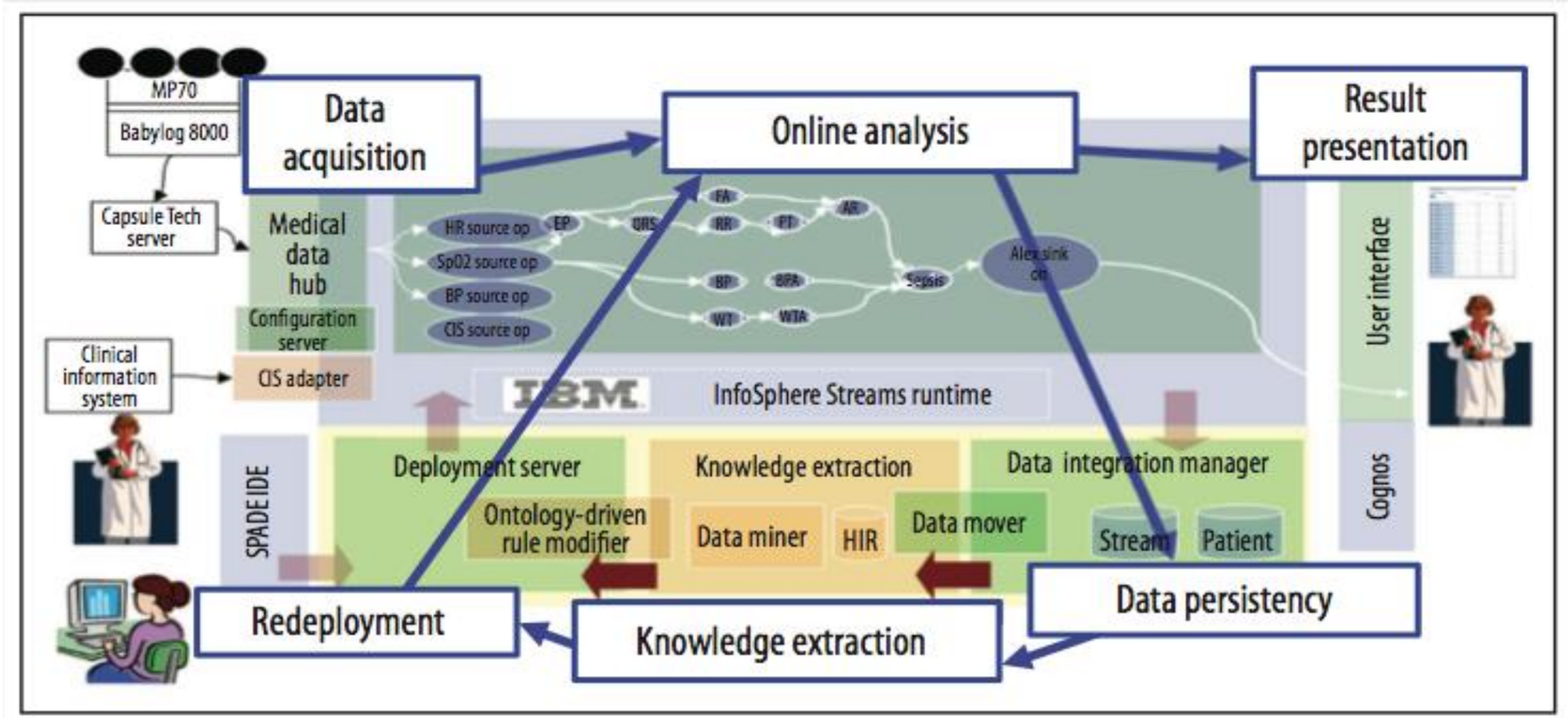
SickKids THE HOSPITAL FOR SICK CHILDREN

Background

- 10% of the world's babies are born premature[1]
- 182 million+ data points a day
- Only a fraction collected and stored
- Visual representations can highlight salient features to aid in the care of critically ill babies

[1] World Health Organisation, Preterm birth, fact sheet No 363, Geneva WHO, 2013.

Artemis Platform



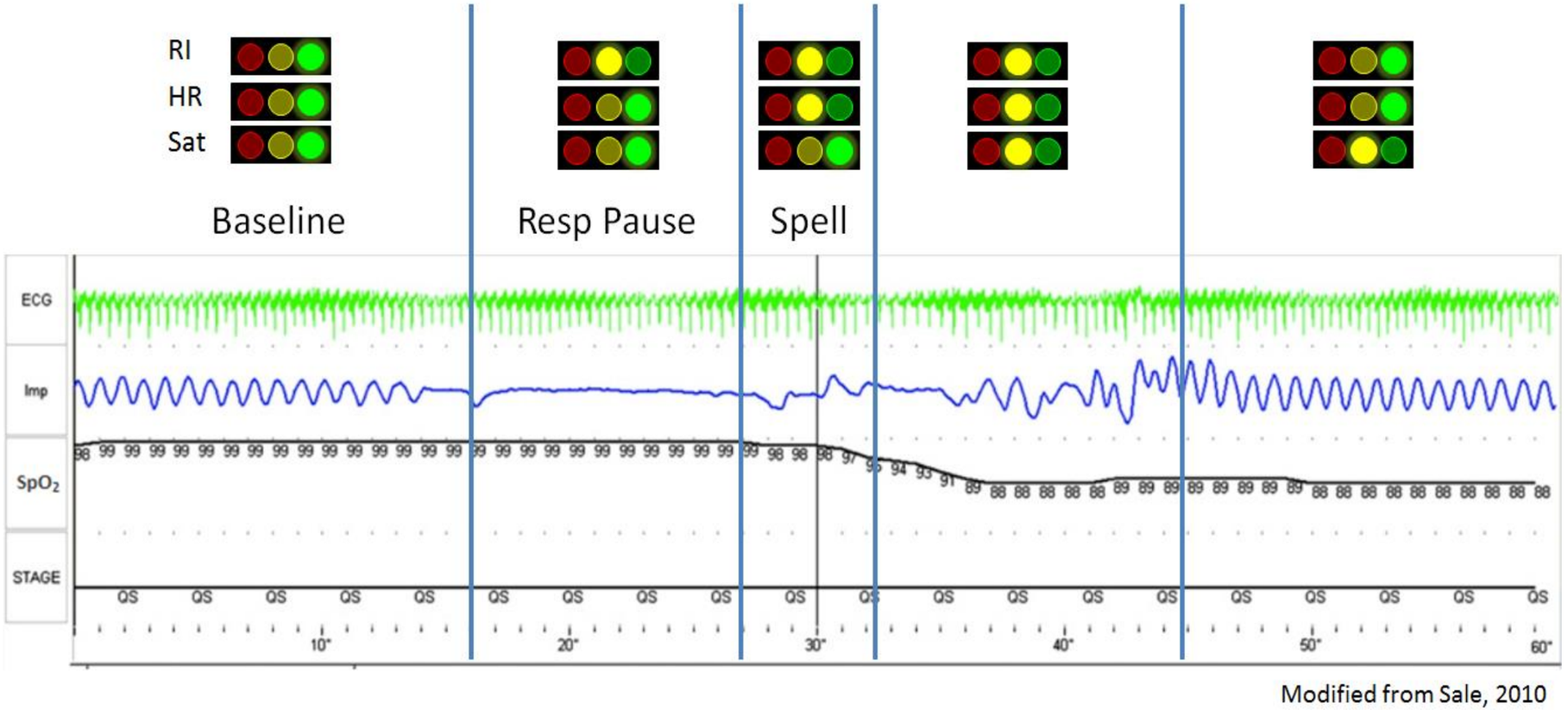
1089 patients recruited (~3 trillion samples)

Problem Characterization

- **Apnoea of prematurity**: Gap in breathing of more than 20 seconds[2]
- Hard to know that a baby is apnoeic
- Bed-side staff broadly classify any cardiorespiratory event as a "**spell**"
- Specialists and extensive monitoring required to diagnosis
- An algorithm was developed that automated the classification of neonatal spells[3]
- Neonatal Sepsis is infection acquired in the hospital
- Interest in predicting sepsis using neonatal spells data

[2] Thommandram A, Pugh JE, Eklund JM, McGregor C, James AG. Classifying neonatal spells using real-time temporal analysis of physiological data streams: Algorithm development. Point-of-Care Healthcare Technologies (PHT), 2013 IEEE. 2013. p. 240–3.

Related Work



Modified from Sale, 2010

Identifying correlations across three physiologic data streams[3]

[3] Pugh E, Thommandram A, Ng E, McGregor C, Eklund M, Narang I, et al. Classifying neonatal spells using real-time temporal analysis of physiological data streams—algorithm development. Journal of Critical Care. 2013;28(1):e9.

Event Classification Algorithm

	Absolute	**Relative**
Heart Rate	< 100 (Preterm) < 80 (Term)	> 10% fall from 30s baseline
Respiratory Rate	> 20 seconds	Pause greater than two breaths
Saturation	< 80% (Preterm) < 92% (Term)	> 10% fall from 30s baseline

Events as Sequences

	1	2	3	4	5
Central	↓ Resp.	↓ Heart Rate	↓ O_2	↑ Resp.	↑ Heart Rate
Vagal	↓ Resp. ↓ Heart Rate	↓ O_2	↑ Resp. ↑ Heart Rate		
Obstructive	↓ Heart Rate (Incremental)	↓ O_2	↑ Heart Rate		
Obstructive Central	↓ Heart Rate (Incremental)	↓ O_2	↓ Resp.	↑ Resp.	↑ Heart Rate
Central Obstructive	↓ Resp.	↓ Heart Rate	↓ O_2	↑ Resp.	↓ Heart Rate
Desaturation	↓ O_2				
Bradycardia	↓ Heart Rate				

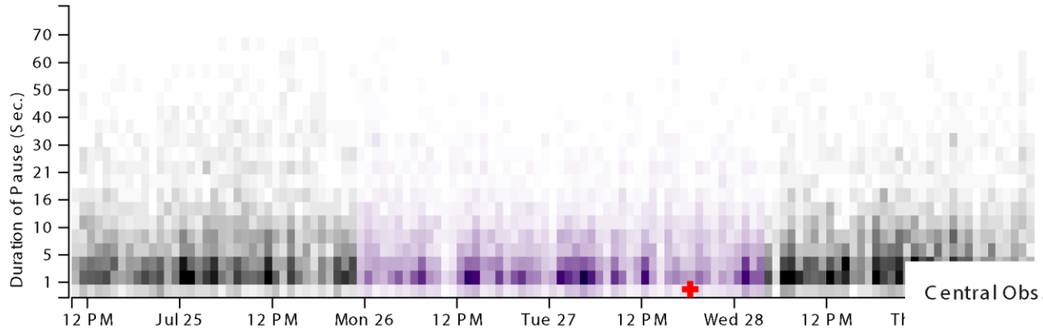
Task Analysis

Domain experts with at least five years of neonatal experiences were solicited.

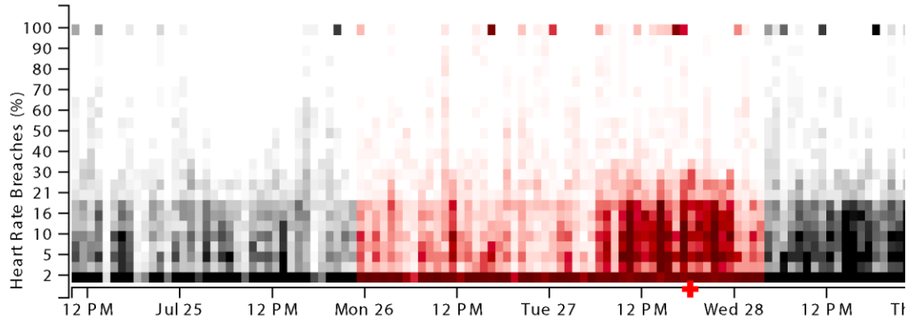
- **[T1]** • Identify the Point of Suspicion of Infection (PSI)
- **[T2]** • Identify events in the respiratory physiologic signal before PSI
- **[T3]** • Analyse events across heart rate and oxygen (SpO_2) streams
- **[T4]** • Identify abnormal events
- **[T5]** • Create mental temporal map of underlying physiology

Design of PhysioEx

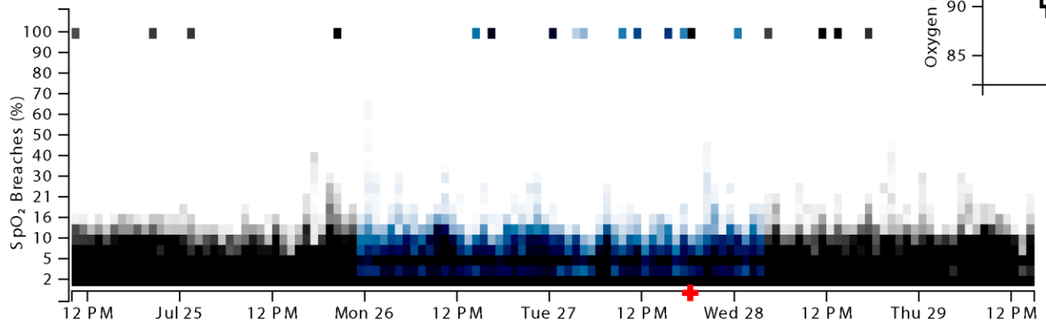
Respiratory Impedance Graph



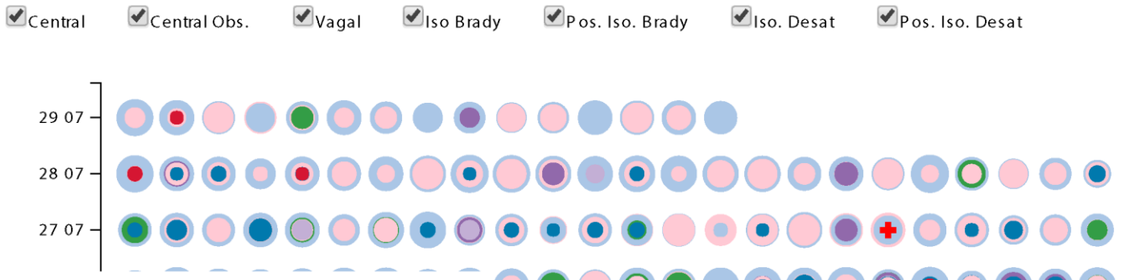
Heart Rate Flux Graph

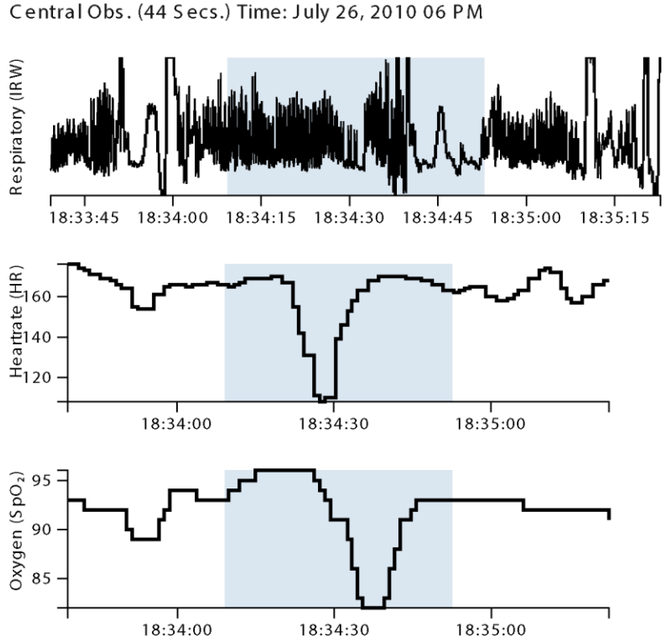


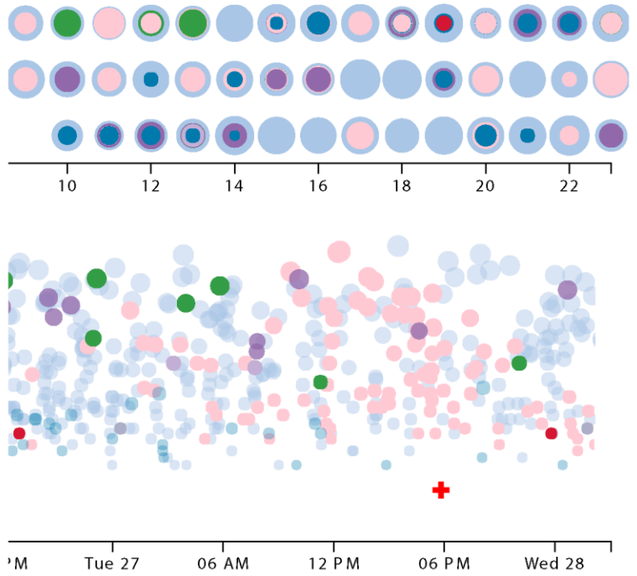
Oxygen Flux Graph

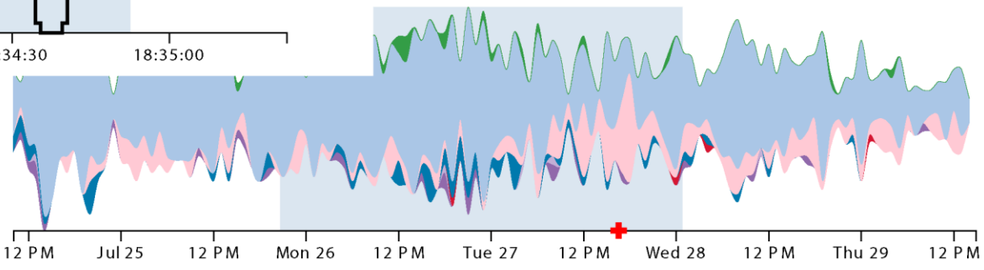


Spells Classification

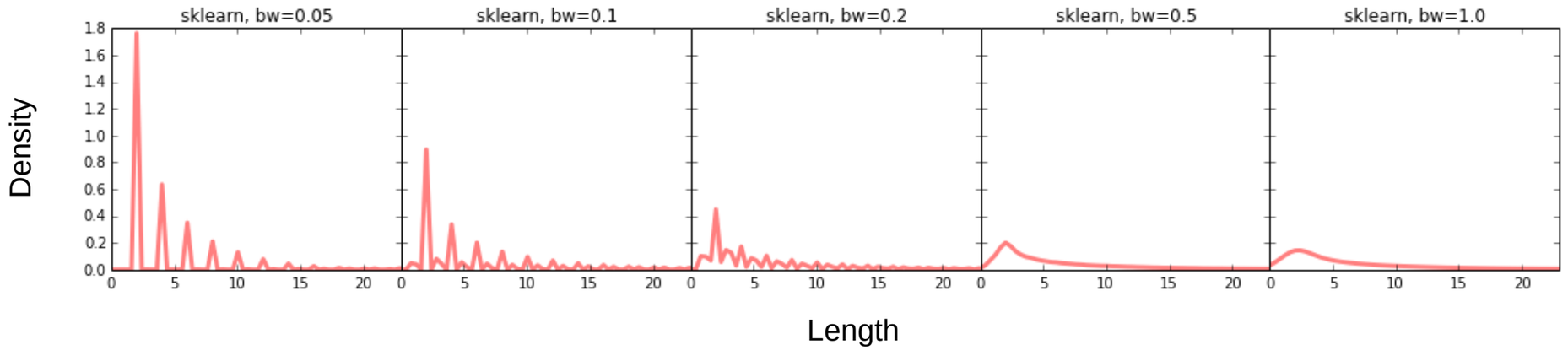








Kernel Density Estimation

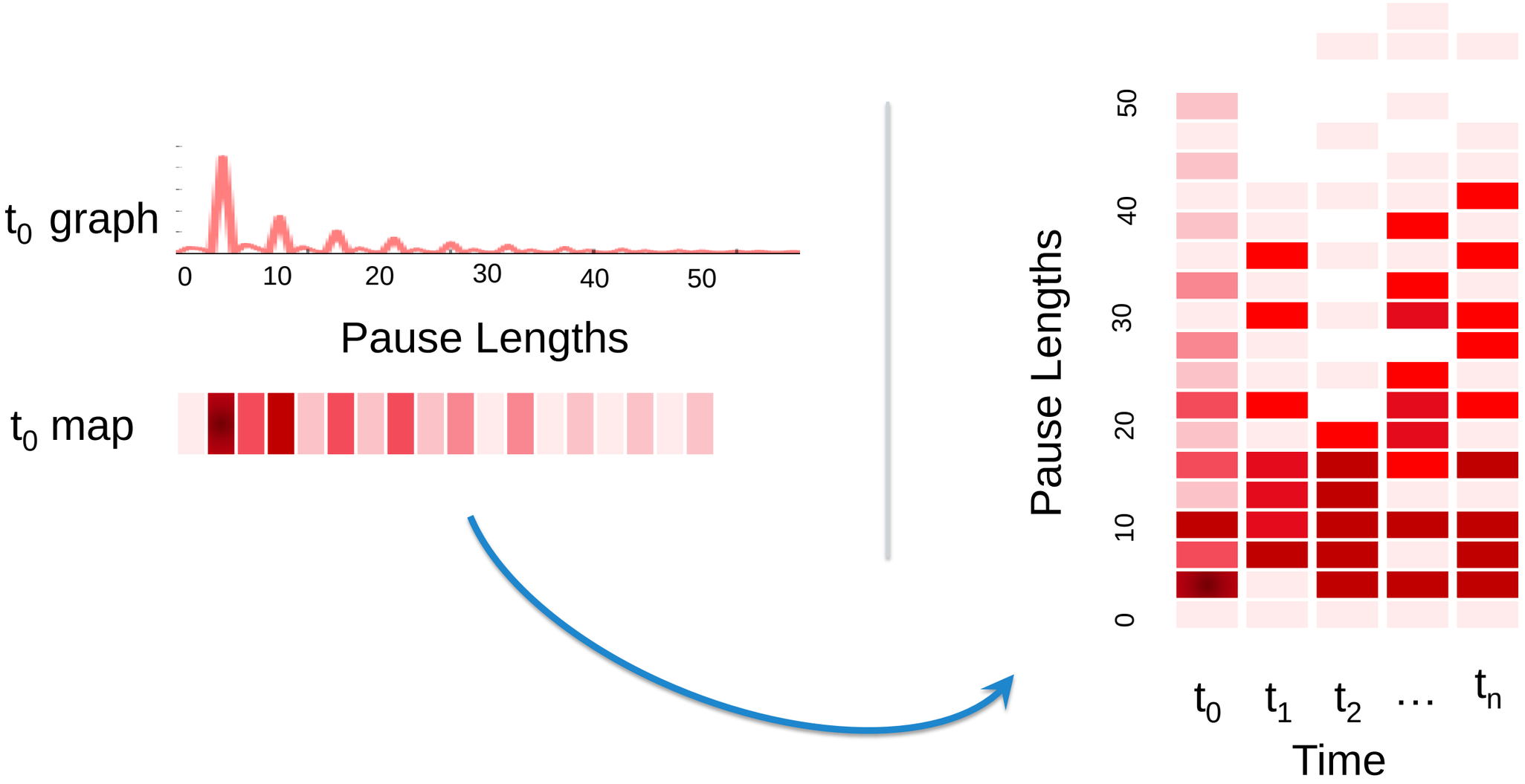


Kernels are aggregated and used to determine **vertical binning**

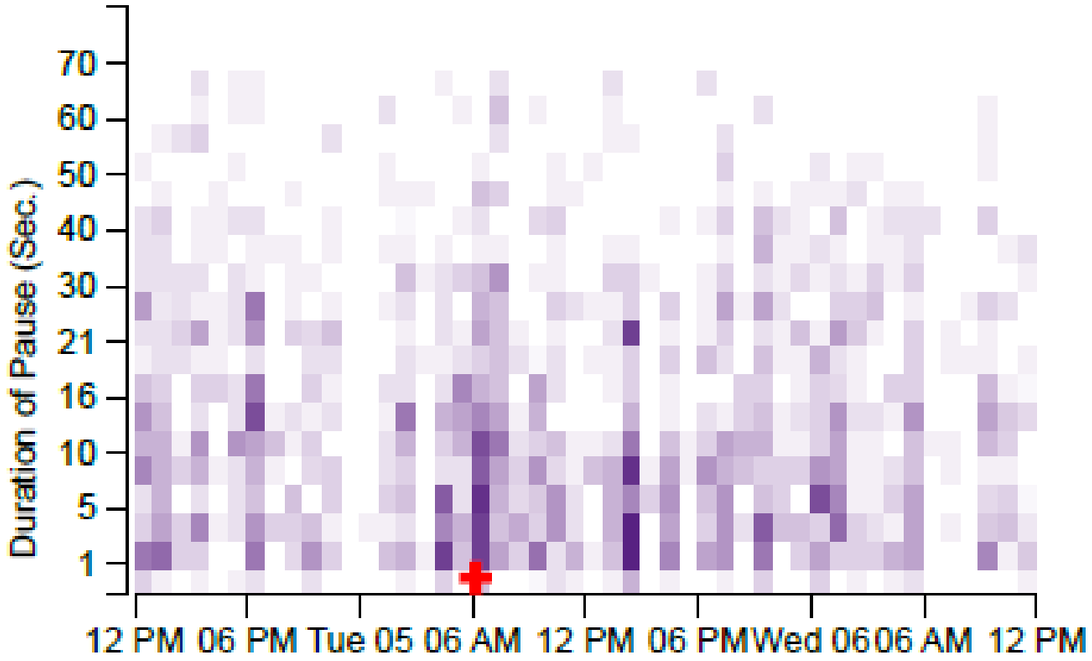
Frequency score generated for each vertical bins, and used to control opacity

Horizontal stacking for each hour of data

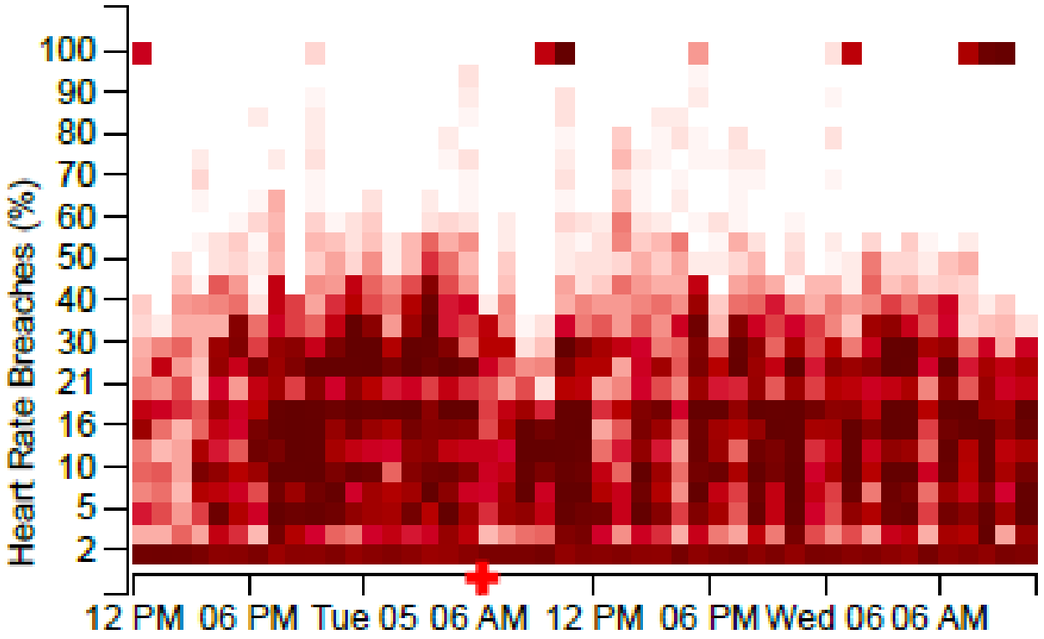
KDE Histogram to Temporal Intensity Maps



Temporal Intensity Maps



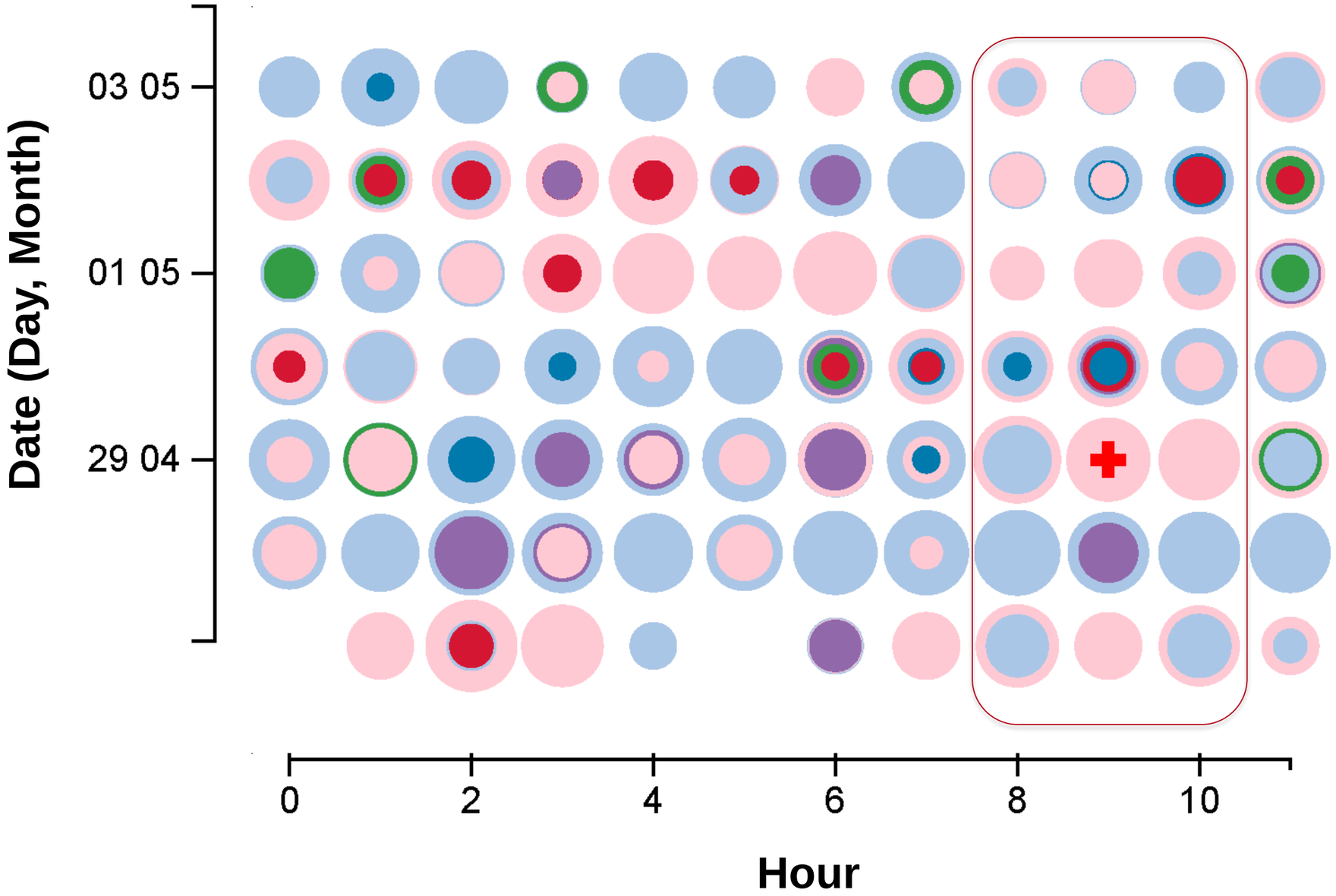
(a) Respiratory Pause

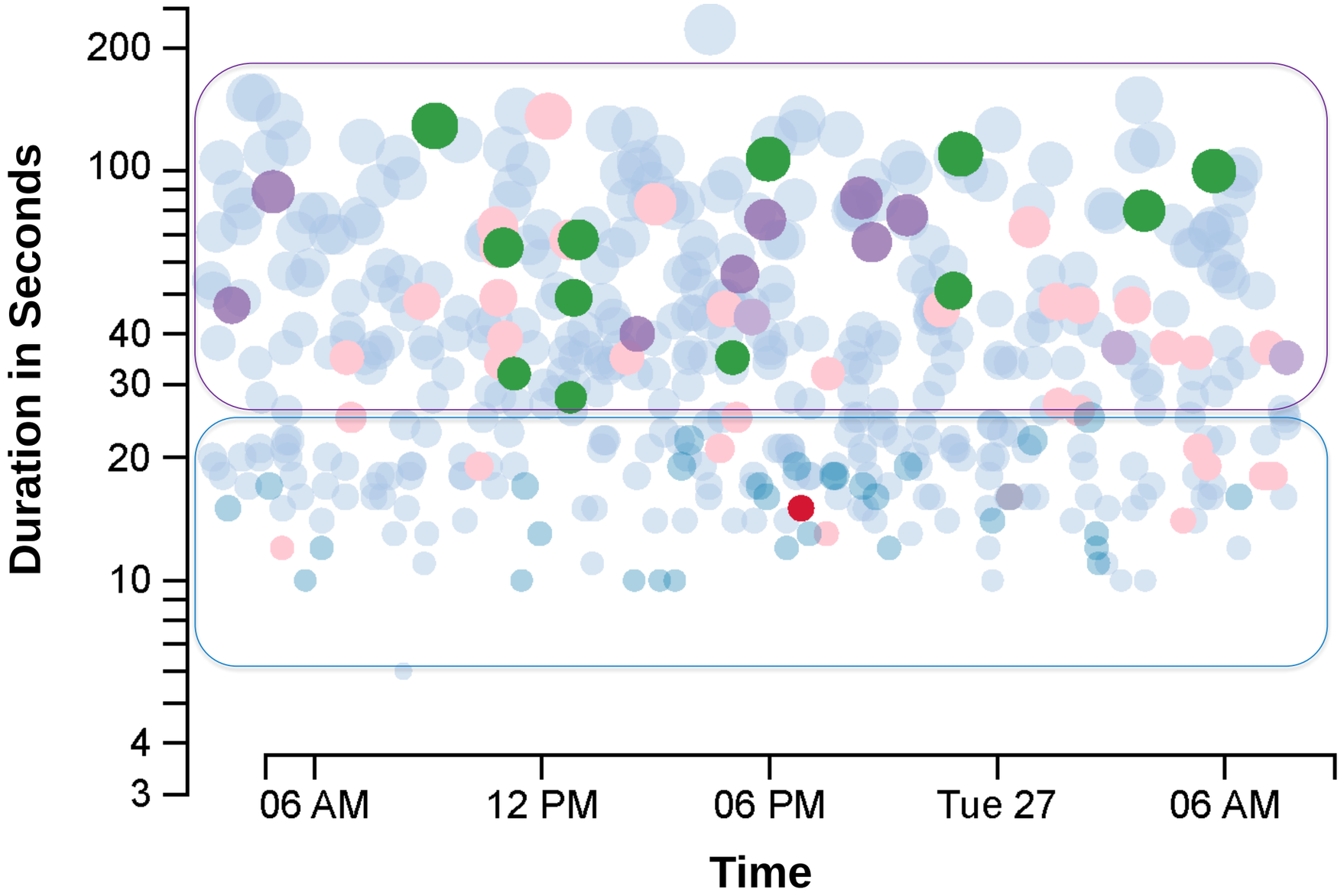


(b) Heart rate flux

Highlight salience in physiologic events[4]

[4] Kamaleswaran R, et al. IEEE EHRVis. 2014.

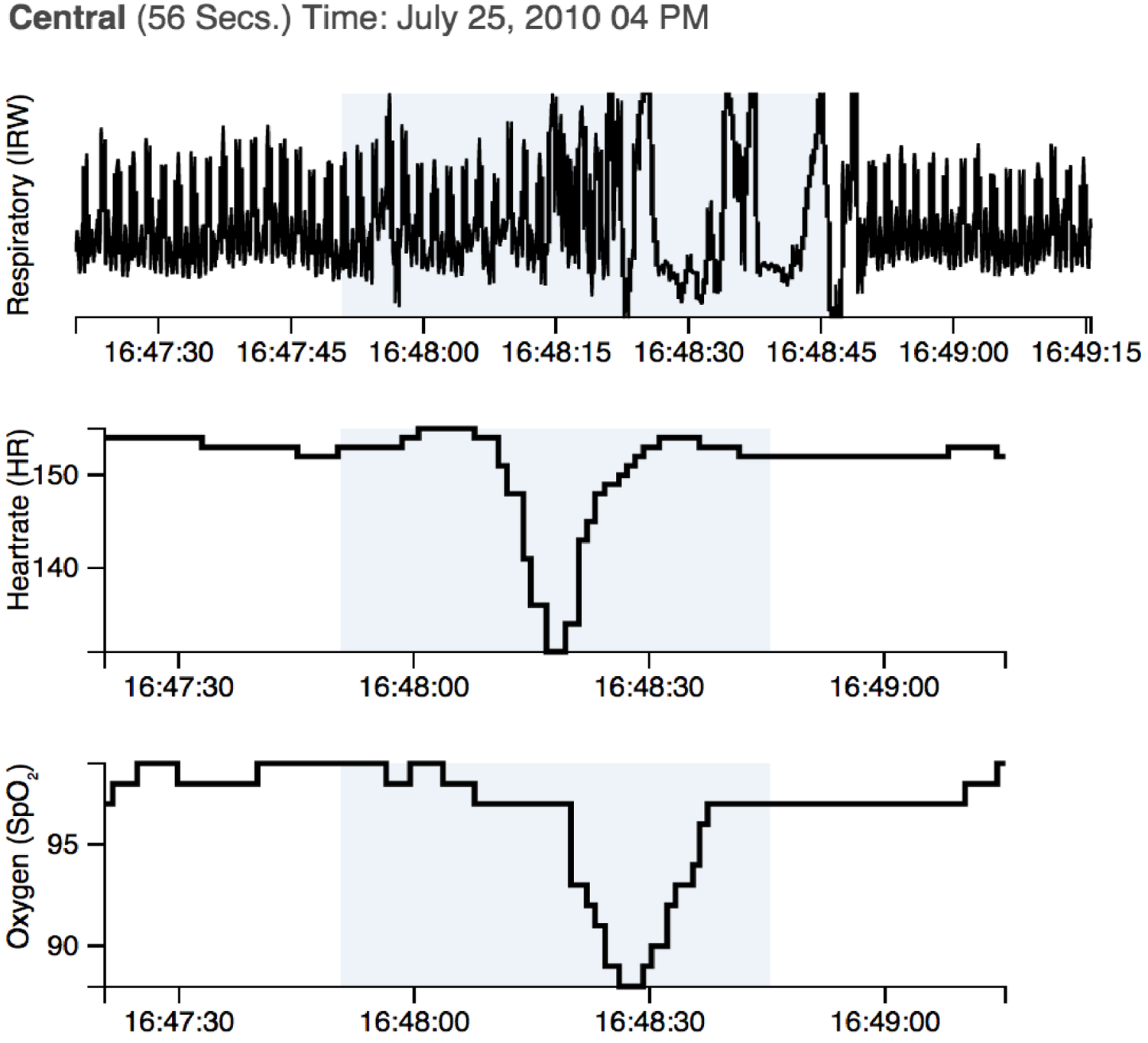

Date (Day, Month)
03 05
01 05
29 04
0
2
4
6
8
10
Hour


Duration in Seconds
200
100
40
30
20
10
4
3
06 AM
12 PM
06 PM
Tue 27
06 AM
Time

3

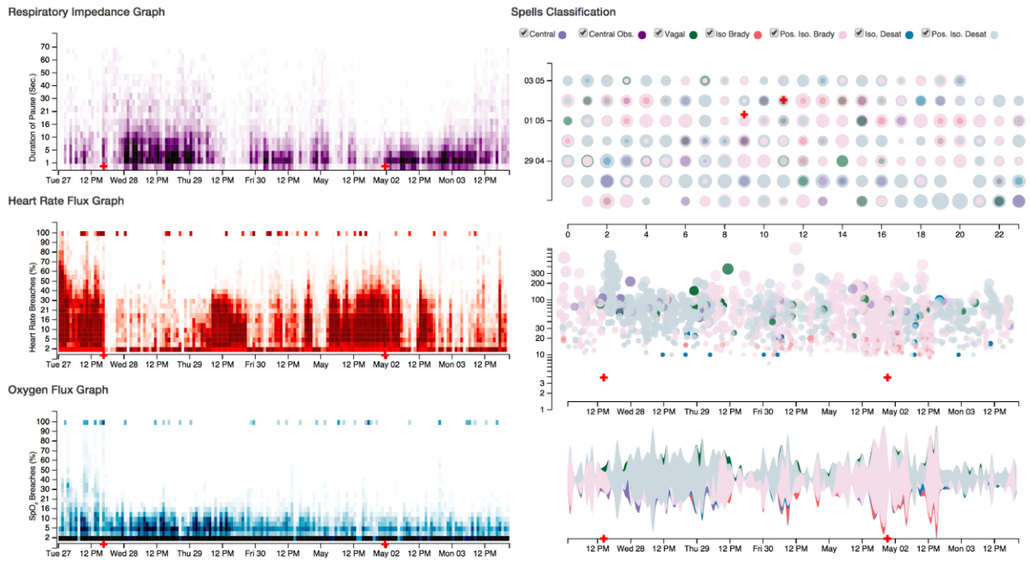
1

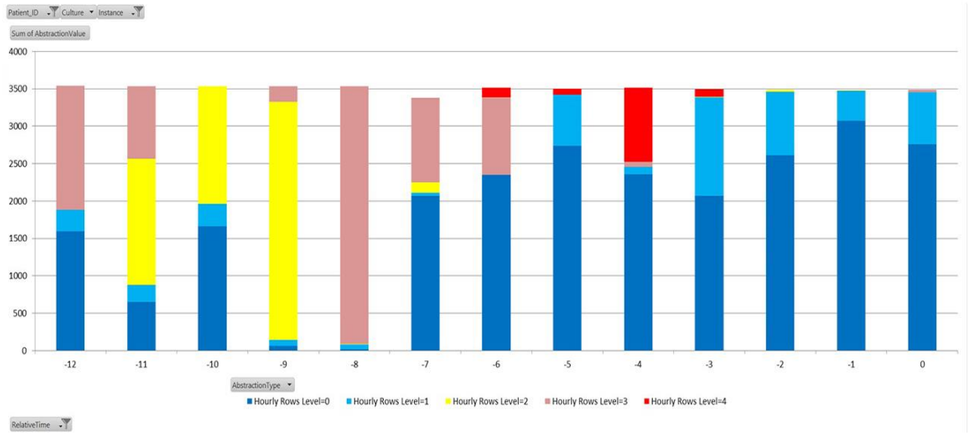
2


Central (56 Secs.) Time: July 25, 2010 04 PM
Respiratory (IRW)
16:47:30
16:47:45
16:48:00
16:48:15
16:48:30
16:48:45
16:49:00
16:49:15
Heartrate (HR)
150
140
16:47:30
16:48:00
16:48:30
16:49:00
Oxygen (SpO2)
95
90
16:47:30
16:48:00
16:48:30
16:49:00

Expert Evaluation

- Participants: 4 domain experts
- Tasks: Exploratory Comparisons
- Treatment: PhysioEx and Stacked Bar Display
- Data Collection: Observation, Semi-structured interviews





Expert Evaluation

Generated *counter evidence* about the relationship between *neonatal spells and sepsis*.

Subjective Feedback:

- Greater advantage to explain **neonatal spells behaviour** than the alternative.

  “now inclined to invest a day in training a neonatal fellow so they would be better able to describe physiological behaviour of spells”

- SequenceGraph provided a unique ability to recognize patterns that commonly occur at various times of the day– novel insight generated.
- Raw Data View closed the loop.

Limitations:

- Tested PhysioEx with four domain experts.
- Results extend to a single tertiary teaching hospital in North America.
- Did not integrate clinical contextual data (nursing notes, dx histories).

Future Work:

- Develop an automated adaptive KDE algorithm to automate bandwidth and threshold selections.
- Evaluate PhysioEx in other case studies involving larger participant groups.

Take home message

- Interpreting non stationary and heavy-tailed waveform data streams is an open challenge.
- One method is to use adaptive nonparametric models like KDE to expose density.
- The Temporal Intensity Map was more descriptive than stacked bar.
- ‘Closing the loop’ a factor when novel tools introduced.
- PhysioEx is a step towards addressing these problems.

Thank you!

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Temporal Intensity Maps (construction)