SimUse: Simulation of Recreational Poly-drug Use

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***Abstract*—This on-going project aims to build an ontological model concerning recreational poly-drug use and to use an agent-based simulation, SimUse, to test and verify related public policies. We consider drug-use (and even more so poly-drug use) to be a complex adaptive system that needs to be studied via a methodology able to describe such a dynamic and complex social phenomenon.**

To contextualize the complexity of poly-drug use and highlight the necessity of a multidisciplinary approach to study this practice we will pay particular attention to justify our theoretical assertions and computational constructions by qualitative researches, statistical surveys and/or theoretical concepts.

The description of the different levels composing the structure of drug use and the dynamics between these levels leads us to consider an ontological approach as the best way to capture and encapsulate poly-drug use. We will describe the global structure of our simulation via an UML diagram as well as the way we want to model the decision process concerning drug consumption. We finish with an illustration of tests that can be run with SimUse: this example presents results of different law enforcement policies and their consequences for decision-makers.

Keywords-component: ontology, drug-use, complexity, agent-based simulation, drug-policy.

I. INTRODUCTION

The scientific literature concerning the field of addiction and drug use furnishes an impressive range of "risk" or "protective" factors where each of them contribute explaining why some people use drugs and why some others do not [1]. These different factors correspond to studies realized on distinct levels of analysis: genetic predispositions; neurophysiology; drug specific neuro-pharmacology; individual psychology; social and environmental conditions; current laws; economical constrains or cultural norms [2,3]. Therefore, a wide range of disciplines has described those "risk" and "protective" influences with their own vocabulary and concepts. This multiplication of theories concerning drug use, even if they all capture a part of the "reason" for drug consumption, fails to assemble the whole part of the puzzle in a single picture [4].

Moreover, the combination of all these factors seems to produce continuous evolutions through time [5] and these last two decades have been marked by different phenomena that have increased the level of complexity characterizing drug consumption. We can say that the social acceptance or "normalization" [6] of illicit drug consumption, the correlative augmentation of "poly-substances" use [7], the constant apparition of new substances and the role that the Internet now plays on their trade and accessibility [8] have deeply modified the situation before the 90's and so, the global comprehension of this consumption.

Based on these observations, policy makers have called for new technologies to analyze the trends of drug consumption and test public policies relative to these questions [9]. In order to study this complexity and its constant evolution we need an adaptive and flexible "toolbox": we propose an ontological agent-based simulation to capture both complexity and dynamic components of this social phenomenon.

Considering that drug use requires a multi-level analysis, we describe firstly the different components and relations that exist between those components in order to construct the ontology and the agent based model. Once this is done, we will explain the different components and characteristics of agents and the different "motors" of interactions between levels in the simulation.

II. CHARACTERIZING DRUG USE: A MULTI-LEVEL NESTED SYSTEM

According to Zinberg [10], to fully understand drug use we have to comprehend the reasons that cause someone to use drugs and conversely the effects of drugs on the user. To do so, he argued that researchers have to consider three different elements: *the drug* (the pharmacologic act of the substance itself); *the set* (the attitude of the person at the time of use, including his personality structure); and *the setting* (the influence of the physical and social setting within which the use occurs)".

Because of the large range of the bio-psycho-social origins of addiction, the predictors and factors influencing substance use have been regrouped into different reality levels. The number of levels varies upon authors (four for Sussman & Ames [11]; three for Hawkins et al. [12]), but we propose five levels to fulfill our work as shown in figure 1.

First, we will review the different elements that have appeared to be fundamental in the construction of a social simulation of poly-drug use.

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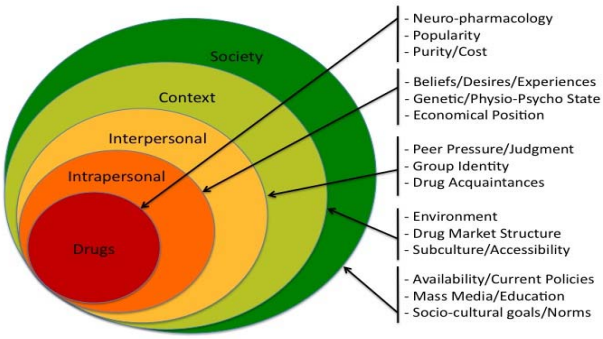

Figure 1. Drug Use as an Interrelated Complex Phenomenon

A. *Drug Level*

1) *Neuro-pharmacological Properties*

Neuroscience has offered a wide range of studies that underscore the specific roles that neurotransmitters play in pleasurable sensations, memory, alertness, mood regulations, analgesic effects and motor regulation [13]. Neuroimaging has allowed researchers to explore the neurological basis of addiction by studying the structural transformations induced by psychoactive substance use [14]. This research has permitted differentiation of which neurotransmitters are activated by which drugs [15].

2) *Purity/Cost*

Drugs have the potential to be (1) *double experience goods*[16], in others words both dealers and users have *imperfect information* concerning the quality of the product and (2) *inelastic goods* – augmentation of the price doesn't generally lead to a diminution of consumption [17]. But some surveys have demonstrated how increasing the price of one drug can modify the consumption of another drug via what economists call '*cross-price elasticity'* [18] underscoring the interdependence of consumption in poly-drug use.

Price and real composition of drug vary from one dealer to another and from one period to another: quality decreases as the substance goes down the distribution chain [19] modifying the potency of the initial product [20].

Furthermore, change in price can lead some drug users to modify their consumption by substituting one drug with others: for example, Petry and Bickel [21] have shown how an increase of heroin price generates increased consumption of Valium and cocaine.

3) *Drug Popularity*

Even if this particular characteristic finds its origin in societal symbolism, drug appreciation and reputation differs from one drug to another. Perceptions of risk [22], general public opinion on public policies [23], the *social and cultural accommodations* to recreational drug use [24] social judgment about deviance and drug use [25] condition the symbolic dimension of drugs; a corollary is that this symbolic dimension influences the perceptions of individuals and therefore, the decision process to consume or not [26].

B. *Intrapersonal Level*

1) *Beliefs/Desires/Experiences*

Repetitive personal experiences lead people to consider their personal world as "taken-for-granted" [27], traumatic and negative life experiences could lead to drug-abuse [28] and trying to avoid cognitive dissonance could lead to perceptual distancing [29] reinforcing drug abuse.

Furthermore, based on their experiences consumers acquire knowledge in the form of expectancies and limits concerning the effects they can get using drugs [30]. These experiences modify expectancies through time [31] transforming the way perceptions and the initial considerations of the danger and enjoyability of such substances.

2) *Genetic, Psychological/Physiological States*

Studies about genetic predisposition [32] and twin behaviors [33] have shown the relevance of genes to explain deviant behaviors related to drug abuse. Add to this, drug use can cause alterations in both psychological and physiological states as shown by research on synaptic plasticity [34] and reward/prediction circuits for craving [35].

3) *Economical/Social Position*

It is clear that users have to be able to afford their consumption before using it and drug consumption varies depending on the social position and economical potential [36]. Add to this, the different symbols attached to drugs, such as for example cocaine as the "rich man's speed" [26] induces specific choices among a panel of drugs depending of the social status.

C. *Interpersonal Level*

1) *Peer Pressure/Familial Influence*

Using reference to social learning theory, Kilpatrick et al. [28] and Flay et al. [37] have shown that children witnessing parental drug consumption have an increased risk of substance abuse. Obviously this influence can be extended to other elements of personal interactions, "peer pressure" has an important influence on experimental drug use. On this subject, a vast literature exists about the social influence of friendship groups [38] indicating that individuals are influenced (positively or negatively) by their friends but also select which peers they have to mix with in order to find and use drugs [39].

2) *Group Identification*

Following on from the last point, rejecting or being rejected by peers/family could lead people to identify themselves with particular groups. Sussman et al. [40] have produced a review of the different studies on peer/group affiliation for adolescents. They highlight the consensus of all these studies to differentiate different kind of identifications (such as Athletes, Academics, Deviants, Elites, and Others) concluding that Deviant generally receive the worst parenting.

3) Drug Acquaintances

The availability of illicit drugs will greatly depend on "social capital" and networking. Friends and acquaintances are mostly the first sources of supply before dealers [41] creating a kind of "chain of distribution", where friends become *tertius gaudens* [42] and can be considered as dealer-users.

D. Contextual Level

1) Environment

Rhodes et al. [43] have pointed to the importance of macro-environmental conditions on drug use: neighborhood conditions [44], economical deprivation, poverty [45], economical and social inequalities [46]. All these sociological elements are related to individual characteristics and have a real impact on individual decision-making.

2) Drug Market Structure

It is obvious that without a drug market inside the geographical area of possible users, there is no possibility for substance abuse, so the study of *drug market structure* can give precious information for understanding drug use [47].

3) Subculture/Accessibility

Ethnographic studies have clearly demonstrated that depending on the location of use, individuals have different type of consumption: access to particular type of drug and reasons to use them vary depending users are situated in pubs [48], rave [49] or discos [50]. Some consumption, such as intravenous injection generally takes place in remote area [51].

E. Societal Level

1) Availability/Current Policies

The *availability* and *situational laws* have a large impact on consumption. *Availability* depends on the geographical/ economical situation of the country, where specific drugs can be more or less easily found [11]; at the same time, *laws and public policies* can forbid or allow different chemical substances, can authorize or make illegal some specific events such as a rave or free party, or impose specific restrictions on clubs and bars [52].

2) Mass Media/Education

Studies in communication have shown how repeated exposure to *media* messages leads to a modification of preferences and conduct [53] and advertisements could increase alcohol consumption [54]; moreover, movies or television series could produce a positive image of deviant behavior such as criminal activities and drug use [55].

3) Socio-cultural Goals/Norms

Norms could be defined as what is “morally” accepted by a society, and it is evident that great differences exist between states of what could be considered as “moral” behaviors: deviance come from this definition [25]; *social goals* [56] induce actions in order to reach them: cult of the performance [57] or reconnaissance by wealth [58].

For drug use, we consider functions that Boys et al. [59] have listed during their ethnographical work which are the markers of some social goals: be sociable, feel happy, remove boredom or keep awake.

Reviewing those predictors gives an idea of the different causes that can lead individuals to trying and continuing drug use. However, it also gives an idea of the absolute necessity of combining those data in order to improve our understanding of drug use. Therefore, we believe that drug use in its global social nature could be interpreted as a complex system.

III. SIMUSE: AN ALIFE FRAMEWORK

A. Global Structure

We consider poly-drug use as a complex adaptive system (CAS), which can be defined as a set of co-adaptive nested systems interacting in a non-trivial and non-linear manner with capacities of self-organization, reproduction and evolution [60,61].

Thus we need to build a model able to represent:

- different levels of a system;
- existing relations between them;
- their components and their characteristics;
- and current interactions between those components.

Computer science concept of ontology seems to tally with our objectives. Originally, ontology was a philosophical concept which, a branch of metaphysics: coming from *ontos* (being) and *logos* (discourse), ontology aims to describe general properties of things. For our purpose, we will consider ontology as *a description of a particular domain defined by its objects, concepts, and their properties and relations* [62]. This framework enables the description of the previous data and concepts in a common language, Unified Modeling Language (UML) [63].

We create five generic classes corresponding to the five levels: *drug, individual, network, context* and *society*. Some of those classes possess sub-classes as specific components (such as the brain of agents that we have renamed "Brain", "Media" or "Wholesaler") or instantiation of a class (such as "Heroin" for the class drug). Our objective is to implement the different elements reviewed previously to typify classes and to characterize elements of each one (cf. fig.2).

These characteristics try reflecting the different relevant attributes to drug-use. Because we want to represent users as adaptive agents, those attributes also work as objective and active values, in the sense where they are both "inputs" (act on external elements) and "outputs" (modified by external elements). Through the different methodologies able to model the complexity of such a system, we have implemented the ontology via an agent-based model (ABM) [64].

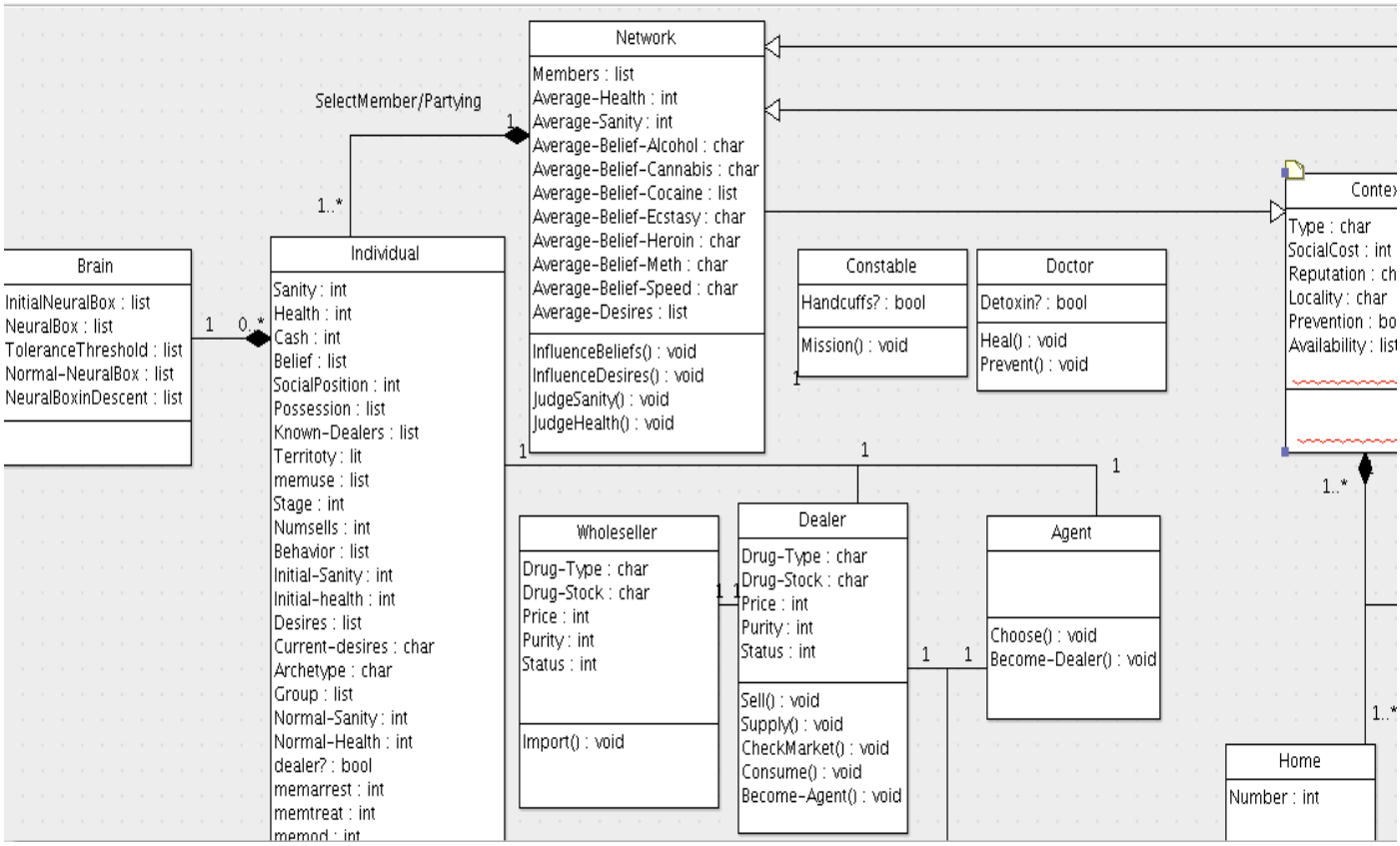

Figure 2. SimUse UML (portion of the agent class)

This framework allows us to recover previous representations we need to model. As indicated by Ferber [65], a Multi-Agent System (MAS) comprises of the following elements:

- An environment (E), a space that generally has a volume;
- A set of passive objects (O) which can be perceived, created, destroyed and modified by the agents;
- An assembly of agents (A) representing the active set of objects;
- An assembly of relations (R) that link active or passive agents to each other;
- An assembly of operations (Op) making it possible for the agents of A to act on objects from O.

In the next two sections, we will pay particular attention to describing interactions between systems (R and Op) and the decisional processes of the agents (A).

B. Interactional Relations

If we consider that "to model a complex system is to model a system of actions" [24], we conceive this system of actions as composed of decisional agents in active and responsive environments.

Therefore, the constant flow of interactions between the different levels of the system creates a dynamic and evolving dimension causing the inner modifications of each components of the upper-level system ("Causes produce effects that are necessary for their own causation" [66]).

We believe that a wide number of interactions exists between these classes. Because modeling consists of a simplification of reality [67], we have selected in this large set of possibilities, those interactions that we deem as relevant for the matter of drug consumption. Our system of interaction can be represented as shown in fig.3:

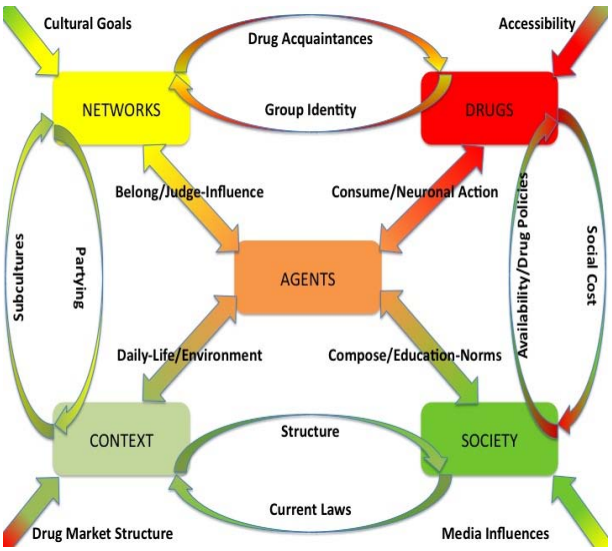

Figure 3. Global Interacting Scheme

Drug use conceived as an adaptive ecosystem should allow a better comprehension and analysis of unintended consequences due to particular changes in the system, for example: side-effects of certain public policies, significant changes in the drug market after multiple arrests, modification of opinions after advertisement campaign, etc [68].

An ontology focused on drug users has to describe and inform a series of decisional processes relative to drug consumption, consequences of such use on the agents and also transformations relative to the socio-economical context of this agent. In the next section, we will exemplify one of these interactions through the decisional process of agents.

C. *Decisional Process*

Considering the large set of external factors that influences drug consumers, and since "the apparent complexity of our behavior over time is largely a reflection of the complexity of the environment in which we find ourselves" [69], we have to consider our virtual users as part of a specific environment and so to consider rationality as "contextualized" and "bounded" [70]. This particular conception of rationality reflects the social implanting of agent's intentionality, the possible revision and adaptation of their beliefs and knowledge [65] and hence the complexity of poly-drug use as a social phenomenon.
Furthermore, the cogitation and decision processes also form a dynamical and complex system, embedded into another complex system (the parts and the whole of a CAS).

In the context of drug use, decisions about substance use do not cease after the first experiment, but continue along the *career* of the individual. Moreover, users give to each drug specific functions, have expectancies about them and modulate their uses depending on several factors (physical, economical, etc) [59]. We consider, according to LeMoigne [61], that each action (here, each drug use) is the realization of teleological projects inside an environment, using particular functions and leading to transformations in the whole system and sub-systems.

Therefore, we exploit the BDI (Beliefs/Desires/Intentions) logic of Wooldridge [71]. This logic argues that human practical reasoning consists of at least two processes: *deliberation* ("What do we want to achieve.") and *means-ends reasoning* ("How do we achieve it."). For our purpose, we will slightly modify this logic to create a **BDM (Beliefs/Desires/Means)** in order to insert both financial, psycho-physiological state and social capital (describe in the first section) in the decisional process.

D. *Populate the Model*

The final agent-based model first needs to describe the process of decision-making experienced by the drug user and its evolution through time. Secondly, it needs to describe the socio-eco-political context in which the agents evolve. It models the constant interactions between the "set" with its "drug" consumption and the "setting" with its transformations. Once our model well calibrated, this will allow us to study the impact of different public policies through simulations. Simulation-based research generally needs to first define the target to delimitate outlines and inform structure of systems [72].

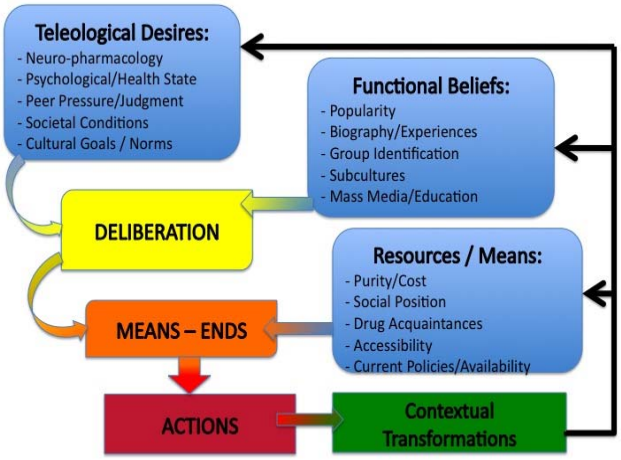

Figure 4. Decision Process through BDM

The different notions reviewed in the second part of this paper give us the core of the global structure as well as the interactions within this structure. However, we are confronted with several gaps concerning the evolution of users' rationality: modifications that happen along the poly-drug use career, in so far as belief revision, experiences accumulation and motivational changes, remain unclear.
Hence, we need to gather sufficient information regarding this concern to implement relevant and accurate decision process. Therefore, we combine statistical data from epidemiologic surveys with qualitative interviews: the first one to quantify and differentiate drug users population; and the second, to obtain a better understanding of the dynamics and stages, drug users can get through during their careers [72].

IV. SIMUSE AT WORK

A. *Presentation*

We implemented the UML structure in Netlogo 4.1.1 [74]. The interface shown in figure 5 represents a virtual town composed of different kinds of places and venues. Streets, Homes, Pubs and Discos are in black, green, blue and violet, respectively (see fig.5). Time is measured in days. The agents' behaviour is related to their subclass routine and weekday.

Users of the simulation can test the impacts of special Events, (e.g Christmas or musical manifestations, etc.), Media Messages (e.g lethal drug news, drugs and alcohol precaution campaign, etc.) as well as different Public Policies, including law enforcement and prevention.

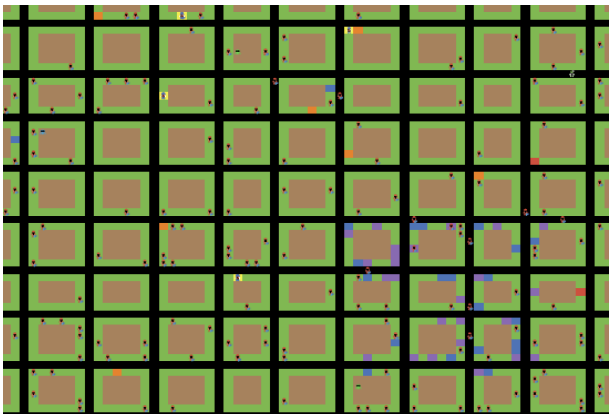

Figure 5. SimUse Interface

The simulation, integrates all different elements from the UML model, allowing users to run scenarios in which the modeler can vary several variables:

- price and stock of drugs;
- number of users, dealers, wholesalers, constables and doctors;
- average number of agents in a network;
- size of the town, number of street and places;
- special events and media messages.

Characteristics of agents (Health, Sanity, Social Position…) are for the most randomized through a normal distribution to represent social and physical diversities. Archetypes of agents, which in the simulation define different elements of Beliefs and Desires, have been implemented according to Blue Moon Research 2003, which aimed to characterize drug use behaviours via a statistical/qualitative survey among the Australian population [75].

B. Testing Law Enforcement Difference

Agent-based models have already proven their relevance in testing public policies relative to drug use [76]. In this section, different scenarios of police actions are tested and quantitatively compared through drug consumption. These scenarios are given below:

1. "Big Operations (BO)" targets wholesalers during their importations.
2. "Bust Dealers (BD)" aims to arrest dealers when they supply or in the middle of a transaction.
3. "Serve and Protect (S&P)" consists in arresting users and/or dealers that possess drug and behave "abnormally" in the street.
4. A "none" policy serves of comparison point to appreciate the outcomes of each policies.

Every policy deploys of the same number of constables on the grid (five, except "none", which has no police in order to save some calculation time). These police officers patrol randomly inside a town constituted of a predetermined and stable number of locations. Prices of every substance remain equal for each simulation.

The virtual population is composed of 400 agents, 15 dealers and 10 wholesalers. Constables have 5% chance to spot trafficking dealers/wholesalers and users under the effect of illicit drugs or involved in a brawl (for the "Serve and Protect" action).
The four possibilities have been each run for 40 iterations of 350 steps. We have measured quantities of drugs consumed for each scenario as well as the number of assaults and deaths.

Results presented here illustrate outcomes resulting from the different police operations for three substances: alcohol (fig.6), cannabis (fig.7) and cocaine (fig.8).

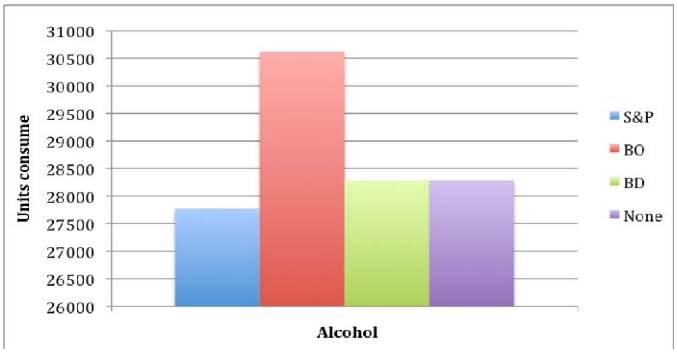

Figure 6. Alcohol Rate

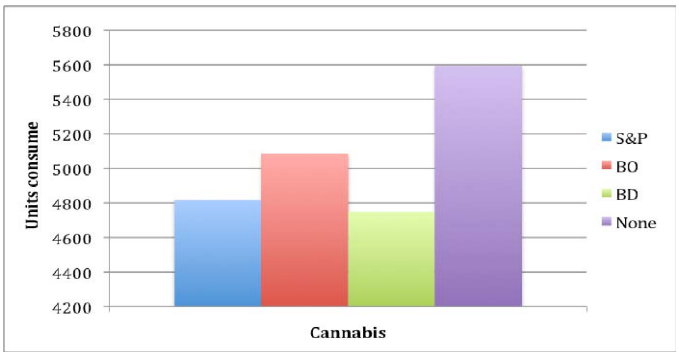

Figure 7. Cannabis Rate

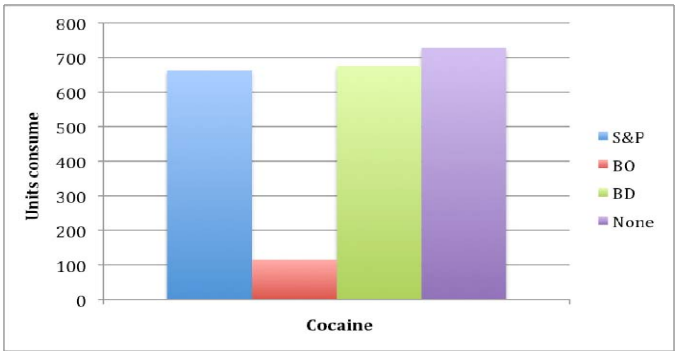

Figure 8. Cocaine Rate

The difference of drug consumption between Cannabis and Cocaine for the "Bust Dealers" policy could be explained in terms of *drug dealer visibility:* routine of our cannabis dealers lead them to spend some times selling in the streets while cocaine dealers generally stay indoor (home, bar or disco).

A more interesting point is the alcohol consumption recorded for the Big Operations strategy. As discussed above, there is a possibility of users substituting one drug for another, if price or quality change [21], but evidence has been found concerning the substitution operated by users between drugs and alcohol: illicit drug users generally consume less alcohol than non-illicit drug users [77]-[78]. This phenomenon has been confirmed by our qualitative interviews: alcohol is the *refuge substance* when no other drugs are available.

A recent report from the Independent Scientific Committee on Drugs (ISCD) indicates via a harm scale that alcohol, in term of social cost, is more dangerous than heroin and crack [79].

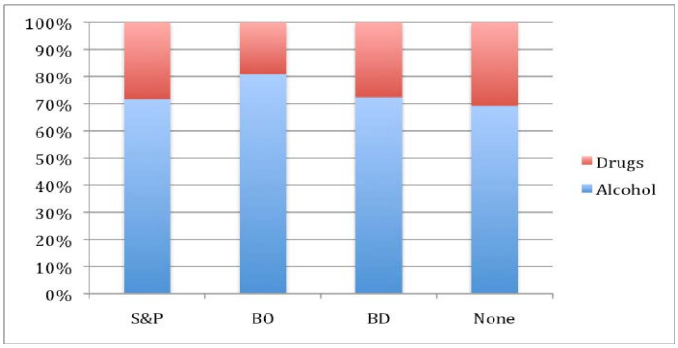

Figure 9. Drugs/Alcohol Ratio for each policies

Considering the ISCD analysis, we need to represent and compare both alcohol/illicit drugs ratio (fig.9) for each policy in order to understand possible impacts of these one.
The question for decision makers is now to know if a "total" war on illicit drugs won't be followed by several sanitary and social problems related to extensive alcohol consumption.

V. CONCLUSIONS AND FURTHER WORK

From reviewing different risk and protective factors involved in poly-drug use, we have underscored the necessity of a multidisciplinary perspective to understand the complexity of poly-drug use. This complexity leads us to consider drug use as a Complex Adaptive System that we want to capture via an UML model. This ontologic model is implemented and simulated with Netlogo in order to run multiple simulations in order to achieve public policies testing.

In our work, the model serves as "mediator" between hypotheses, quantitative values and qualitative precision, permitting us to test "what-if" situations *in-silico*. This abductive capacity of this process seems to be perfectly suited for studying a CAS such as a social complex phenomenon.
Testing Law Enforcement Difference is one of the possible "what-if" scenarios. We are running further experiments on impact of price increasing/decreasing, mass media effects, some mixed law enforcement and prevention strategies or social costs of different public policies related to this matter.

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