Comparison of Bed-Sensors for Nocturnal Behaviour Assessment

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Dr. Bruce Wallace

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Research Focus: Ambient assessment of well-being and
  supportive smart systems to support independence and aging
  in place.

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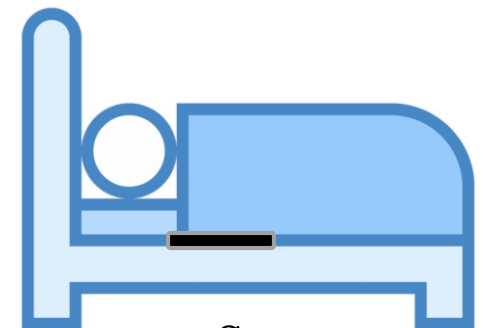SOINS CONTINUS
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Disclosure

Agenda

- Why Bed Sensing
- The Bed Sensors
- Test Method
- Experimental Results
- Summary

Bed Sensing Applications

- Applications – looking at just the bed
  - Presence: Time in bed, Nocturnal events
  - Sleep state
  - Respiration: Rate, breathing patterns, apnea
  - Physical Health: Dynamics of bed exit
- Sensor Technologies
  - force sensitive resistors
  - vibration/sound sensors
  - piezoelectric film sensors
  - fibre optic
  - Infrared proximity

Sensor
under mattress

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Background Use Case
Supportive Smart Home

- Providing supportive cues to reorient PLWD

  e. g. Bed Sensor → Cue lighting for Bathroom

- Issue – Detecting the bed exit
  - Sensor used in that study was a source of many issues (errors, did not function in some beds)
  - It actually would not work in the bed in this study

- Research focus for this work
  - Are emerging commercial sensor an option?
  - Do they provide additional knowledge (sleep)?

Sensors pt 1

- The Emfit QS
  - Pressure sensitive capacitor
  - Assesses the subjects motion through ballistocardiography.
  - Reports presence, sleep state & score

Emfit QS (E)

- Withings Sleep
  - Single air bladder and pneumatic sensor
  - Assesses the variations in the pressure in air chamber associated with the movements.
  - Reports presence, sleep state & score

Withings Sleep (W)

Sensors pt 2

- Best Buy Canada's Assured Living solution / Telehealth Sensors
  - Pressure sensitive capacitor with adaptive threshold.
  - Reports presence
- Best Buy Canada's Assured Living solution motion sensors
  - Sensors located in the bathroom and a flight of stairs
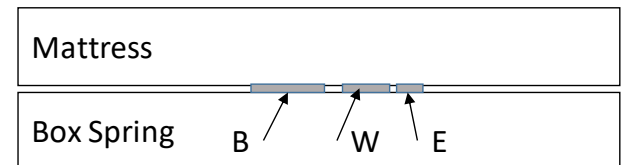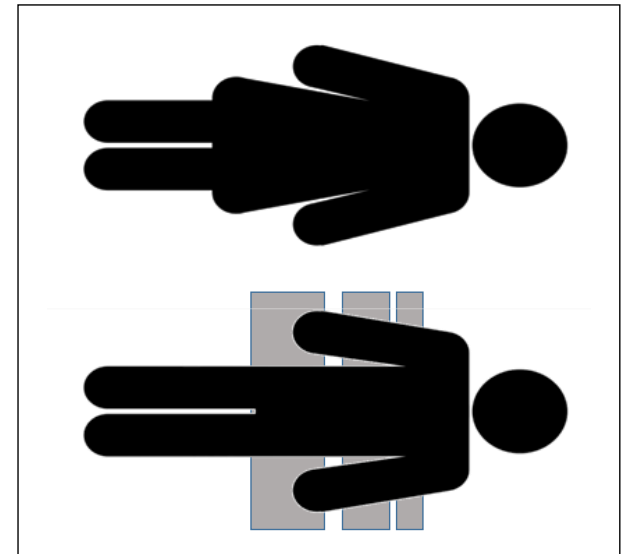 - Reports activity

BestBuy Assured Living (B)

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Method

- Double occupancy queen sized bed
- Sensors placed on subject 1 side of bed.
- Sensors placed in the bed per their respective installation instructions
- Each connected to the Internet/cloud.
- Test period of 75 consecutive nights
  - The B sensor introduced 21 days into the study when it arrived
- Participant maintained nightly logs
  - Entry and exits times
  - Sleep quality
- Sensor data access through portals for each sensor

Subject	Gender	Age (yr)	Height (m)	Weight (kg)
1	M	55	1.85	85
2	F	50	1.65	60

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Time in Bed Results

- Comparison of the results for the each sensors log
- Sensor B times very similar to logs.
- Sensor W shows less time than the log
  - Cropping of the overnight period on some nights.
- Sensor E shows extra time compared to log
  - Later rise time reported matching subject 2.

Sensor	Nights (count)	Start Time Error (count)	End Time Error (count)	Mean Time in Bed (min)	St. Dev. Time in Bed (min)
Log	75	na	na	562.4	39.6
W	75	7	9	550.9	44.2
E	75	4	19	580.2	36.9
B	54	0	1	566.2	39.4

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Nocturnal Exits

- Bed Sensor B detected all of the bed exits during the study period with no errors
- Motion Sensors from the B system did have two errors that are directly attributable to a failed battery in a motion sensor.
- W sensor had 3 missed bed exits and reported three exits that did not occur
  - Missed exits FN appear to also be associated with the cropping of the overnight period noted for this sensor.
- E sensor frequently misses bed exits.
  - Doubling occupancy with 1 person remaining in bed

Sensor	Actual Exits (n)	Exits Detected (TP)	Exits Missed (FN)	Extra Exits Reported (FP)
W	92	89	3	3
E	92	30	62	0
B bed	73	73	0	0
B motion	73	71	2	0

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Sleep Time

- Sensors (W and E) provide information regarding sleep state and time asleep
- The results show a large difference between the values reported for the two sensors.
  - Causes:
    - Inclusion of sleep within the score for sensor E from participant 2.

| Sensor	Nights (n)	Mean Time Asleep (min)	St. Dev. Time Asleep (min)	Mean Light Sleep (min)	Mean Deep Sleep (min)	Mean REM Sleep (min)
W	75	437.1	50.5	350.7	64.8	21.5
E	75	520.8	47.3	291.4	92.9	136.6

Portal vs API Data

- Sensors (W and E)
  - Summary data in web Portal
  - API allows raw data access
- Cropping by Sensor W
  - Upper image shows portal view of a night
  - Lower image shows API data for same night.
  - Portal data starts after bed exit 2 hours into the API data

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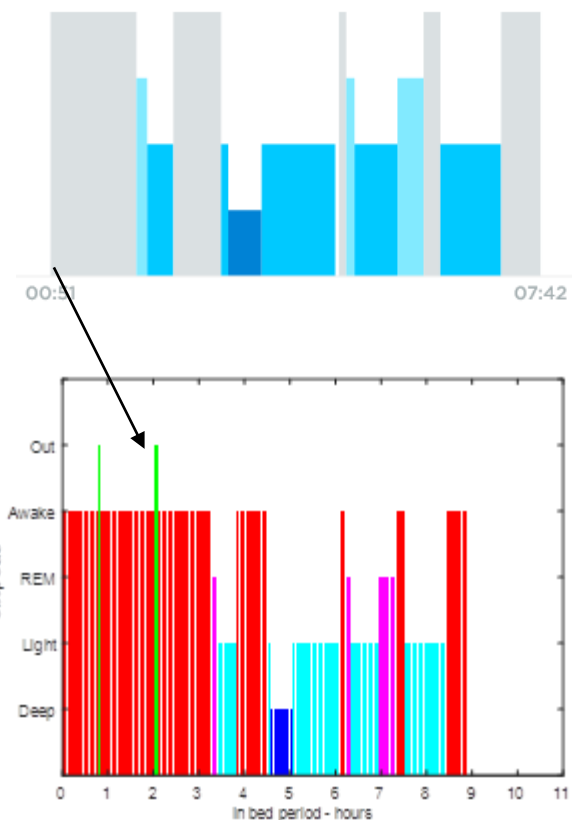
Sleep Score

- Sensor E and W report a sleep score
  - Neither sensor manufacturer provides details on the methodology or algorithm used for this assessment.
- Portal vs API score
  - Sensor W: Identical data
  - Sensor E:
    Web portal sleep score range of 73 − 100
    API sleep score range of 73 − 124
    Portal score capitated at 100
- Score comparison E and W is shown
  - Comparing score for each sensor by night
  - Data shows no correlation in the two scores from the two sensors
  - W score aligns more with subject logs
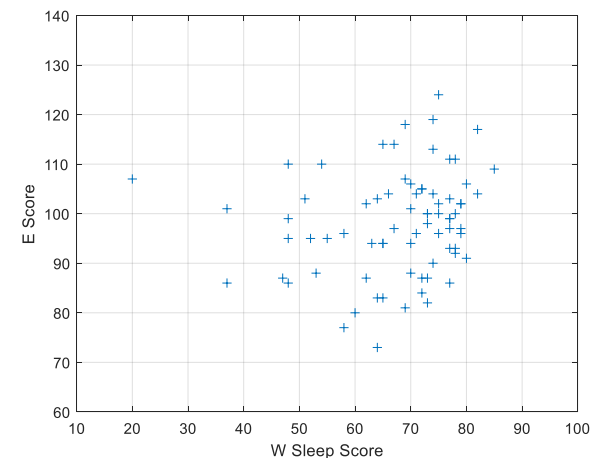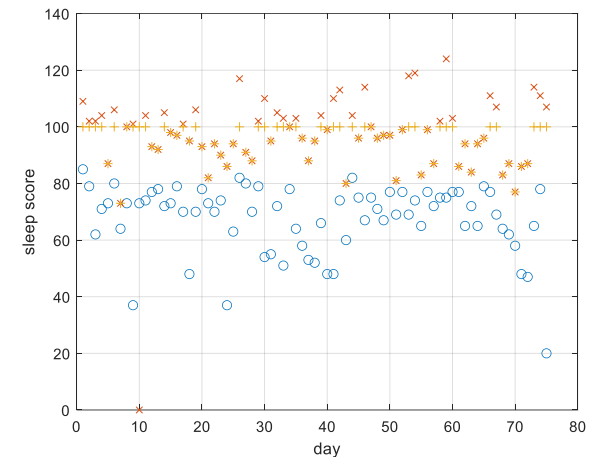
Summary

- Sensor B
  - Provides accurate assessment of the time in bed for the specific subject.
  - Limited to only the assessment of bed occupancy.
- Sensor E and W
  - Have potential for significantly more knowledge to be obtained
- Sensor W
  - Effective at detecting entry and exits from the bed
  - Limitation: It reports a single sleep period in each day and the start and end of the period are not based on first bed entry and last exit.
- Sensor E sensor
  - Reports multiple sleep periods per day period leading it to be better and more appropriate for use within a study where naps or multiple daily sleep periods
  - Appears to have had more difficulties associated with confusion between the bed occupants.
- Future work
  - Fusion based algorithm of the more accurate assessment of time in bed provided by the B sensor with the more detailed knowledge of sleep related measures provided by the W, E sensors or other sensors located through-out the home

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Questions

Acknowledgements