Project Details	
Project Code	MRCNMH26Br Burke
Title	Understanding Combination Use of Tobacco, E-cigarettes, and Cannabis: Predicting Modifiable Risks and Treatment Pathways Using Machine Learning
Research Theme	NMH
Project Type	Dry lab
Summary	Combination use of tobacco, e-cigarettes, and cannabis is increasingly common, particularly among young people, yet little is known about how these patterns influence mental health outcomes or treatment response. This PhD project will apply a four-part research strategy—including systematic review, predictive modelling, and machine learning validation—across large-scale cohort studies to identify modifiable risk factors and translate these into tailored digital mental health interventions. The student will receive advanced training in data science, epidemiology, and translational digital health.
Description	**Background:** Combination use of tobacco, e-cigarettes, and cannabis is rising among adolescents and young adults and has been associated with a range of negative outcomes, including increased risk for anxiety, depression, and impaired functioning. However, evidence on the long-term mental health impact and the modifiable pathways linking these behaviours is limited, fragmented, and often cross-sectional. There is a clear public health need to identify which patterns of substance use predict poor outcomes and which risk factors may be targeted in prevention and intervention efforts. This PhD project addresses this evidence gap by integrating evidence synthesis, prediction modelling, and real-world translation. It will provide a comprehensive assessment of how combination use of tobacco, e-cigarettes, and cannabis shapes mental health trajectories and how these insights can guide interventions. The student will work with large, harmonised datasets from ALSPAC, NHANES, and the Millennium Cohort Study and translate findings into digital intervention strategies using platforms such as our industry collaborators SilverCloud. **Key Research Question:** What are the modifiable risk factors and predictive pathways linking the combination use of tobacco, e-cigarettes, and cannabis to mental health outcomes, and how can these inform targeted digital interventions? Project Objectives (Four Studies): Study 1: Systematic Review and Evidence Synthesis • Conduct a systematic review and meta-analysis of longitudinal studies investigating the mental health outcomes of combination use of tobacco, e-cigarettes, and cannabis. • Identify common patterns, moderators, and methodological limitations in the existing literature. • Output: PRISMA-compliant published review and database of variables for model development. Study 2: Predictive Modelling in Large Cohorts • Use ALSPAC, NHANES, and the Millennium Cohort Study to train machine learning models (e.g., random forests, gradient boosting)

predicting poor mental health outcomes based on patterns of substance use and related factors.

• Explore model performance across different age groups and socioeconomic subgroups.

• Output: Feature importance rankings and risk prediction tools.

Study 3: Transfer Learning for Cross-Cohort Validation

• Apply transfer learning methods (e.g., domain adaptation, feature reweighting) to assess model transportability across datasets.

• Evaluate model discrimination and calibration in each cohort and examine which features remain predictive across settings.

• Output: Robust, generalisable models and transportability performance benchmarks.

Study 4: Translation to Intervention via SilverCloud Platform

• Identify modifiable risk factors and behaviours from predictive models.

• Design behavioural "micro-targets" for digital delivery via the SilverCloud mental health platform.

• Pilot natural experiments or in silico simulations to estimate impact of modifying key risk factors.

• Output: Intervention prototypes or research-ready modules for digital implementation.

Student Ownership:

The student will take leadership in shaping the project direction, particularly in selecting machine learning methods, defining outcomes of interest, and translating results into digital intervention components. They will be encouraged to lead dissemination, including publication and stakeholder engagement. Optional paths include focusing more deeply on digital health delivery or on methodological innovations.

Skills Development:

The student will develop expertise in:

• Longitudinal data analysis and cohort harmonisation

• Advanced machine learning and model validation

• Transfer learning techniques in public health contexts

• Systematic review and meta-analysis

• Translational research and digital intervention design

International and Policy Impact:

Findings from this project can directly inform policy on youth substance use and mental health. The predictive models and identified modifiable risk factors may support risk screening in schools, clinics, and digital platforms. The translational component has direct relevance to NHS partners and mental health services, aligning with prevention and early intervention strategies.

PPI and EDI:

PPI will be embedded throughout, including through collaboration with youth advisory groups and lived experience panels. The project will actively consider social, cultural, and economic variation in substance use patterns and mental health outcomes. The student will receive training in inclusive research practices and will be encouraged to reflect on diversity and accessibility in their design of intervention components.

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