A LARGE-SCALE EXPLORATION OF FACTORS AFFECTING HAND HYGIENE COMPLIANCE USING LINEAR PREDICTIVE MODELS

ICHI ’17

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Hand Hygiene

- Why care about hand hygiene?
Why care about **hand hygiene**?

* Healthcare workers (HCWs) are the primary vector in spreading **hospital acquired infections (HAIs)** to **patients**.
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MRSA ← Antibiotic resistant → C Diff
How do we measure hand hygiene compliance?
Hand Hygiene Compliance

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\[
\text{compliance (rate)} = \frac{\# \text{ events}}{\# \text{ opportunities}}
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○ Event: Application of hand soap or alcohol-based rub
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- **Event:** Application of hand soap or alcohol-based rub

- **Opportunity:** A chance to practice hand hygiene according to *some* hand hygiene directive.
Hand Hygiene Compliance

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  \]

- **Event**: Application of hand soap or alcohol-based rub

- **Opportunity**: A chance to practice hand hygiene according to *some* hand hygiene directive.
  
  * Once upon entrance and once upon exit of a patient’s room (our study).
Want to measure and quantify the extent of compliance:
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- Manual, human observation
  - Hawthorne effect.
  - Timing, distance, location of human observers affects rates (error prone).
  - Costly.
  - Small sample size.
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  - Costly.
  - Small sample size.
* Automated, sensor-based methods.
  - Promise to overcome the above.
Sensor-based Surveillance

1. Instrumented doorways and soap/rub dispensers
2. Periodic transmission
3. Reported stats are stored
Hand Hygiene Data

- Elicited 3274 total days of hand hygiene activity.
- 5,296,749 hand hygiene events were observed (after post-processing).
- 21,273,980 opportunities were identified (after post-processing).
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- Largest study of hand hygiene compliance on record!
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Largest study of hand hygiene compliance on record!

* Overall compliance rate of: 25.03%
Gojo Industries deployed sensors to: 19 facilities in 10 states, covering 8 CDC divisions.
## Our Hand Hygiene Data

<table>
<thead>
<tr>
<th>Facility</th>
<th>State</th>
<th>CDC Div</th>
<th>Tot Disp</th>
<th>Tot Door</th>
<th>Days Rep</th>
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</thead>
<tbody>
<tr>
<td>91</td>
<td>OH</td>
<td>ENC</td>
<td>234292</td>
<td>518772</td>
<td>252</td>
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<td>101</td>
<td>OH</td>
<td>ENC</td>
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<td>105</td>
<td>TX</td>
<td>WSC</td>
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<td>119</td>
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<td>WSC</td>
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<td>Mnt</td>
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<td>ENC</td>
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<td>Pac</td>
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<td>New E</td>
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<tr>
<td>155</td>
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<td>M-At</td>
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<td>619507</td>
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<td>156</td>
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<td>38200</td>
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<td>313396</td>
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<tr>
<td>168</td>
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<td>ENC</td>
<td>112604</td>
<td>353631</td>
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<td>OH</td>
<td>ENC</td>
<td>4788</td>
<td>15122</td>
<td>32</td>
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<tr>
<td>Total</td>
<td>10</td>
<td>8</td>
<td>5296749</td>
<td>21273980</td>
<td>3274</td>
</tr>
</tbody>
</table>

A big table of facility-specific summary statistics.
What questions can be answered with this data?
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- Do facilities have different cultures regarding hand hygiene compliance?
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- Do facilities have different cultures regarding hand hygiene compliance?
- Can atmospheric effects be associated with higher/lower rates of hand hygiene?
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- Do **facilities** have **different cultures** regarding hand hygiene compliance?
- Can **atmospheric effects** be associated with higher/lower rates of hand hygiene?
- Are there **temporal factors** that influence rates of hand hygiene (holidays, nights, weekends)?
What questions can be answered with this data?

- Do facilities have different cultures regarding hand hygiene compliance?
- Can atmospheric effects be associated with higher/lower rates of hand hygiene?
- Are there temporal factors that influence rates of hand hygiene (holidays, nights, weekends)?
- Do higher/lower rates of influenza mortality lead to higher/lower rates of compliance?
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- Do facilities have different cultures regarding hand hygiene compliance?
- Can atmospheric effects be associated with higher/lower rates of hand hygiene?
- Are there temporal factors that influence rates of hand hygiene (holidays, nights, weekends)?
- Do higher/lower rates of influenza mortality lead to higher/lower rates of compliance?
Calculate facility-specific 12-hour* compliance rates.

\[ \text{rate} = \frac{\# \text{dispenser}}{\# \text{door}} \] (1)
Compliance Rate Aggregation and Factor Derivation

- Calculate facility-specific 12-hour* compliance rates.

\[
rate = \frac{\#dispenser}{\#door}
\]  

- \textit{nightShift} Feature:
  - 7 pm to 6:59 am. Added as a binary feature \( nightShift \in \{0, 1\} \).
Factor Derivation: Atmospheric-based

- **Temperature and Humidity**
  - Spatially assimilated NOAA data. Four values reported/day for each of the $2.5^\circ \times 2.5^\circ$ regions.
  - Day shift: 6am, Night shift: 6pm.
Factor Derivation: Atmospheric-based

- Temperature and Humidity

Spatially assimilated NOAA data. Four values reported/day for each of the 2.5° × 2.5° regions.

Factor Derivation: Flu Severity

- Flu severity
  - 122 reporting cities.
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  - 122 reporting cities.

\[
repCity = \text{argmin}\{\text{dist}(\text{facility}, city_i) : i = 1, \ldots, 122\} \tag{2}
\]

where \(\text{dist}(\text{fac}, \text{city}) \triangleq \|(\text{fac}_{\text{lat}}, \text{fac}_{\text{lon}}), (\text{city}_{\text{lat}}, \text{city}_{\text{lon}})\|_2\).
Factors Derivation: Temporally-based

- **Holidays**
  - Shift falls on a Federal holiday: New Year’s Eve, Martin Luther King Day, President’s Day, Memorial Day, the 4th of July, Labor Day, Columbus Day, Veteran’s Day, Thanksgiving or Christmas.
Factor Derivation: Temporally-based

- Weekend
  - Shift falls on a Saturday or Sunday.
Factor Derivation: Temporally-based

- *julyEffect*: New residents
  - Shift falls on one of the days in the range: July 1st - 7th.
Methods

- M5 Ridge Regression
- RReliefF Feature Ranking
- Marginal Effects modeling
Method: M5 Ridge Regression

1. Accurately estimate hand hygiene compliance rates.
2. Accurately reports the direction and degree of effect of our defined features.
Method: M5 Ridge Regression

○ **Want a method that:**
  1. Accurately estimate hand hygiene compliance rates.
  2. Accurately reports the direction and degree of effect of our defined features.

○ **Obtained by:**
  1. Use M5 for feature selection (1)
  2. Use sequential backwards elimination with Ridge Regression (2)

\[
\mathbf{h}^* = \arg\min_{\mathbf{h} \in \mathcal{H}_l} \| \Lambda(\mathbf{X})\mathbf{h} - \mathbf{y} \|^2_2 + \lambda \| \mathbf{h} \|^2_2 \\
\text{s.t.} \quad \rho(h_j) \leq 0.05 \quad \forall \quad j
\]
Method: RReliefF Feature Ranking

○ **What:**
  ○ A regression-based method for feature ranking.
Method: RReliefF Feature Ranking

- **What:**
  - A regression-based method for feature ranking.

- **How:**
  - Probability that two instances have the same predicted rate.
  - Probabilistic differences by feature are used to create the ranking.
Method: Marginal Effects

Estimate the effects of a feature by

1. Setting all other feature values equal to the mean (average) of each instance $i$.
2. Predict $\hat{r}_i$.
3. Plot $\hat{r}_i$. 
M5 Ridge Regression performance.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
<th>Correlation</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.3441</td>
<td>0.1702</td>
<td></td>
</tr>
</tbody>
</table>
Key Findings: Facility

Do facilities have different cultures regarding hand hygiene compliance?

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Avg Val</th>
<th>Avg Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility</td>
<td>0.029(±0.001)</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>$h_j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility = 101</td>
<td>$h_{j \in \text{Fac}^-} \in [-0.103, -0.016]$</td>
</tr>
<tr>
<td>Facility$^+$ = 91</td>
<td>$h_{j \in \text{Fac}^+} \in [0.008, 0.261]$</td>
</tr>
</tbody>
</table>
Key Findings: Flu Severity

Do higher rates of *influenza mortality* lead to higher rates of compliance?
Can atmospheric effects be associated with higher/lower rates of hand hygiene?

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<tr>
<th>Attribute</th>
<th>Avg Val</th>
<th>Avg Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Temp</td>
<td>0.005</td>
<td>3.3(±0.46)</td>
</tr>
<tr>
<td>Rel. Humid.</td>
<td>0.001</td>
<td>6.3(±0.64)</td>
</tr>
</tbody>
</table>

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<tr>
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</tr>
</thead>
<tbody>
<tr>
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</tr>
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Conclusions

There appear to be facility-specific cultures and attitudes regarding hand hygiene compliance.

Temperature and humidity appear to have a positive impact on hand hygiene compliance.

Greater levels of flu severity, as measured by mortality, are positively associated with hand hygiene compliance.

Also find that holidays, night shift, weekends, and the first week of July see decreases in hand hygiene compliance (results not discussed).
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