Comparing individual exposure to air and noise pollution in Montreal during rush hours according to the mode of transportation used

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Background

Benefits of urban cycling
• Increasing physical activity
• Reducing chronic diseases (diabetes, cardiovascular diseases, certain types of cancer) (Hamer et al., 2008; Hu et al., 2003; Sato et al., 2007; Gordon-Larsen et al., 2009; Woodcock et al., 2009)
• Reducing air pollutant emissions (Hatzopoulou et al., 2013; Rojas-Rueda et al., 2011)

Health risks of urban cycling
• Traffic incidents (injuries and mortality) (Skic et al., 2009; Morency et al., 2011)
• Exposure to air pollution (CO, NO₂, NOₓ, PM₂.₅, PM₁₀)
  • Development of asthma (Jerrett et al., 2008; McConnell et al., 2006)
  • Potential risk to cardiovascular health (Brugge et al., 2007; Rioux et al., 2010)
• Prolonged exposure to road traffic noise
  • Psychological stress (Passchier-Vermeer and Passchier, 2000)
  • High blood pressure (Bluhm et al., 2007)
  • Development of cardiovascular disease (Babisch, 2006)
  • Hearing loss (Seto et al., 2007)

Differences in air pollution and inhaled doses according to the modes of transportation used
• Systematic review of 39 studies (Cepeda et al., 2017)
  • Car commuters: higher exposure to air pollutants
  • Active commuters: higher inhaled doses than car commuters
Three Research Objectives

Comparing Travel Times

Comparing Individual-Level Exposure to

- Traffic Noise dB(A)
- Air Pollution NO₂
- Inhaled Dose of NO₂

Mapping the Results (Web-Atlas)
Data Collection

1. **Real-time measurement of noise exposure**
   Brüel & Kjaer - Personal Noise Dosimeter Type 4448
   - Average value of dB(A) every minute (Laeq 1 min.)
   - Calibration of the device once a day using the Sound Calibrator Type 4231

2. **Real-time measurement of NO₂ exposure**
   Aeroqual Series 500 (Portable Air Quality Sensor)
   - Nitrogen dioxide (NO₂) sensor
   - Temperature and humidity sensor
   - Average value of NO₂ logged every minute

3. **Garmin Forerunner 920 XT**
   - Multisport GPS Watch
   - Heart rate monitor

4. **Garmin VIRB XE**
   - Action camera
   - GPS
Data Collection

Collection period
2016-06-16 to 2016-06-30 (dry weekdays)

Participants
8 master’s students and 1 urban studies professor
- 3 teams of 3 people each
  - One person by car
  - One person by bicycle
  - One person by public transit

Trips during rush hours (N = 99)
8 am: from an outlying Montreal neighbourhood to the downtown area
5 pm: in the opposite direction

Trip duration (min.)

<table>
<thead>
<tr>
<th></th>
<th>Car (min.)</th>
<th>Bicycle (min.)</th>
<th>Public Transit (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1,239</td>
<td>1,280</td>
<td>1,375</td>
</tr>
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</table>

Trip length (km / miles)

<table>
<thead>
<tr>
<th></th>
<th>Car (km)</th>
<th>Bicycle (km)</th>
<th>Public Transit (km)</th>
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</thead>
<tbody>
<tr>
<td>N =</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Min.</td>
<td>5.8 / 3.1</td>
<td>6.0 / 3.7</td>
<td>6.0 / 3.1</td>
</tr>
<tr>
<td>Max.</td>
<td>20.0 / 12.4</td>
<td>20.8 / 12.4</td>
<td>20.0 / 12.4</td>
</tr>
<tr>
<td>Mean</td>
<td>10.2 / 6.2</td>
<td>11.3 / 6.8</td>
<td>10.4 / 6.2</td>
</tr>
<tr>
<td>Total</td>
<td>344 / 213</td>
<td>337 / 209</td>
<td>364 / 226</td>
</tr>
</tbody>
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Temperature (Celsius / Fahrenheit)

<table>
<thead>
<tr>
<th></th>
<th>Car (°C)</th>
<th>Bicycle (°C)</th>
<th>Public Transit (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min.</td>
<td>10 / 50</td>
<td>39 / 102</td>
<td>28 / 82</td>
</tr>
<tr>
<td>Max.</td>
<td>39 / 102</td>
<td>6.8</td>
<td>6.2</td>
</tr>
<tr>
<td>Mean</td>
<td>28 / 82</td>
<td>6.8</td>
<td>6.2</td>
</tr>
</tbody>
</table>
Methodology: Estimating Ventilation and Inhaled Dose of NO₂

1. Test for each participant
Marie-Eve Mathieu
Department of Kinesiology
Physical Activity and Health Lab.
University of Montreal

2. Individualized equation between heart rate (Garmin) and ventilation (Moxus)

Progressive and maximal test

3. Estimation of the ventilation per minute based on heart rate values measured by the multisport Garmin watch during the trip

4. Estimation of the dose of NO₂ inhaled per minute during the trip

μg NO₂ = (V / 1000) * P with
V = Ventilation (liters per min.); P = NO₂ value
Results: Comparing Travel Times

<table>
<thead>
<tr>
<th></th>
<th>Order of finishers</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
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<tr>
<td></td>
<td>3</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Travel times* (min.)</th>
<th>Travel time differences from car (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Quartile</td>
<td>Median</td>
</tr>
<tr>
<td>Car</td>
<td>25.8</td>
<td>34.0</td>
</tr>
<tr>
<td>Bicycle</td>
<td>28.7</td>
<td>34.6</td>
</tr>
<tr>
<td>Total</td>
<td>31.0</td>
<td>40.2</td>
</tr>
</tbody>
</table>

3<sup>rd</sup> Quartile

|                      | 49.8                  | 45.5   | 50.0 |

* Note: Differences in mean values are not significant at P=0.05 (Kruskal-Wallis test and Tukey Test).
Results: Comparing Levels of Exposure to Road Traffic Noise

Anova: $R^2 = 0.236; F = 571; P = 0.000$

70 dB(A): Guideline value in a traffic area (World Health Organization)

Significant impacts on health (including hearing impairment)

Level of noise (dB(A)) by minute

- Mean: 66.9
- Difference from the mean by car: --
- 69.0
- 69.0
- 69.0
- 73.0
- 73.0

* Significant difference at P=0.01 (Tukey Test)
Results: Comparing Levels of Exposure to Air Pollution

Anova: $R^2 = 0.002; F = 4.07; P = 0.017$

Anova: $R^2 = 0.274; F = 711; P = 0.000$

Significant impacts on health

200 μg/m³: Short-term (1-hour) NO₂ guideline value (WHO)

* Significant difference at P=0.01 (Tukey Test)
Mapping the Results: A Web-Atlas

Comparing individual exposure to air and noise pollution in Montreal according to the mode transportation used.
Concluding Remarks

Calendar burned & Health benefits

- **Inhaled dose**: three times higher for cyclists than for car users
- Importance of measuring noise and the inhaled dose of air pollutant for cyclists, especially in cities with high levels of noise and air pollution
Future Work

Improvements in the methodological approach
   - Biometric T-Shirt (Hexoskin)
     - Heart Rate & Breathing Rate & Minute Ventilation

Planned activities (2016-2017)
   - Cyclists’ exposure to air and noise pollution
     - Mexico City (March 2016): 201 km collected
     - Saigon (Vietnam) (July 2017)
     - Lyon (France) (October 2017)
     - Auckland & Christchurch (New Zealand) (???)
## Results: Comparing Travel Times

<table>
<thead>
<tr>
<th></th>
<th>Car</th>
<th>Bicycle</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Quartile</strong></td>
<td>65.8</td>
<td>81.2</td>
<td>71.6</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>88.7</td>
<td>102.8</td>
<td>82.3</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>97.4</td>
<td>101.0</td>
<td>96.1</td>
</tr>
<tr>
<td><strong>3rd Quartile</strong></td>
<td>115.6</td>
<td>125.4</td>
<td>115.2</td>
</tr>
</tbody>
</table>