IN4ACT WEBINAR SERIES

"YOU CAN'T MANAGE WHAT YOU DON'T MEASURE": SOCIAL PHYSICS AND INDUSTRY 4.0 FOR INVESTIGATING HUMAN FACTORS INSIDE BUSINESS ORGANIZATIONS

FEBRUARY 12th, 1pm

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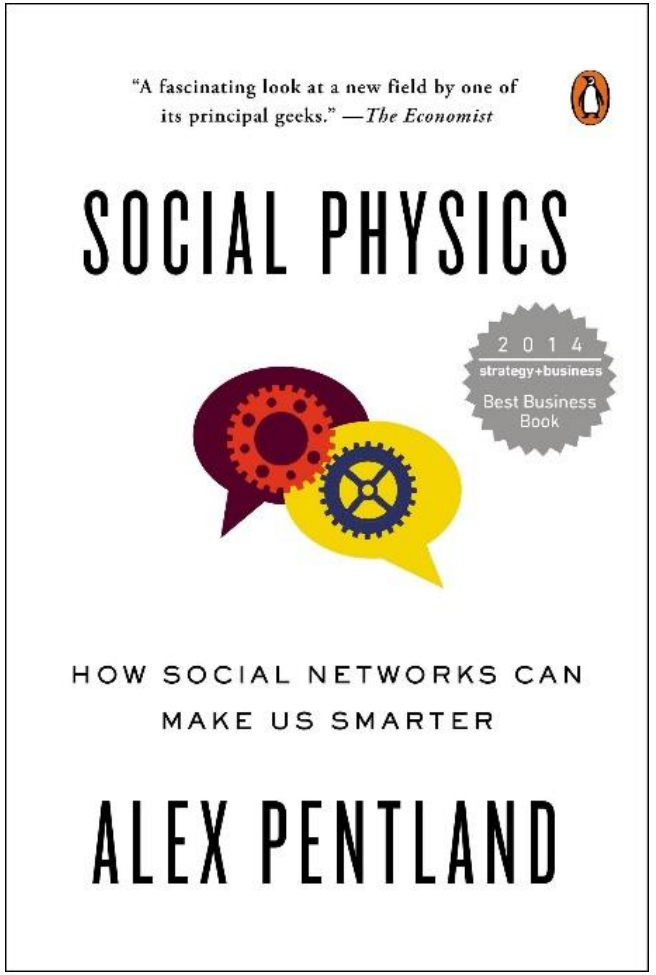
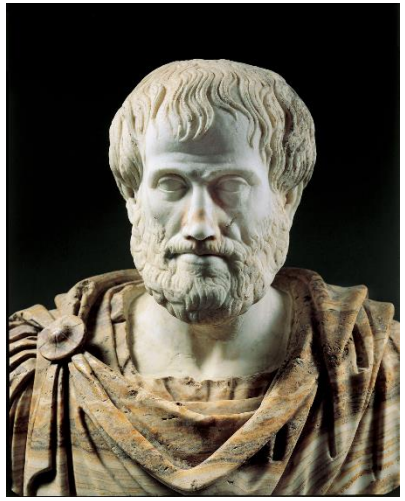
OVERVIEW

- Social Physics history and definition
- Application examples of Social Physics
- Social Physics & new technologies
- Social Physics & Business Organizations
- Case studies:
  - Breast Surgery
  - Emergency Department
  - Logistics Hub



SOCIAL PHYSICS: HISTORY

The **Human Being** is a **Social Animal** and more or less all its activities take place in a group.



Aristotle (384-322 BC)

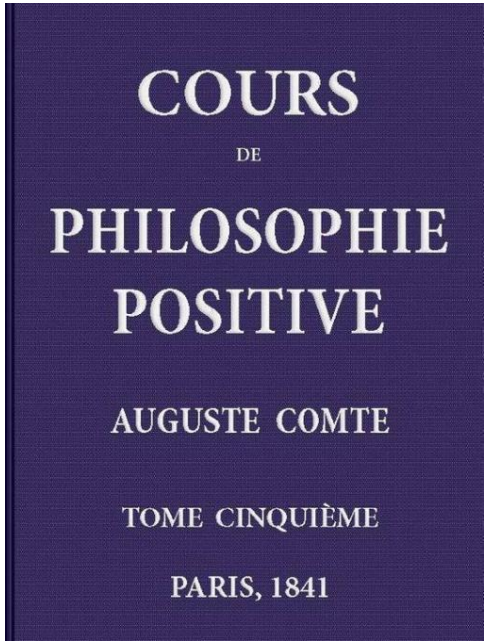
"Man is by nature a social animal; an individual who is unsocial naturally and not accidentally is either beneath our notice or more than human. Society is something that precedes the individual."

We must stop thinking of people as independent decision makers, and realize that **social dynamics** shape our ideas/perceptions and are the driving forces behind economy, political revolutions, and organizations.

SOCIAL PHYSICS: HISTORY

SOCIOLOGY is the study of social life, social change, and the social causes and consequences of human behavior. Sociologists investigate the structure of groups, organizations, and societies and how people interact within these contexts.

(American Sociological Association)



The father of Sociology

Auguste Comte (1798-1857)

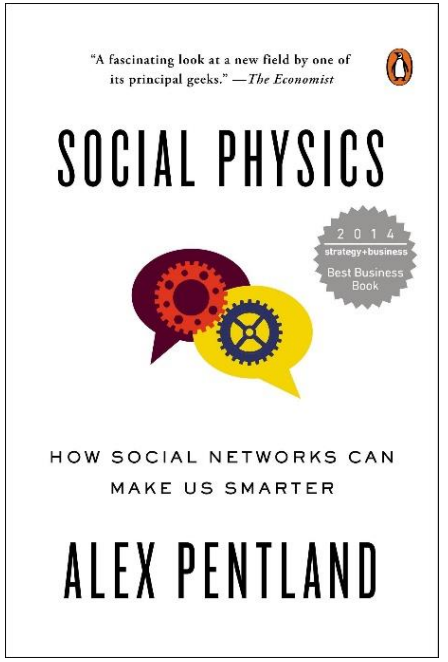
SOCIAL PHYSICS: DEFINITION

*"**Social Physics** is a social science that describes mathematical connections between information and idea flow and people's behaviors.*

Social Physics help us understand how these flows end up shaping the norms, productivity, and creativity output of our companies, cities, and societies. It enables us to predict the productivity of small groups, of departments within companies, or of entire cities." (Alex 'Sandy' Pentland)

Unlike traditional sociological approaches to understanding human society, social physics doesn't use **abstract models of human behavior**.

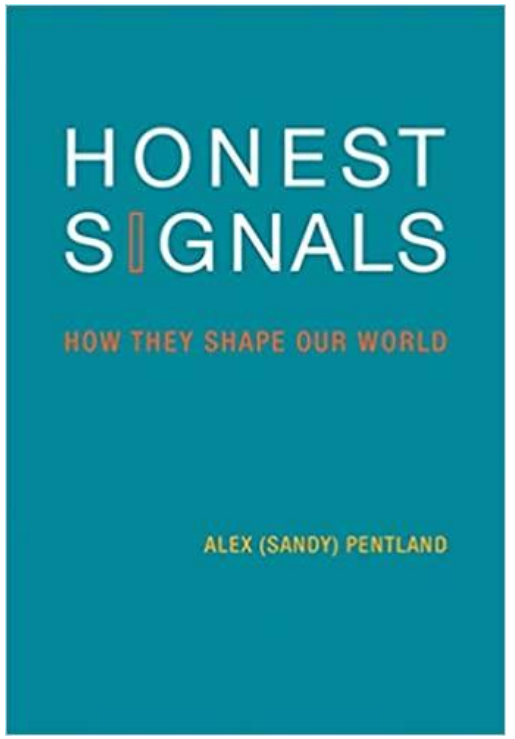
It uses **living labs**: analysing real direct data from "every" facet of human behavior.



SOCIAL PHYSICS: DEFINITION

Physics tries to understand how the flow of energy translates into changes in motion

Social physics seeks to understand how the flow of information and idea translates into changes in human behavior

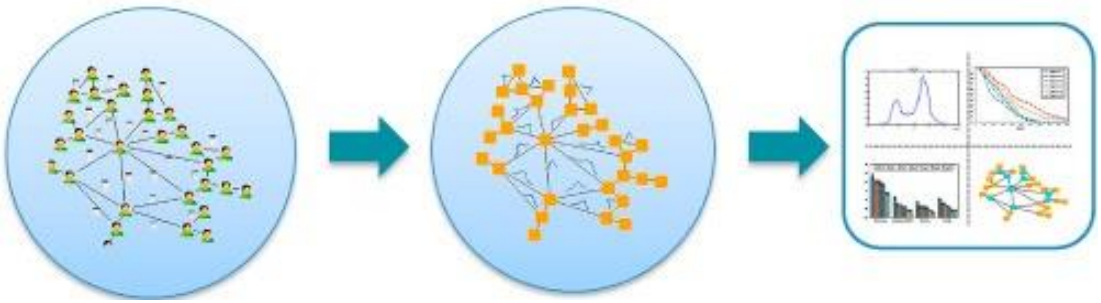


Social physics functions by analyzing patterns of human behaviors, information exchanges and the so-called "Honest Signals" in the '**real world**'.

SOCIAL PHYSICS RESEARCH APPROACH

Social Physics permits:

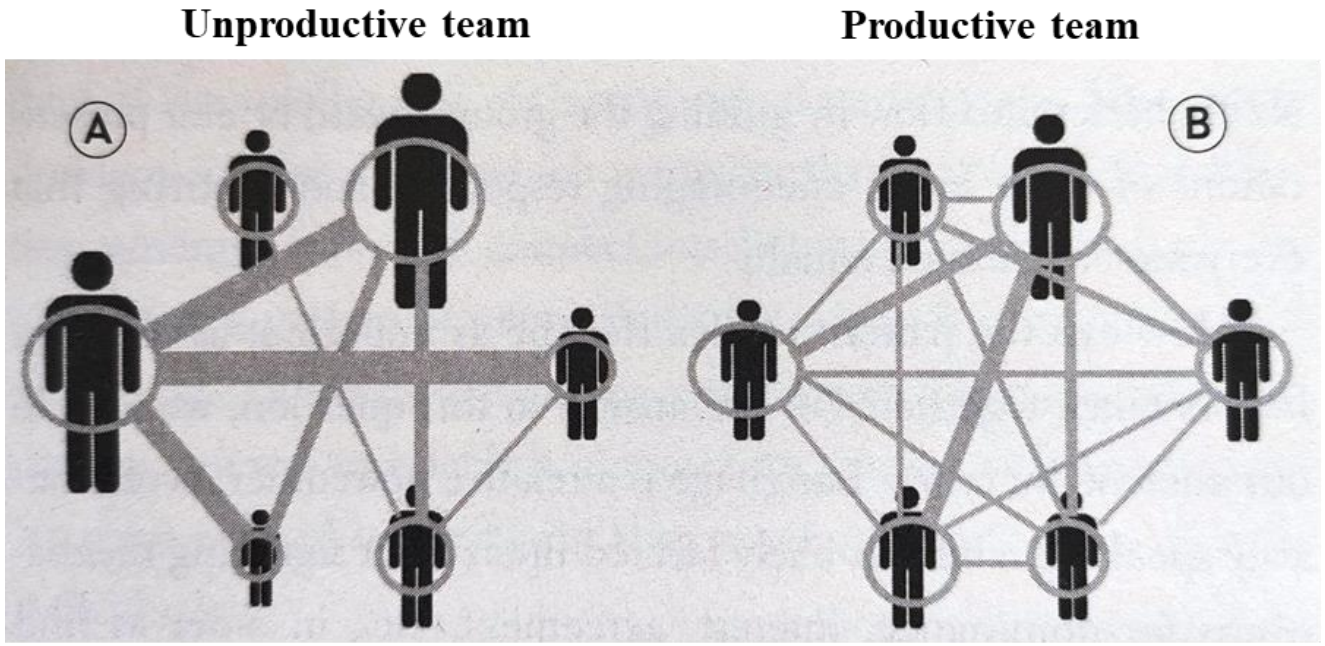
- **Investigation** and **modeling** of human behaviors (individual/collective patterns of behaviors) during the real human activities
- **Assessment** of the human behavior **effects** on many different elements of our society (business organizations, cities and communities, private life, etc.)



Many different behaviors can be studied

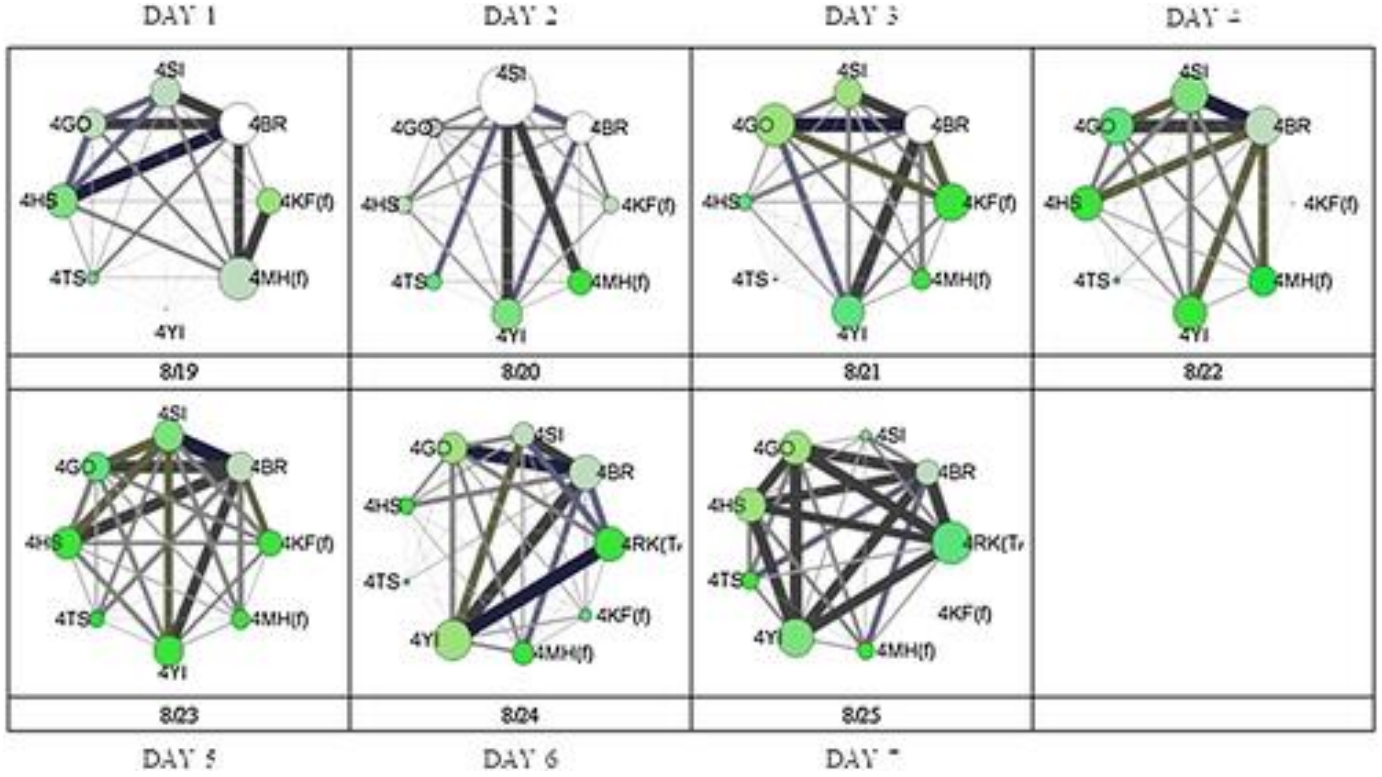
SOCIAL PHYSICS: APPLICATION EXAMPLES

Spoken interactions in creative groups like product development teams. Example of “brainstorming”/”ideas generations” phase:

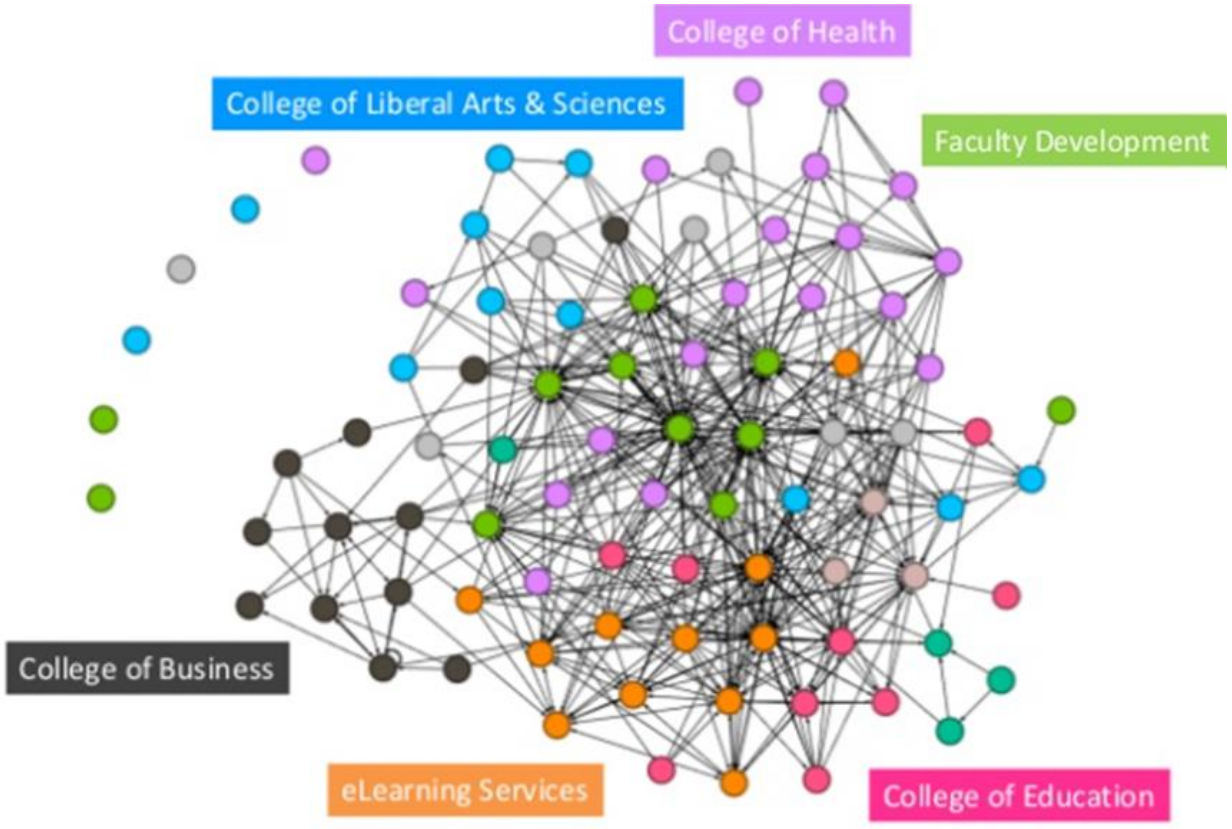


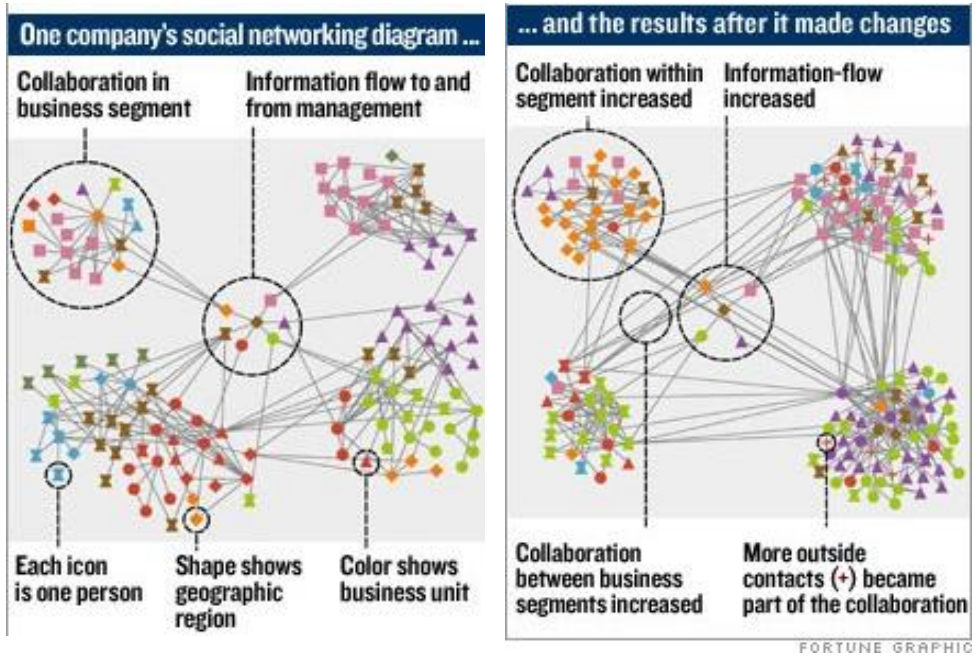
SOCIAL PHYSICS: APPLICATION EXAMPLES

Evolutions of creative team interactions:



SOCIAL PHYSICS: APPLICATION EXAMPLES

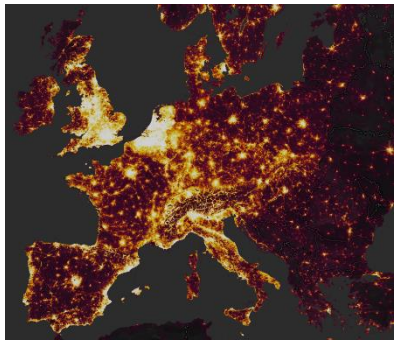


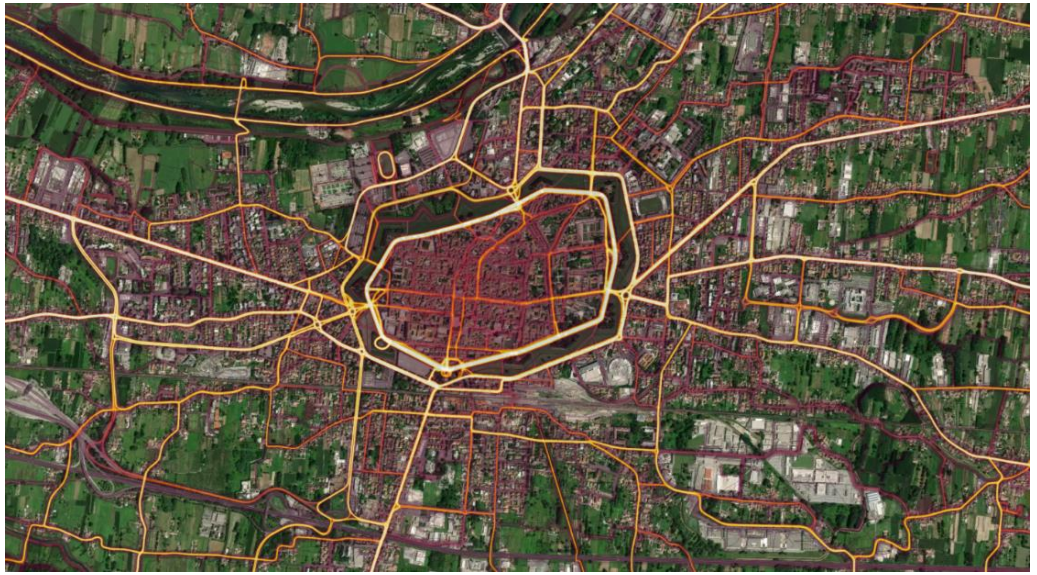


Investigations of group behaviors in business organizations and related intervations

SOCIAL PHYSICS: APPLICATION EXAMPLES

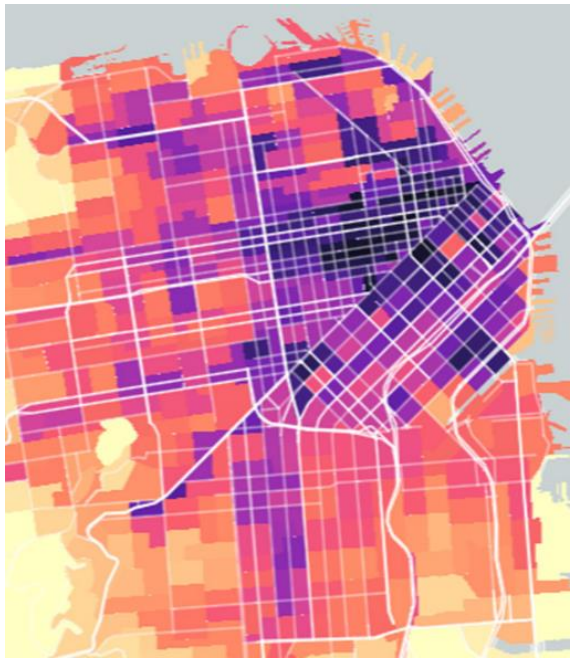
STRAVA

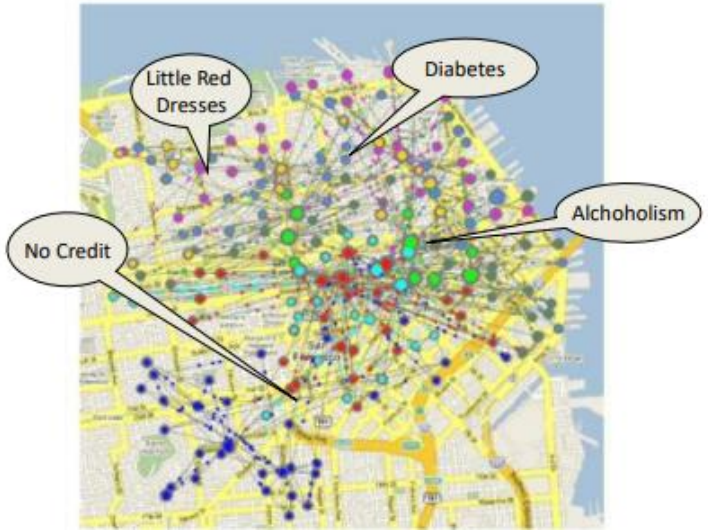




Investigations of human behaviors in the urban areas, for designing better cities or understand potential problems

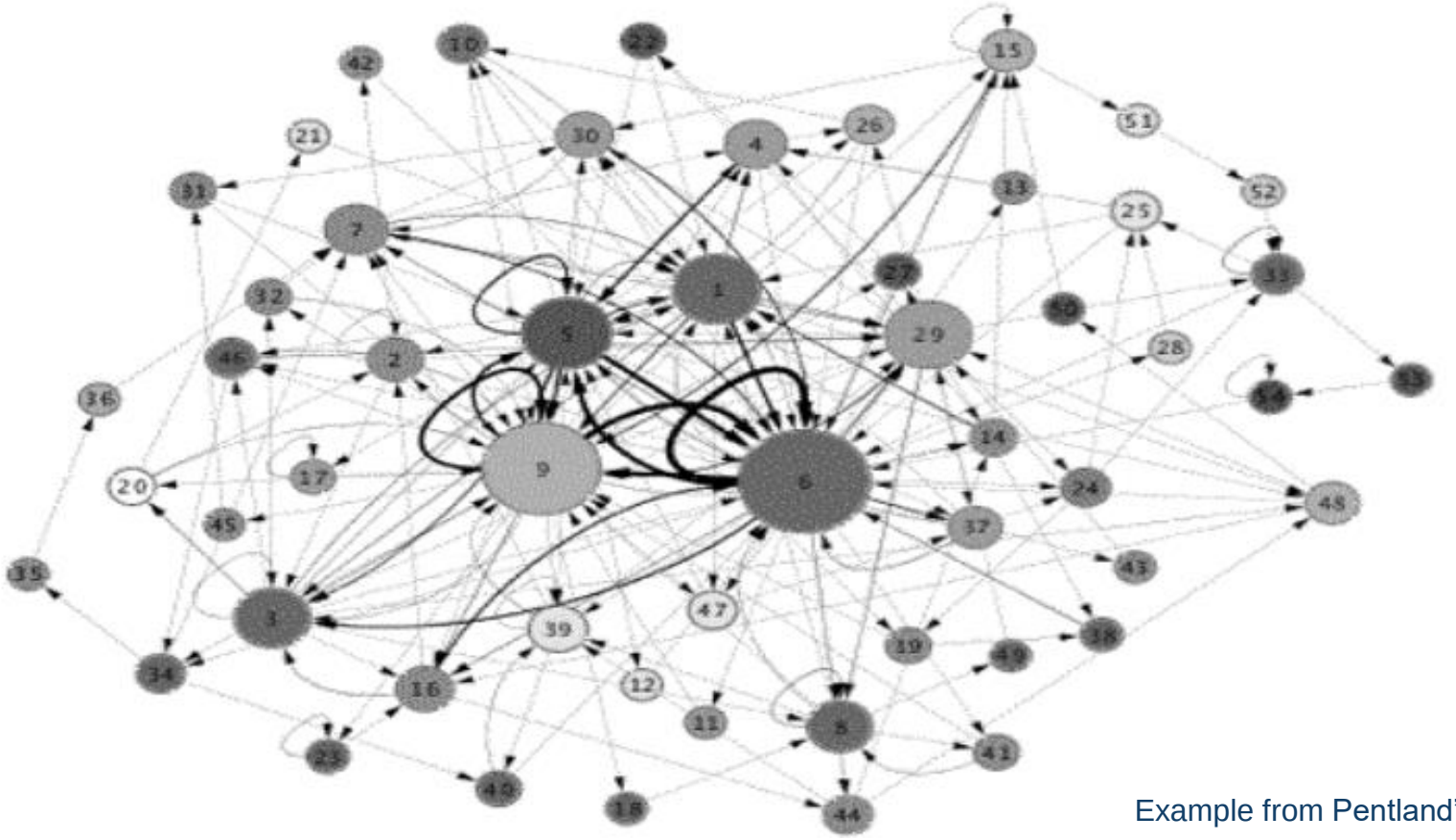
SOCIAL PHYSICS: APPLICATION EXAMPLES





Investigations of human behaviors in the urban areas, for designing better cities or understand potential problems

SOCIAL PHYSICS: APPLICATION EXAMPLES



Example from Pentland's book

But, also investigation of behaviors of individuals (example with credit card expenditure data)

SOCIAL PHYSICS & NEW TECHNOLOGIES

Why was this idea of "Social Physics" only recently born

In the past, it was not possible to simply measure patterns of human behaviors, information exchanges and the so-called "Honest Signals" in the 'real world'. Social Physics needs lots of (detailed) data.

New availability of data on human activities and interactions "in internet"

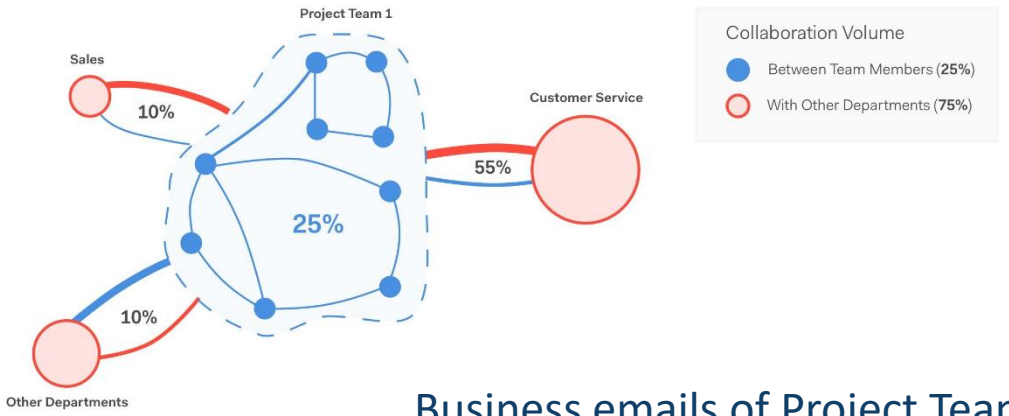
"Big Data"

New 4.0 tools (IoT) - wearable sensors and similar technologies

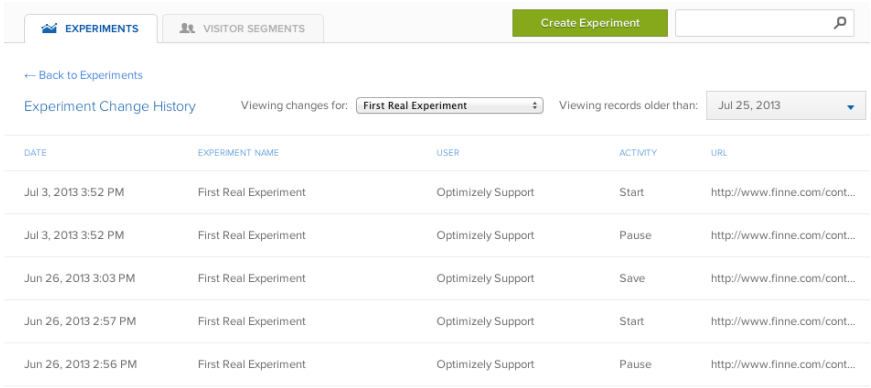
Usually the data are analyzed with statistical techniques, machine learning algorithms, SNA, etc.

SOCIAL PHYSICS & NEW TECHNOLOGIES

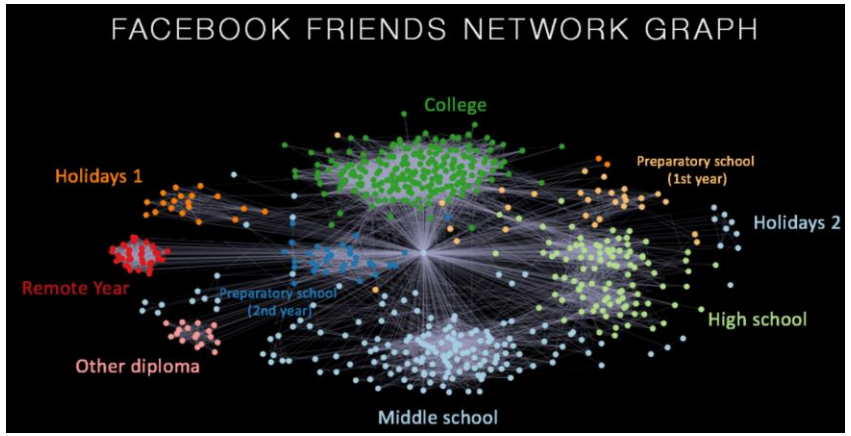
New availability of data on human activities and interactions: e.g., emails, social apps, event logs



Business emails of Project Teams



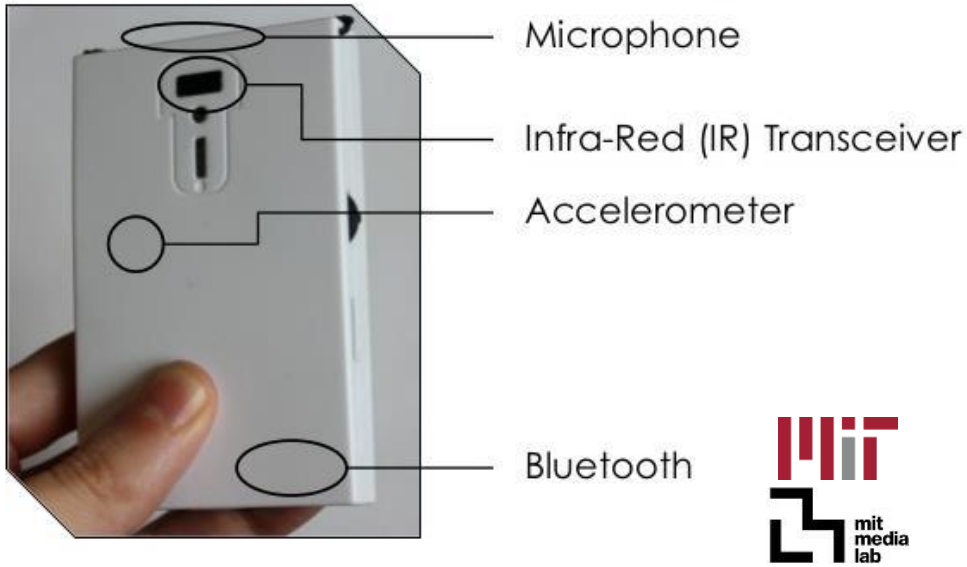
Logs of activities or documents history



Facebook network

SOCIAL PHYSICS & NEW TECHNOLOGIES

IoT - wearable tools: e.g. Sociometric Badges (invented by Pentland)

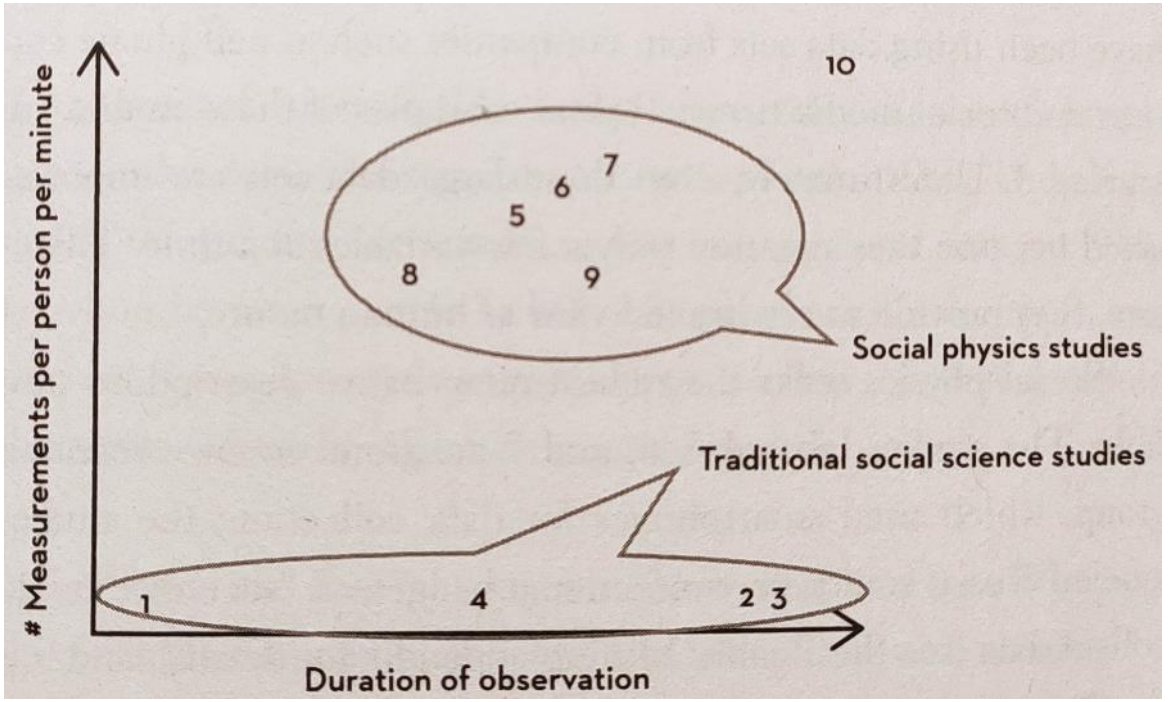


- ✓ four different sensors: accelerometer, microphones, Bluetooth, and IRDA
- ✓ automatic and direct measures of individual and collective behaviors/dynamics
- ✓ main measures: body/posture movement, speaking activity, audio (back and front), interaction networks, mirroring between SB wearers, face-to-face
- ✓ privacy guaranteed

SOCIAL PHYSICS & NEW TECHNOLOGIES

IoT – wearable tools: e.g. Smartwatches, Smartphones and environmental sensors

SOCIAL PHYSICS & RESEARCH METHODS



Source: Pentland (2014)

Figure 1. Qualitative overview of social science observatories and experiments, with the horizontal axis showing data collection duration and the vertical axis showing richness of the information collected. Data sets include: (1) Most social science experiments, (2) Midwest Field Station,* (3) Framingham Heart Study,† (4) Large Call Record data sets‡ (5) Reality Mining,§ (6) Social Evolution,** (7) Friends and Family,†† (8) Sociometric Badge studies,‡‡ (9) Data for Development (D4D) data set,§§ (10) where the world is headed.

"Traditional social science studies" VS "Social physics studies":

- Number and pervasiveness of behavioral measurements
- Number of observations
- Reliability

Social physics seeks the richest quantitative descriptions possible

SOCIAL PHYSICS & RESEARCH METHODS

"Traditional social science methods" VS "Social physics methods":

How to measure human behaviors? Commonly they are assessed by interviews, questionnaires, direct observations, and reports

Affected by:

Subjectivity bias, memory effect, and observer's influence (Kim et al., 2012; Chaffin et al., 2017)

Limits →

- Limited number of observed aspects
- Lower reliability of results (not based on objective data)
- Time-consuming

SOCIAL PHYSICS & RESEARCH METHODS

"Traditional social science methods" VS "Social physics methods":

The advent and spread of IoT tools are offering the opportunity of evaluating human behaviors with novel data-driven methodologies (in workplace, in private life, in sport activities, etc.).

Wearable sensors can provide direct and quantitative measures of human behavior

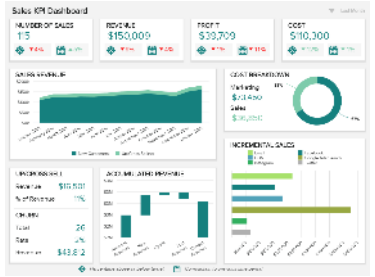
Advantages
(Chaffin et al., 2017)

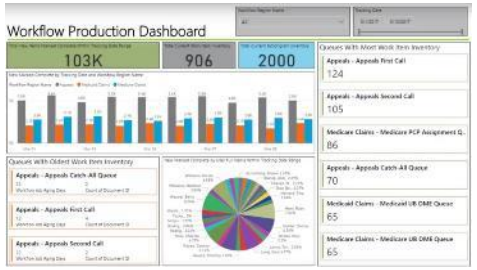
- ✓ Results more objective
- ✓ Data collection in real-time
- ✓ Greater number of behavioral variables gathered

SOCIAL PHYSICS IN BUSINESS ORGANIZATIONS & CASE STUDIES

SOCIAL PHYSICS & BUSINESS ORGANIZATIONS

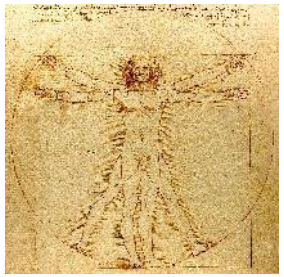
Many tools are available for monitoring, investigating and improving business processes in the everyday life of business organizations (e.g. machine KPIs, sales dashboards, etc.).





But, one crucial element tend to be often overlooked while observing organizations: "**the people**".

Organizations are made of people and, still today, the majority of business activities rely on people.



SOCIAL PHYSICS & BUSINESS ORGANIZATIONS

The attitudes of employees and their collaborative dynamics **highly influence** the **organizational performances**.

→ Managing these factors is therefore crucial for all organizations

For many years, evaluating these dynamics or imagining an organizational monitoring system for such aspects appeared impossible.

Social Physics changes the situation

SOCIAL PHYSICS & BUSINESS ORGANIZATIONS

Social Physics permits to investigate the **employees' behaviors** and **attitudes** in business organizations and to plan **adequate interventions** for improving them with a potential positive effects on business performance

Example:

- Investigation in a call center (Bank of America)

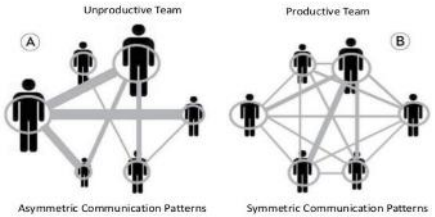
Increase in productivity if employees take breaks together with colleagues and if they interact during such breaks.

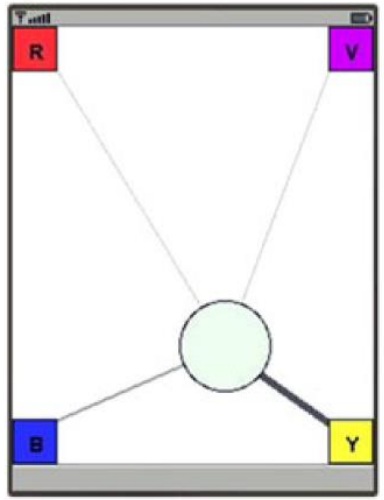
SOCIAL PHYSICS & BUSINESS ORGANIZATIONS

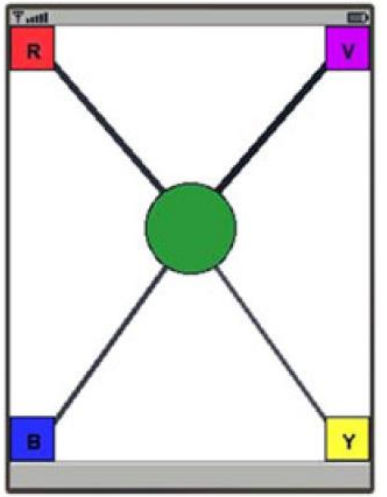
Example with Sociometric Feedback Application:

- Investigation of creative teams (workshops @ MIT)

In this test, Sociometric Feedback Application provides **feedbacks to the participants** of creative teams during a workshop, **to improve team interactions** and the members participation. This application seems able to enhance the team performance.







CASE STUDIES

1. Investigation of teams during **breast surgery** with Sociometric Badges

2. Study of **Emergency Department** team behaviors with Sociometric Badges

3. Analysis of human and environmental factors in a **logistics hub** with smartwatches, smartphones, and smart sensors

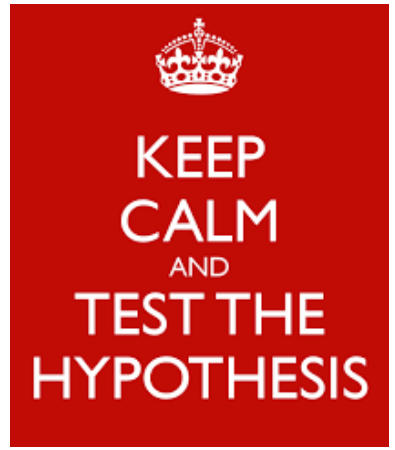
CASE STUDY: BREAST SURGERY

Aim: Investigation of team coordination dynamics during breast surgery and their relationship with the occurrence of surgical glitches

Tools: Sociometric Badges

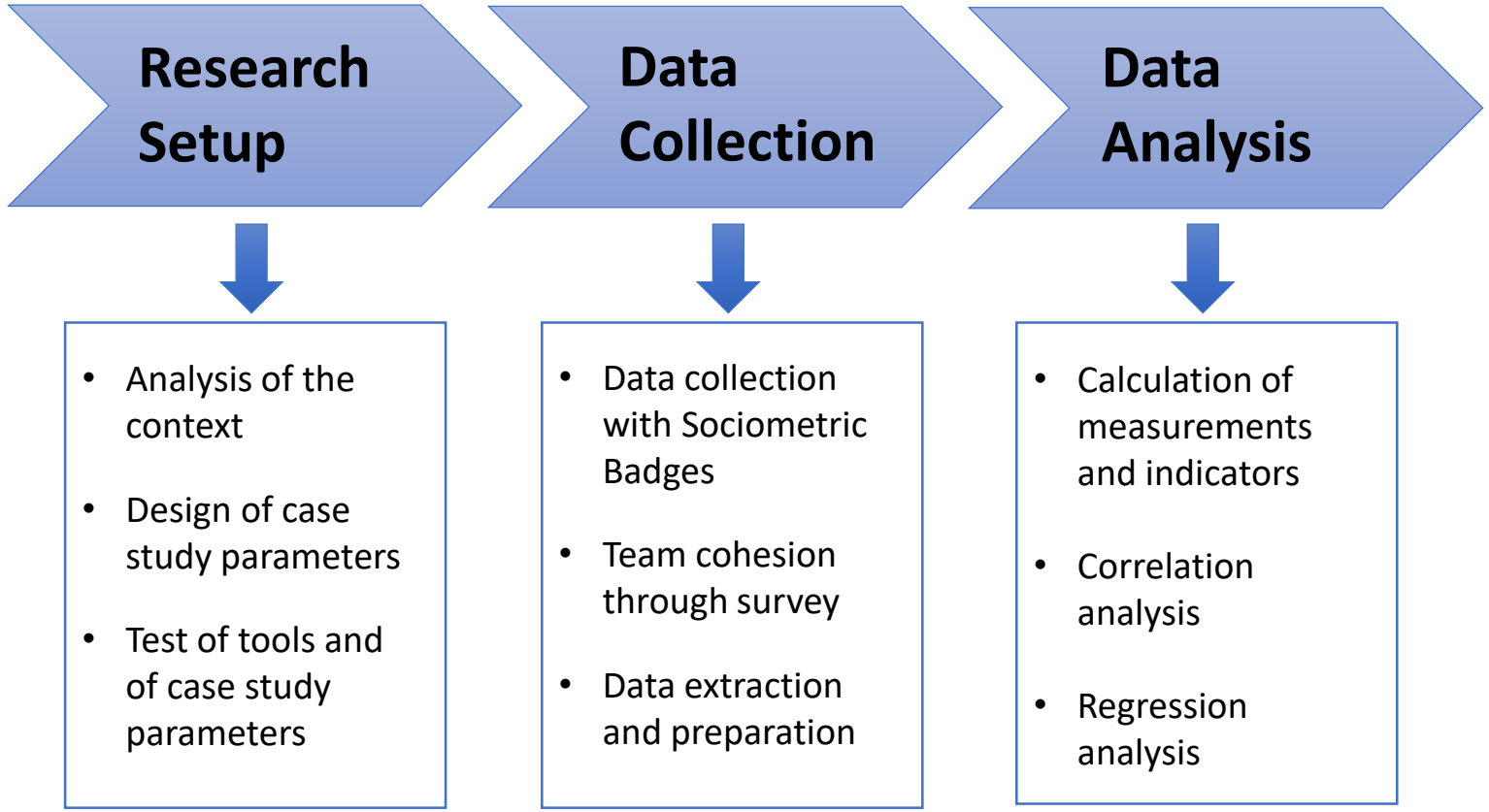
Research hypothesis:

*Hypothesis for routine surgery - The **lower** the proportion of **explicit coordination** of the surgical team by verbal interaction, the **higher** is the **performance** of the team*



CASE STUDY: METHODOLOGY

Standard methodology for the investigations with Sociometric Badges:



CASE STUDY: BREAST SURGERY – DATA COLLECTION

We collected data from **82 breast surgeries** (cancer-related problems) in the Breast Unit of the University Hospital of Pisa (Italy).

- High level of task routineness and low uncertainty
- Surgical procedures being well defined beforehand
- All cases were chosen randomly.

<u>Surgical team composition</u>:

- 2 surgeons, 1 scrub nurse, 1 assistant nurse (base team) + 1-2 additional surgeons or nurses could take part
- minimum of 4 to a maximum of 7 team members

CASE STUDY: BREAST SURGERY - MEASURES

INDEPENDENT VARIABLES

Team behaviors (body/posture movement, speaking activity, audio, proximity, mirroring)

Team cohesion (through appropriate survey)

DEPENDENT VARIABLE

Surgical glitches occurred during the operations (through the report)

CONTROL VARIABLES

Operating Team (size), Surgery duration, People inside OR

CASE STUDY: BREAST SURGERY

Outcome:

- **Glitches ON/OFF** (binary variable)

A surgical glitch --> every possible medical/procedural problem that could affect the patient or her length of staying in the OR.

Input (Sociometric variables + Team cohesion):

- **Speech** – measured through the front and back microphone (explicit coordination behaviors by verbal interactions)
- **Mirroring** – built to understand the similarity in the behavior of the members (proxy for implicit coordination behaviors)

+ Team Cohesion – assessed through a survey filled in by team members

CASE STUDY: BREAST SURGERY

Correlation analysis: - various significant correlations

- no significant correlations control variables - Glitches ON/OFF

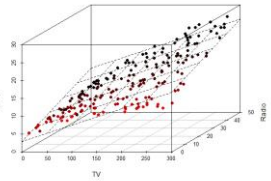
		Silence
Glitches ON/OFF	Correlation	-,421**
	Sig. (2-tailed)	,001
	N	66

Logistic Regression Model					
Variables	B	S.E.	Sig.	Exp(B)	VIF
Silence	-2.209	.696	.009	.110	1.185
Team Cohesion	-1.708	.657	.001	.181	1.027
Mirroring	-1.587	.748	.034	.205	1.166
Constant	-2.764	.731	.000	.063	-

Regression analysis: - logistic regression model with 3 independent variables

- no significant regression model with control variables (in all cases)

Interpretation of findings: - interpretation of results with practitioners and health managers



CASE STUDY: BREAST SURGERY

KEY FINDINGS

Findings endorse the idea that surgical performances are affected by **team behaviors** and by **team attitude**.

Lower explicit coordination (verbal interaction)

Higher implicit coordination (mirroring)

\- → Glitches → Positive effect on surgical outcome

Confirmation of the hypothesis

Team Cohesion

\- → Glitches → Positive effect on surgical outcome

Practical implications (for “routine surgery”):

- Increase the **proportion** of **implicit coordination behaviors**, for example fostering deliberative communication rather than reactive communication
- Well-defined task distribution for avoiding discussions during the surgery

CASE STUDY: EMERGENCY DEPARTMENT

Aim: To investigate the influence of ED practitioner behaviors on the patient satisfaction during the Emergency Department service

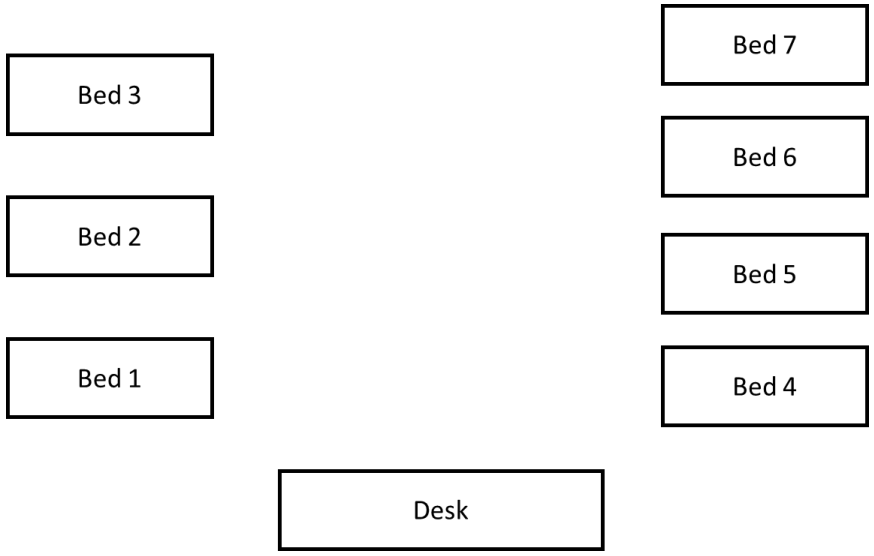
Tools: Sociometric Badges

Case study: was carried out at the ED of the University Hospital of Pisa (Italy).

CASE STUDY: EMERGENCY DEPARTMENT – DATA COLLECTION

ED Team: 1 physician, 1 nurse, 1-2 trainees

+ health workers (not associated to teams)



ED organization: for “work cells” with each team allocated for a single cell

Data collection:
- 90 episodes recorded correctly
- 253 practitioners observations
- 575 monitoring hours

CASE STUDY: EMERGENCY DEPARTMENT - MEASURES

OBJECTIVE MEASURES/INDEPENDENT VAR.

Behaviors of team and patient
(body/posture movement, speaking activity, audio, proximity, mirroring)

SUBJECTIVE EVALUATIONS/DEPENDENT VAR.

Quality perceive - patient survey
(overall satisfaction, care effectiveness, team responsiveness)

CONTROL VARIABLES

Throughput time, sex, age, number of team members, severity

CASE STUDY: EMERGENCY DEPARTMENT

Correlation analysis: - various significant correlations

- no significant correlations control variables-patient perceptions

Doctor's Posture Activity

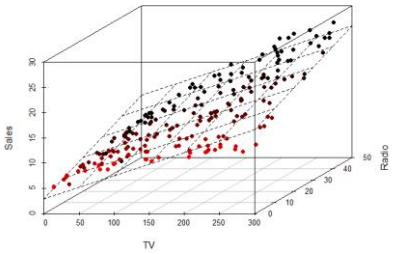
Overall Satisfaction	Correlation	**-,509****
	Sig. (2-tailed)	,001
	N	42

Regression analysis: - one model for each patient perception variables

- no significant regression model with control variables (in all cases)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
Care Effectiveness	B	Std. Error	Beta			Tolerance	VIF
(Constant)	,000	,111		,000	1,000		
Doctor's Posture Activity	-,385	,121	-,385	-3,206	,000	,871	1,241
Mirroring audio- Network	-,386	,119	-,386	-3,259	,002	,953	1,049
Audio – Patient speaking	,349	,141	,349	2,471	,018	,871	1,491
Nurse's Body Movement Activity	,331	,142	,331	2,327	,026	,861	1,507

Interpretation of findings: - interpretation of results with practitioners and health managers



CASE STUDY: EMERGENCY DEPARTMENT

Main behavioral factors affecting the patient satisfaction:

- The **presence of the doctor** "near" the patient (eye-contact)
- **Role of communication leader** within the ED team assumed by the **doctor**
- Patient listening: The **possibility for the patient of speaking sufficiently** about his/her health conditions and doubts/fears (listen to the patient!)
- Patient monitoring: **Frequent checks by the nurses** for assuring adequate patient monitoring
- Respect for the speeches of others: doctor should **avoid speaking over others**

Finally, the patients' judgment seems surprisingly **not affected** by the **overall throughput time**.

CASE STUDY: EMERGENCY DEPARTMENT

Relevant managerial indications for improving patient service satisfaction:

✓Doctors should remain **physically close** to the patients (possibly in **eye contact range**), avoiding exit from the work cell – different organization of "materials"

✓Doctors should assume the role of communication leader but they must avoid to speak over other people

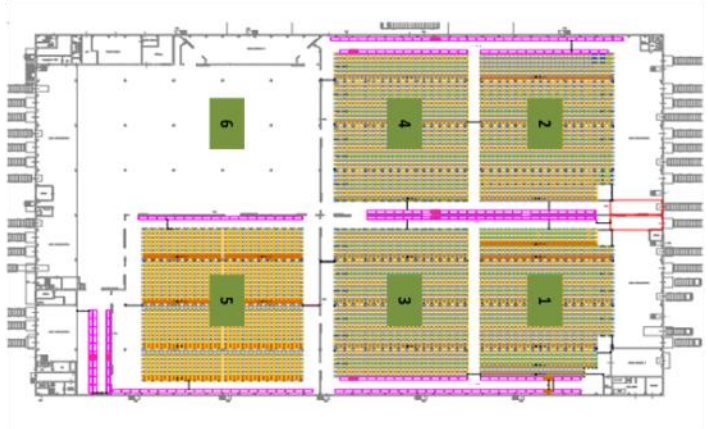
✓ED team should pay attention to the patient centrality during the service, by frequently monitoring the patients' health conditions and by actively involving the patient into the conversation

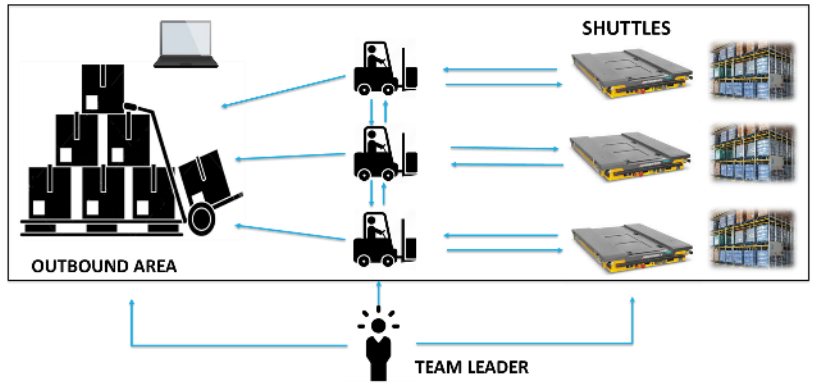
CASE STUDY: LOGISTICS HUB

Aim: empirically explore human and environmental factors affecting the performance of warehouse workers in material handling activities

Tools: smartwatches, smartphones, and smart environmental sensors

Case study: was carried out in a semi-automated logistics hub (tissue products) in Italy, on the order picking process

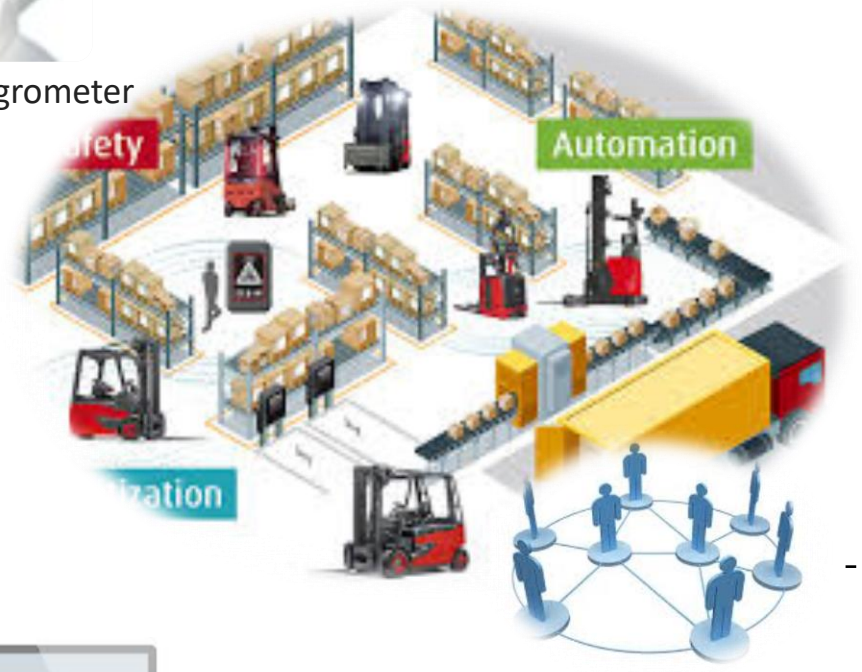


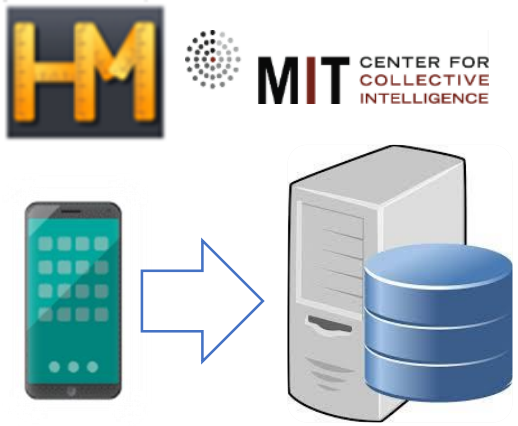


CASE STUDY: LOGISTICS HUB

Thermo Hygrometer

Lux Meter





Server

Smartwatches

Productivity of the workers

Data collection:

- **4** operators + **1** TL (≠ time)
- **8 hours** a day (different shifts)
- **5 days** a week
- **2 months** of observation
- **1600 hours** of work monitored

CASE STUDY: LOGISTICS HUB - MEASURES

(i) physical activity/human movement (ii) speech features
(iii) interaction with other individuals
(iv) Additional variables aggregated by Happimeter app

(i) luminosity
(ii) temperature
(iii) humidity

(i) Variables related to workers activities
(ii) to shifts (e.g. day)

(i) hourly number of correctly processed orders – **Dependent Variable**

Lag Variables: The one-hour lag of variables

CASE STUDY: LOGISTICS HUB

Data Analysis:

1) **Machine learning regression** model based on **CatBoost** (Prokhorenkova et al., 2018), was trained to understand whether body sensing parameters, environmental conditions, etc. (**all predictors**) of workers could support the **prediction of their hourly productivity**.

We evaluated our results through **Monte Carlo cross-validation with 500 repetitions**

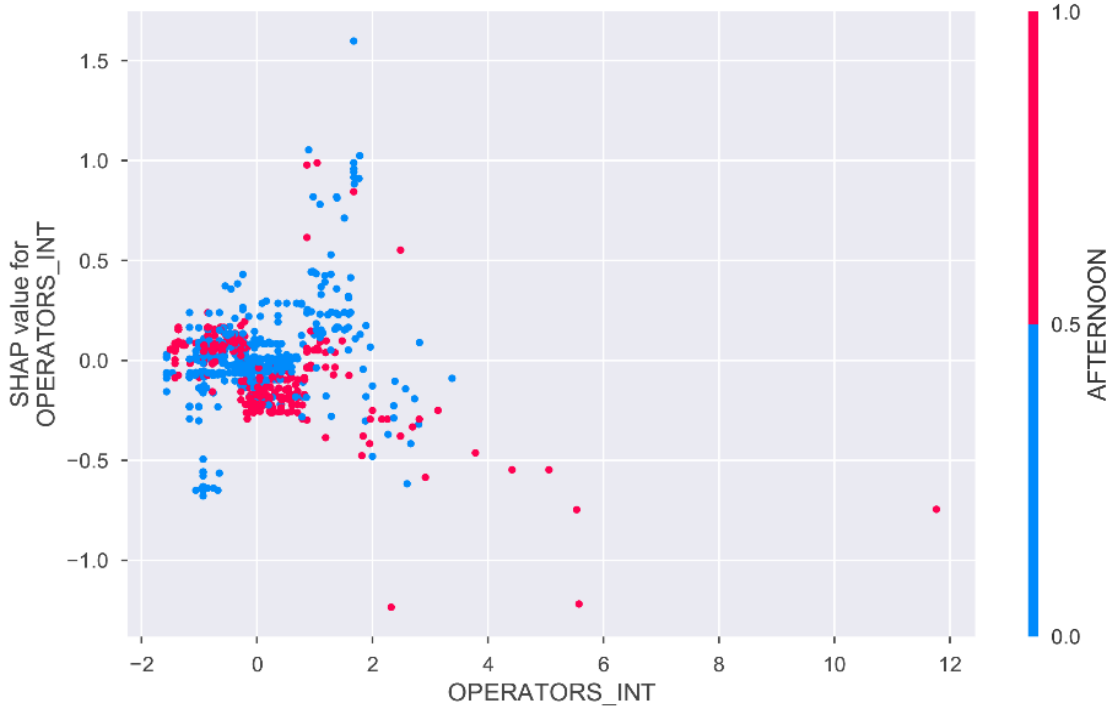
CatBoost is an algorithm for **Gradient Boosted Regression Trees** (GBRT) that is able to **processing categorical features** on its own. It is also faster than other GBRT and tends less to overfit.

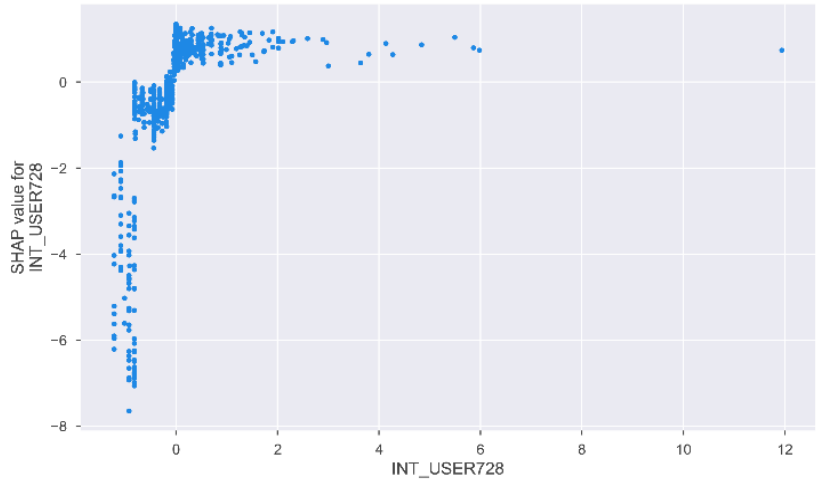
2) Then, we evaluated the importance of each predictor through the calculation of **Shapley values**

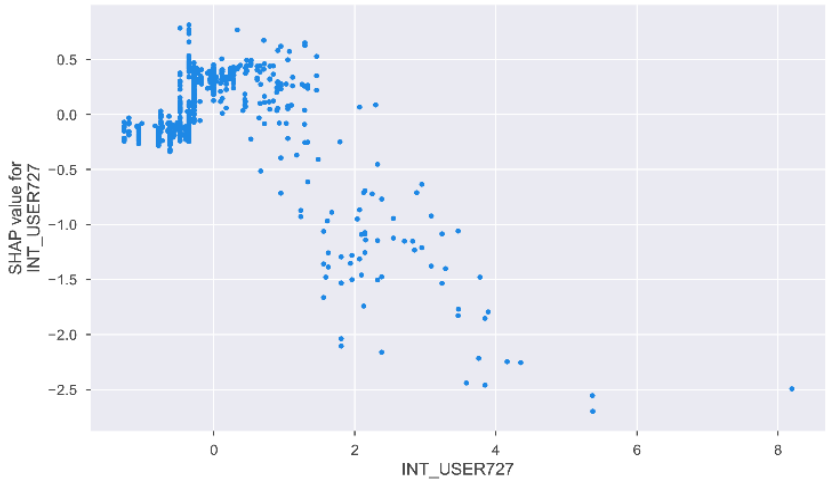
SHapley Additive exPlanations (SHAP) is a **game theoretic approach** for the **determination of features importance**, applicable to the output of different machine learning models (particularly appropriate for tree ensembles). (Lundberg & Lee, 2017)

CASE STUDY: LOGISTICS HUB

Productivity seems to be influenced by workers' interactions

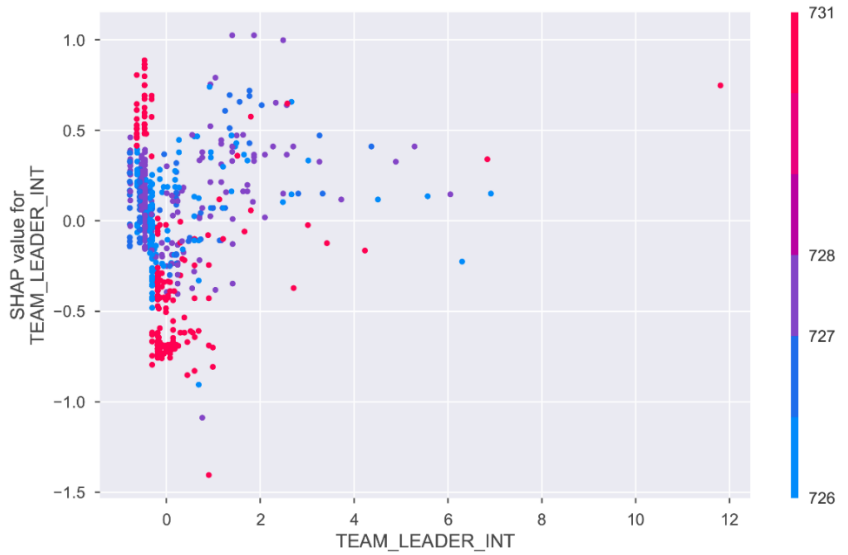


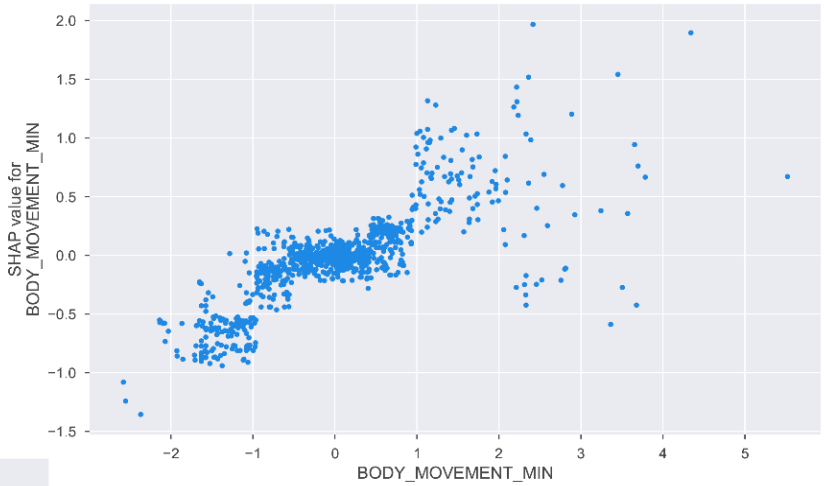


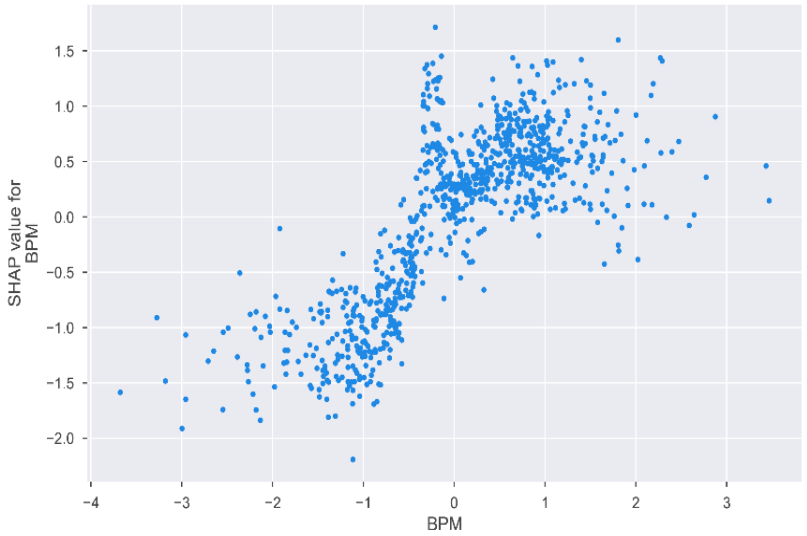


CASE STUDY: LOGISTICS HUB

Productivity seems to be influenced also by workers' "activation"

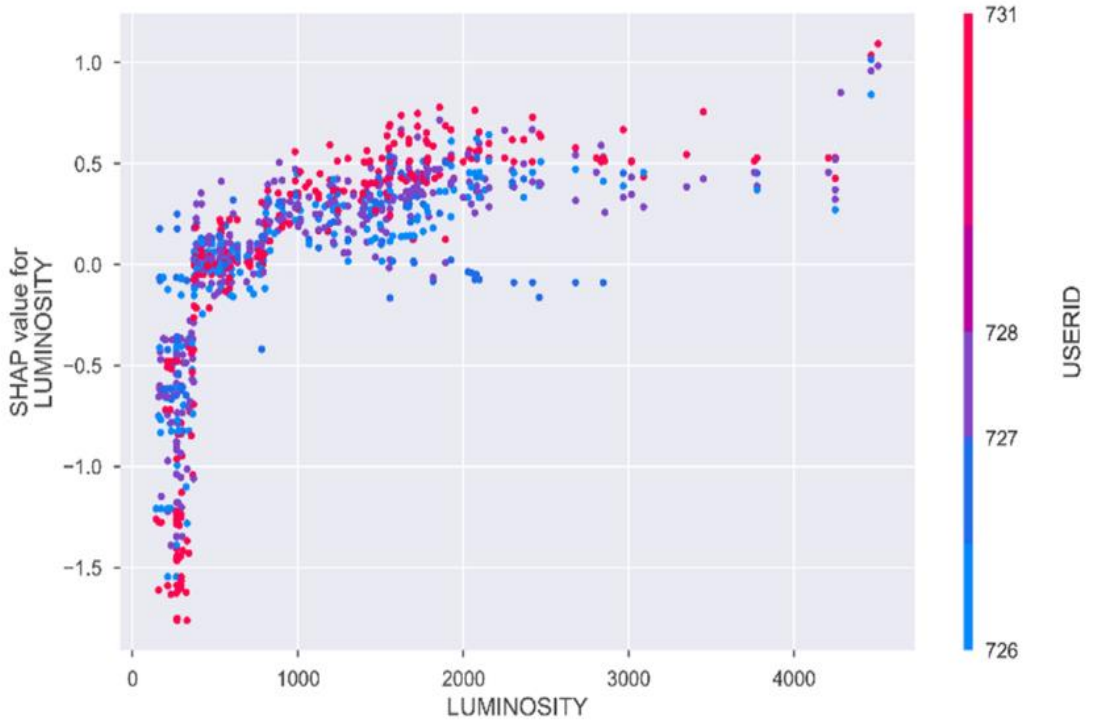


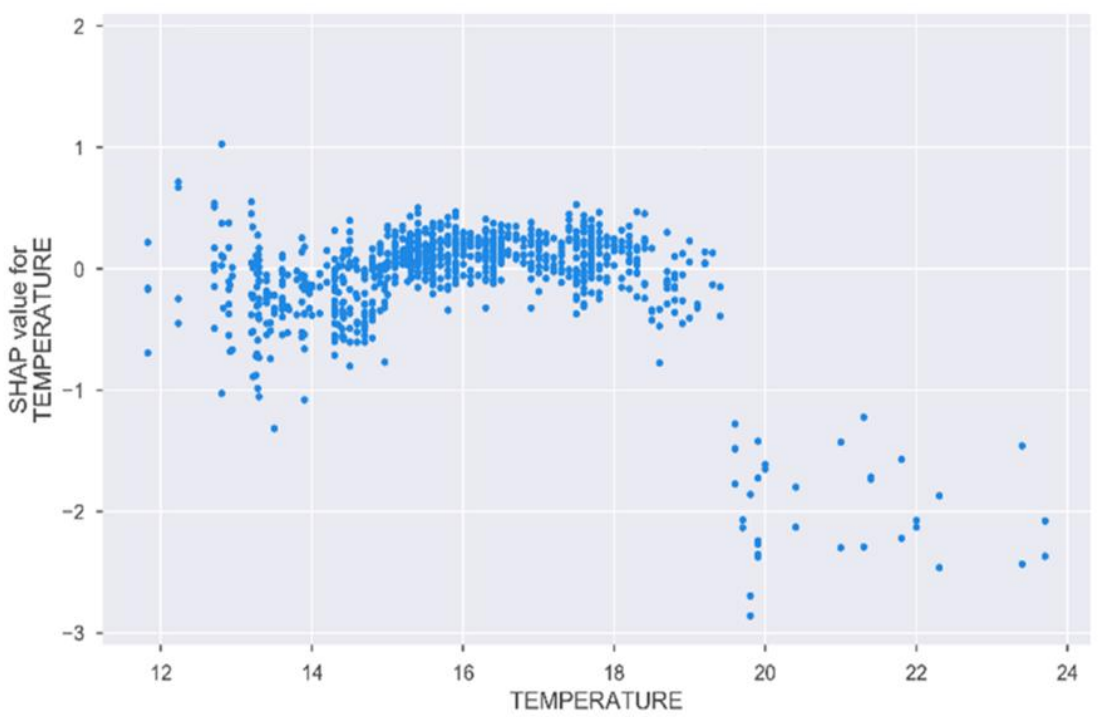




CASE STUDY: LOGISTICS HUB

Productivity appears affected by environmental conditions of the workplace





CASE STUDY: LOGISTICS HUB

Results empirically confirm that human and environmental factors affect the performance of warehouse workers:

KEY FINDINGS

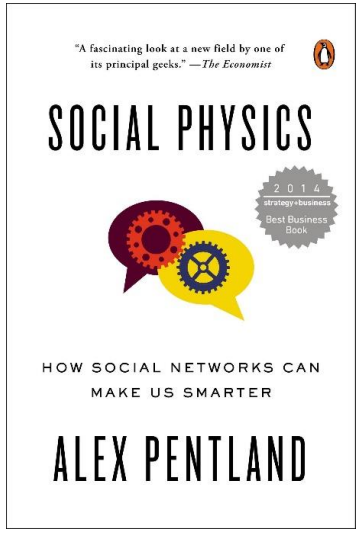
- **Individual characteristics** 1) some **operators** are more productive while working under identical conditions, 2) some **operators** are more susceptible to the **contingent context** than others
- **Interactions between workers**, with different effects based on the moment of the day
- The **relationship** of employees with their supervisor
- The **level of "activation"** of operators, here represented by BPM and Body Movement
- Potential remarkable role of **environmental conditions** of the workplace





FINAL REMARKS

- Social Physics appears really promising for investigating human behaviors in groups, communities and cities
- Social Physics supports the investigation of human factors in business organizations: to investigate the employees' behaviors, to understand team attitude and collaboration dynamics, and to intervene for improving the influence of such aspects on business performances
- IoT - 4.0 tools & "big data" may increase the pervasiveness and the extension of Social Physics analysis
- Our case studies showed how Social Physics analysis can become reality for increasing the performance and the "value" in business organizations



RESEARCH IN PROGRESS & OTHER TOPICS

Research still in progress:

- ❖ Analysis of Multidisciplinary Meetings of the Breast Unit of an Italian University Hospital with the Sociometric Badges
  - ➢ **Opportunity to involve 1-2 KTU faculties** with a ***"Management Research"*** background for finalizing the research (Data collection and the Preliminary analysis were already carried out)

Opportunity for new research in this field:

- Opportunity for KTU faculties to propose novel organizational contexts where apply "Social Physics" concepts, in particular exploiting Smartwatches

RESEARCH IN PROGRESS & OTHER TOPICS

Other topics of interest:

- Business Process Management (BPM) and Process Mining
- Healthcare Management
- (Behavioral) Operations Management
- Closed-loop Supply Chains & Circular Economy *(new research area for me)*
- Social Network Analysis for studying organizational/society dynamics *(new research area for me)*

Thank You

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