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# Linked police and health data: how to apply capture-recapture to correct for under-reporting and bias

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## Linked police and health data

1) police data : in most countries

(killed= well-recorded in industrialized countries)

Injured= large under-reporting and bias

2) Health data :

National hospital discharge data = inpatients

Emergency departments (ED)  $\approx$  outpatients

The Rhone road trauma registry  $\approx$  outpatients and inpatients

# Linked police and health data : under-reporting, Rhone example

annual mean	Police data	Health data	linked	total	Tot./pol	Tot/health
2006-2016	2800	7600	1700	8600	3,1	1,1

France, Rhone county (1,8 M)

Health data:  
Rhone road trauma registry  
= outpatients + inpatients

		In health data (B) ?		total
		yes	no	
In police data (A) ?	yes	<b>1700</b>	<b>1100</b>	2800
	no	<b>5900</b>	<b>?</b>	
total		7600		n=8600+ ?

# Correcting for under-reporting: capture-recapture on linked police and health data

		In health data (B) ?		total
		yes	no	
In police data (A) ?	yes	$n_{AB}$	$n_{A\bar{B}}$	$n_A$
	no	$n_{\bar{A}B}$	$n_{\bar{A}\bar{B}} = ?$	
total		$n_B$		$n = ?$

Simple 2-list method (IF capture-recapture conditions are met):

Petersen estimate :

$$\frac{n_{AB}}{n_A} = \frac{n_B}{n} \quad \longrightarrow \quad \hat{n} = \frac{n_A \times n_B}{n_{AB}}$$

# Capture-recapture conditions

## 2 implicit conditions:

- same geographical area and same time period
- perfect identification of subjects of interest (injured, in a road crash)  
(implies same definition in both sources)

## 4 key conditions:

- close population
- perfect record-linkage
- independence between sources (registrations)
- homogeneity of capture : for a given source/ registration (ex: police),  
the different casualties have the same probability of being recorded,  
whatever their characteristics

## discussion of some capture-recapture conditions

1) positive dependence between hospital and police data  
=> capture-recapture estimate will be a lower bound

2) capture by police-reporting is not homogenous ;  
it usually varies with

- injury severity
- mode of transport (pedestrians, bicycle, M2W, car, etc)
- single-vehicle / multi-vehicle crash or crash opponent (yes/no)
- type of road network
- driver / passenger
- type of police

3) health-reporting slightly varies with  
- injury severity

## under-reporting and **biais** : example

<b>annual mean</b>	<b>police</b>	<b>health</b>	<b>linked</b>	<b>total</b>	<b>Tot./pol.</b>	<b>Tot/health</b>
M2W, with opponent	557	865	371	1052	1,9	1,2
M2W, without opp.	96	1063	65	1094	11,4	1,0
bicycle, with opp.	157	332	100	389	2,5	1,2
bicycle, without opp.	6	916	4	919	146,4	1,0
car, with opp.	1092	2415	647	2859	2,6	1,2
car, without opp	269	1050	178	1140	4,2	1,1
<b>total</b>	<b>2789</b>	<b>7563</b>	<b>1733</b>	<b>8619</b>	<b>3,1</b>	<b>1,1</b>

France, Rhone county, 2006-2016 (health data= outpatients+ inpatients)



# capture-recapture on each strata : mode \* crash opponent

		In health data (B) ?		total
		yes	no	
In police data (A) ?	yes	$n_{AB}$	$n_{A\bar{B}}$	$n_A$
	no	$n_{\bar{A}B}$	$n_{\bar{A}\bar{B}} = ?$	
total		$n_B$		$n = ?$

Petersen estimate :

$$\hat{n} = \frac{n_A \times n_B}{n_{AB}}$$



## => Capture-recapture with stratification on mode\* crash opponent:

annual mean	Police data	Health data	linked	total	Tot/ police	Tot/ health	<b>CRC</b>	CRC/ pol.	CRC/ health.
M2W, with opp.	557	865	371	1052	1,9	1,2	<b>1300</b>	2,3	1,5
M2W, without opp.	96	1063	65	1094	11,4	1,0	<b>1573</b>	16,4	1,5
bicycle, with opp.	157	332	100	389	2,5	1,2	<b>523</b>	3,3	1,6
bicycle, without opp.	6	916	4	919	146,4	1,0	<b>1437</b>	229,1	1,6
car, with opp.	1092	2415	647	2859	2,6	1,2	<b>4073</b>	3,7	1,7
car, without opp	269	1050	178	1140	4,2	1,1	<b>1583</b>	5,9	1,5
total	2789	7563	1733	8619	3,1	1,1	<b>12016</b>	4,3	1,6

**But** capture-recapture (CRC) with stratification on mode\* crash opponent: pb with #MAIS3+

annual mean	Police data	Police MAIS3+	Pol prop3+	Health data	Heath MAIS3+	Health prop3+	total	Tot. Prop3+	CRC	CRC mais3+	CRC prop3+
M2W, with opp.	557	103	<b>18%</b>	865	95	<b>11,0%</b>	1052	11,7%	<b>1300</b>	237	<b>18%</b>
M2W, without opp.	96	29	<b>30%</b>	1063	61	<b>5,7%</b>	1094	6,3%	<b>1573</b>	470	<b>30%</b>
bicycle, with opp.	157	20	<b>13%</b>	332	21	<b>6,2%</b>	389	6,9%	<b>523</b>	68	<b>13%</b>
bicycle, without	6	2	<b>37%</b>	916	37	<b>4,0%</b>	919	4,1%	<b>1437</b>	533	<b>37%</b>
car, with opp.	1092	57	<b>5%</b>	2415	49	<b>2,0%</b>	2859	2,3%	<b>4073</b>	212	<b>5%</b>
car, without opp	269	31	<b>12%</b>	1050	38	<b>3,6%</b>	1140	4,1%	<b>1583</b>	183	<b>12%</b>
<b>total</b>	<b>2789</b>	<b>338</b>	<b>12%</b>	<b>7563</b>	<b>386</b>	<b>5,1%</b>	<b>8619</b>	<b>5,6%</b>	<b>12016</b>	<b>1952</b>	<b>16%</b>

**Estimated number of MAIS3+ is too high and biased**

## discussion of some capture-recapture conditions

1) positive dependence between hospital and police data  
=> capture-recapture estimate will be a lower bound

2) capture by police-reporting is not homogenous ;  
it usually varies with

- **injury severity**
- mode of transport (pedestrians, bicycle, M2W, car, etc)
- single-vehicle / multi-vehicle crash or crash opponent (yes/no)
- type of road network
- driver / passenger
- type of police

3) health-reporting slightly varies with  
- injury severity

## Linked police and health data : predict MAIS3+

France, Rhone  
county (1,8 M)

Health data:  
Rhone road  
trauma registry  
= outpatients +  
inpatients

		In health data (B) ?		total
		yes	no	
In police data (A) ?	yes	<b>1700</b>	<b>1100</b>	2800
	no	<b>5900</b>		
total		7600		

Construct  $P(\text{MAIS } 3+ / 1-2)$  on the linked dataset (MAIS from Health data)

$P(\text{MAIS } 3+ / 1-2)$  as a function of crash and injured road user characteristics (from police data)

Apply the model to the subset "police data only"

=> predicted or observed MAIS3+ for all casualties observed in the Rhone county



Capture-recapture on mode \* crash opponent \* **MAIS** (1-2/3+):

annual mean	Police data	Police MAIS3+	Pol prop3+	Health data	Heath MAIS3+	Health prop3+	total	Tot. Prop3+	CRC	CRC MAI3+	CRC prop3+
M2W, with opp.	557	103	<b>18%</b>	865	95	<b>11,0%</b>	1052	11,7%	<b>1314</b>	130	<b>9,9%</b>
M2W, without opp.	96	29	<b>30%</b>	1063	61	<b>5,7%</b>	1094	6,3%	<b>1634</b>	82	<b>5,0%</b>
bicycle, with opp.	157	20	<b>13%</b>	332	21	<b>6,2%</b>	389	6,9%	<b>527</b>	30	<b>5,6%</b>
bicycle, without opp.	6	2	<b>37%</b>	916	37	<b>4,0%</b>	919	4,1%	<b>1464</b>	56	<b>3,8%</b>
car, with opp.	1092	57	<b>5%</b>	2415	49	<b>2,0%</b>	2859	2,3%	<b>4096</b>	72	<b>1,8%</b>
car, without opp.	269	31	<b>12%</b>	1050	38	<b>3,6%</b>	1140	4,1%	<b>1600</b>	52	<b>3,3%</b>
<b>total</b>	<b>2789</b>	<b>338</b>	<b>12%</b>	<b>7563</b>	<b>386</b>	<b>5,1%</b>	<b>8619</b>	<b>5,6%</b>	<b>12175</b>	<b>549</b>	<b>4,5%</b>

## Capture-recapture :

**However:**

Some strata may contain **small frequencies:**

ex: injured cyclists without crash opponent in police data

**More than 3 variables** are associated with under-reporting:

- injury severity,
- mode of transport
- single-multi vehicle crash,
- type of road network,
- driver/passenger
- type of police

**=> multivariate modelling**

# Multivariate multinomial model

## Multinomial response variable Y :

- 1= Casualties recorded in police data only
- 2= Casualties recorded in health data only
- 3= Casualties recorded in both  
(disjoint subgroups)

## Explanatory variables: those associated with under-reporting

- injury severity,
- mode of transport
- single-multi vehicle crash,
- type of road network,
- driver/passenger
- type of police

model with interaction between the 3 variables = stratification on 3 variables  
model with interaction between 2 var + var3 as main effect = no equivalent

## Multivariate multinomial model

with SAS software:

```
PROC LOGISTIC data = collBUR out=modelCRC;  
class source (ref = "1") mode_oppon (ref="carWithO") MAIScode (ref= "MAIS3p") / param = ref;  
model source = mode_oppon MAIScode var3 var4 var5 / link = glogit;  
weight decimal_freq; * freq=integer_freq;  
format _all_;  
ods output ParameterEstimates=est;  
run;
```

Source : where the casualty is registered

1= in police data only / 2= in health data only, 3= in police AND health data



# Multivariate multinomial model

with R software:

```
modelCRC <- multinom(source ~ mode_oppon + MAIScode + var3 + var4 + var5,  
data=collBUR, weights=freq)
```

```
summary(modelCRC)
```

```
betas_modelCRC <- coef(modelCRC)
```

## Multinomial model on French data :

- Type of police (3 categories) \* type of road
- Daytime/nighttime
  
- Mode of transport \* crash opponent
- MAIS (1-2 / 3+)
- Hospitalized (yes/no)
- (Age)
- (Gender)
- Driver /passenger

**Thank you for your attention**

**UMRESTTE**

**UNITÉ MIXTE DE RECHERCHE  
ÉPIDÉMIOLOGIQUE ET DE SURVEILLANCE  
TRANSPORT TRAVAIL ENVIRONNEMENT**

Sous la co-tutelle de :

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Additional slides

# Correcting for under-reporting and bias with capture-recapture on linked police and health data

ex: French Rhône county, 1996-2004, average annual frequencies

		In hospital data (B) ?		
		yes	no	
In police data (A) ?	yes	<b>1700</b>	<b>1100</b>	2800
	no	<b>5900</b>	<b>?</b>	
		7600		n=8600+ ?