Dynamic Modeling of Addiction Trajectories : An Exploratory Approach Across Addiction Types

Longitudinal Data Analysis within the Addiction Aquitaine Cohort **(ADDICTAQUI)**

E. Kervadec[1,3], F. Serre[1,2], S. Moriceau[1,2], P. Desnavailles[1,2], V. Beltran[1,4], J.P. Daulouède[4], F. Jean[1,5], M. Navarro[6], M. Auriacombe[1,2]

1. University of Bordeaux, CNRS, SANPSY, UMR 6033, France
2. Inter-Hospital Addiction Services, Charles Perrens Hospital and CHU Bordeaux, France
3. APHP, CHU Paul Brousse, Department of Psychiatry and Addiction Medicine, France
4. BIZIA, Doctors of the World, Bayonne Hospital Center, France
5. Mental Health and Addiction Medicine Services, Calais Hospital Center, France
6. Bordeaux Population Health Research Center, INSERM, Team HEALTHY, UMR 1219, France

SCIENTIFIC CONTEXT

Addiction, whether involving substances or activities, is a psychiatric disorder marked by **loss of control, compulsive use despite harm, and high relapse risk**[1]. It remains a leading public health concern due to its **global burden in terms of mortality and morbidity**[2]. While specific substances or behaviors lead to distinct consequences, converging evidence supports a **transdiagnostic model of addiction**[3,4,5], where common neurobiological and psychological mechanisms (e.g., craving, impulsivity, affect dysregulation, impaired decision-making) underlie the disorder, **regardless of its object.**

Gaps in the literature

- Longitudinal studies **focus on a single substance**, specific treatment episodes or subpopulations
- Cross-sectional or retrospective approaches **fail to capture temporal dynamics**[6]
- ***Need for a shared longitudinal conceptual framework across addiction subtypes***

OBJECTIVES

1. **Model a shared temporal trajectory of use (substance or behavior) at the population level, across multiple addictions**
2. **Identify distinct trajectory groups and their baseline predictors**

MATERIALS & METHODS

ADDICTAQUI COHORT

Prospective, multicenter cohort[8] (France, since 1994)
Standardized hetero-evaluations (ASI[9], MINI[10], craving) across multiple addictive substances and behaviors
Sub-sample for longitudinal analysis: patients with ≥3 follow-ups during the first 18 months

Inclusion at the beginning of treatment
M0 — M3 — M6 — M12 — M18

Inclusion criteria: addiction treatment request, DSM-IV/5 diagnosis (SUD or behavioral), age >18 y.o., fluent in French

Outcome: days of use (last 30 days) of *primary addiction*

Addiction subtypes:

DATA ANALYSIS (R version 4.4.3)

Statistical Considerations

- Non-linearity and oscillations *(daily use, abstinence, relapse)*
- Non-normality of distributions, bounded outcomes[7]
- Bimodal data *(accumulation at 0 and 30 days of use)*
- *May lead to invalid inference and misleading statistical significance if not properly addressed*
- **Need for data-appropriate models**

Longitudinal trajectory modeling:
Beta-Binomial Generalized Linear Mixed Model[11]
Logit link function, random intercept/slope, spline
Dispersion parameter dependent on addiction object
Estimation: *MLE Laplace*, {glmmTMB} – Fit: *AIC/BIC*, {DHARMa}

Trajectory clustering:
K-means longitudinal clustering {kml}[12]
Baseline covariates logistic regressions on cluster assignment

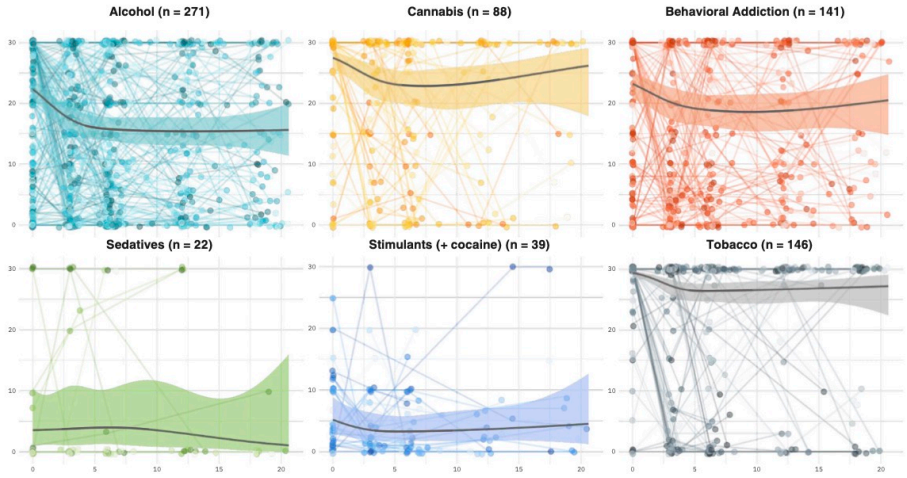

FIGURE 1 – Conditional model estimates of use trajectories during follow-up, representing typical individuals within each addiction group

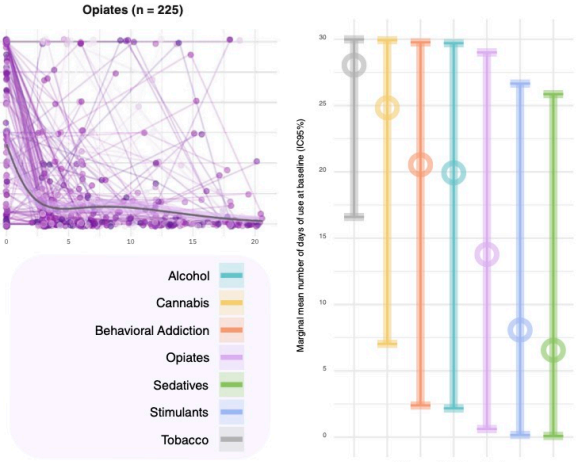

FIGURE 2 – Estimated marginal levels of use (substance or behavior) at baseline

RESULTS

STUDY POPULATION

n = 932
Age: 39.4 years (SD = 11.7)
Male: 64.1%
Single: 51% **Full-time job:** 49.5%
Problematic polyaddiction: 25.9%
Mean baseline days of use: 18.95 (IQR: 5–30)

Psychiatric history (ASI):
- Depression (72.9%)
- Anxiety (82.5%)
- Suicidal ideation (57.9%)
- Suicide attempt (33.3%)
- Hallucinations (9.8%)

LONGITUDINAL MODELING

Marginal estimates show an early average reduction in use during follow-up, associated with substantial baseline variability

Steeper decline for opiates
- **β (opiates x time)** = – 3.08 (p < .001)

High inter-individual variability
- **σ** (intercept) = 1.83
→ IC95% range: ~ 2 to 30 days/month at baseline

Group-specific dispersion improved fit
- Lowest precision: → Sedatives (φ = 0.15) → Tabac (φ = 0.33)
- Highest: → Stimulants (φ = 4.71)

LONGITUDINAL CLUSTERING

Optimal partition : 2 clusters

Rapid-Improvement Cluster (58%)
- Declining use: mean days ↓ 13.7 → 4.4 (M0–M18)

Persistent-Use Cluster (42%)
- Stable high use: ~ 24 - 26 days over time

Univariate logistic regression for Persistent-Use Cluster:
- Older age (OR = 1.03, p < 0.001)
- Tobacco (OR = 5.76), Cannabis (OR = 2.82)
- Medical problems (OR = 1.02, p < 0.01)
- ↓ Odds: Opiates, Stimulants, Methadone treatment

Multivariate model (n = 697) confirms:
- ↑ Odds: Age, Medical problems, Cannabis, Tobacco
- ↓ Odds: Opiates, Sedatives, Stimulants

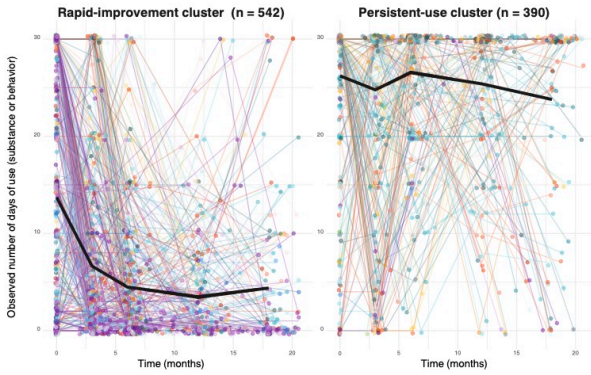

FIGURE 3 – Individual trajectories grouped by {kml} cluster

DISCUSSION

This study explored **addiction trajectories** across substances and behaviors using a **shared modeling framework**. A **global trend of reduced use** was observed, especially in **the first 6 months**, aligning with known therapeutic effects.

Inter-individual variability and abrupt transitions highlight the **limitations of linear models** in capturing substance use or behavioral addiction dynamics.[13,14]

Faster **improvements in opioid users** likely due to specific treatments like methadone. In contrast, **tobacco and alcohol use was associated with more persistent use** and greater heterogeneity, possibly due to weaker treatment effects.

Cluster-based analysis revealed a **persistent-use group** more likely to involve tobacco or cannabis users, older individuals, and those with somatic comorbidities. These individuals may not be "non-responders" but have **specific vulnerabilities** requiring personalized care.

Limits & Perspectives

Use-days as a shared metric have interpretive limitations.
Possible selection bias.
Future models should integrate craving and poly-addiction, using system dynamics approaches.

Conflicts of Interest: None.
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References: Dr. Kervadec ResearchGate page

Contact: ***ewen.kervadec@u-bordeaux.fr***