Hypatia: health modelling made simple

Background

Digital mental health interventions are increasingly popular as scalable, personalised, and adaptive solutions to the mismatch between mental health provision and demand. In parallel, there has been increasing interest in the use of computational models to characterise, formalise, and test potential cognitive mechanisms that may precipitate or maintain symptoms of mental illness. This novel field, *computational psychiatry*, has suggested a substantial number of potential targets for digital mental health interventions (computational *targets*), alongside a method of determining what cognitive processes are altered by digital interventions (computational *biomarkers*). These biomarkers may provide a method of assessing the efficacy of digital interventions in a more fine-grained manner, given that common trait measures may miss crucial state-level or latent clinically-relevant mechanistic changes (Gega et al., 2022; Yardley et al., 2016). Unfortunately, barriers to entry for mental health researchers are high: mathematical and computer science skills are frequently needed to use computational models, and platform integration and data storage skills are required to design interventions. Additionally, a key issue for the use of computational models in digital interventions is optimising the design and user experience of interventions/assessments while also maximising phenotypic precision for scientists (Gan et al., 2021; Nair et al., 2020). These barriers prevent the design of novel digital interventions, or cost significant time and financial resources which may further stifle innovation for many scientists/clinicians in smaller labs.

Prototype

Our aim is to let digital mental health researchers do what they do best - identify important clinical needs and develop interventions - and let us, team *Hypatia*, take care of providing robust, reliable, cutting edge tools to phenotype, assess, and drive mechanistic change in participants. Our tool (*Figure 1*) will remove technically demanding elements for digital mental health researchers by taking care of all the rigorous mathematical and programming requirements needed to build and fit computational models, packaged within a user-friendly and intuitive web-based interface (*Figure 2*). This will allow researchers to achieve three main goals: a) explore how changes to design features of their interventions affect model parameters; and b) fit their models within a computational modeling framework by providing a simple and open source software platform that allows researchers to engage with computational modeling without prior expertise in programming; c) explore these models to both tailor therapy and track its effect over time. Whilst our prototype currently focusses on feedback-driven learning (with reinforcement learning models) as a simple example, our tool has the potential to be expanded and scaled to accommodate multiple clinically-relevant models and task environments. This will be achieved through continuous collaborations with industry, lived experience, and academic partners. With simple, easy to use interfaces, our modelling tool will provide ready-to-use data and figures to demonstrate how a digital intervention may influence, and improve, key clinically-relevant cognitive markers of interest.

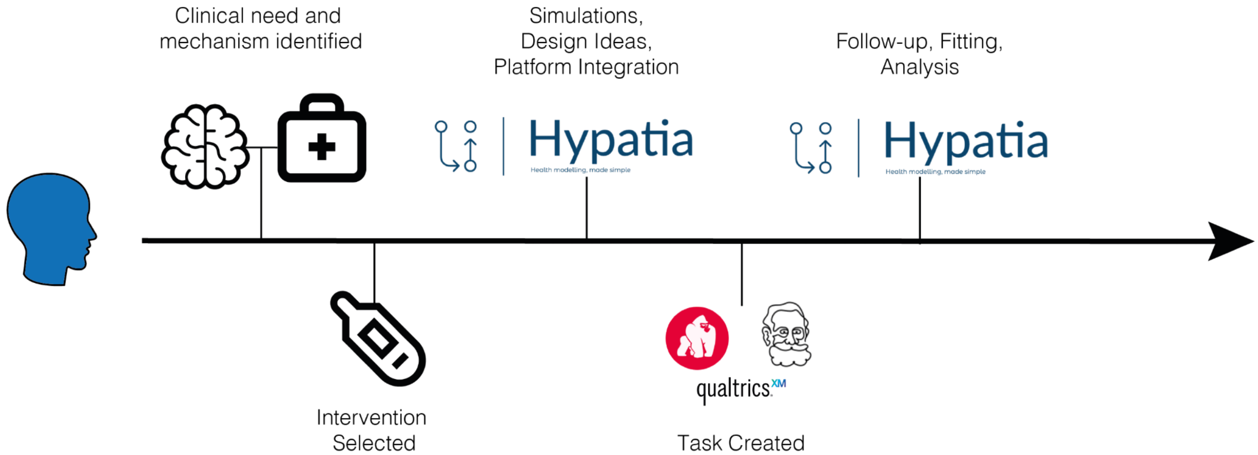

Figure 1. User journey with Hypatia. From inception to implementation, *Hypatia* will be of assistance to design, prediction, and analysis of sophisticated behavioural data.

Plans for future work

During the one-year grant period we will produce a user-friendly open source web-based tool that offers cutting-edge computational techniques that address causal mechanisms of mental health without the need for technical knowledge. Specifically, our tool will allow: 1) selection, simulation, and optimisation of task environments for intervention on computational targets and for assessment of computational biomarkers, utilising consultation with UX/UI experts and experts by experience to advise researchers on design tips, and 2) track individuals' change over time using cutting edge, gold-standard approximation techniques. Importantly, we will aim to integrate our tool with popular experiment platforms (i.e., platforms for researchers to run experiments) to have ready-to-go models matched with their task offerings. To ensure that this process responds to the needs of both experimenters and those with lived experience, and to respond to Wellcome's diversity, equity and inclusion, and trustworthy data science strategies, our project will encompass four non-sequential goals:

Tool development and integration

A postdoctoral research associate (PDRA) will be recruited to manage the development of the prototype over the one-year grant period. Their role will be to build our tool out to accommodate popular computational models and task environments that are clinically-relevant. To ensure that our tool will be accessible and easily integrated with existing languages, we will develop this tool using common open-source languages such as R, Stan, and Shiny. To ensure that our tool provides rigorous data analysis, model fitting will be achieved using cutting edge tools and algorithms such as Markov-Chain Monte Carlo estimation.

We will integrate our platform with already developed experimental platforms such as Gorilla, Qualtrics and Pavlovia - this will either be directly within their solutions, or we will provide easy, step-by-step guides to how our simulated environments can be translated into an intervention design, and how collected data can be accessed and input into our interface. Importantly, usability will be at the heart of the solution, and we will work with UX/UI experts to ensure no programming experience is necessary for any user, although for those wishing to examine the code, we will always keep the code open and accessible.

Consultation

Individuals with lived experience, UX/UI designers, and experts in digital mental health will be consulted and employed in the team to ensure that the implementation of new models, environments, and aesthetics of the platform are accessible and in line with their views and needs. This will be developed on a needs-basis, with background infrastructure (model implementation, reliability checks) and task prompts based on feedback from those with lived experience being prioritised for development. Lived experience will also be integrated during the dissemination of this work (e.g., video tutorials, workshops, Twitter coverage).

Integration

We will liaise with experimental platforms to enable easy translation between task environments and modelling output. In practical terms, this will involve 1) creating our simulation interface to incorporate common tasks hosted on these sites which are identified as most useful to digital researchers, and show most promise for assaying mechanisms of theoretical relevance, and 2) developing our fitting interface to be able to easily input the data sheets produced as outputs by experimental platforms.

Output

Our main output will be an interactive and open-source tool which allows researchers with limited computational modeling knowledge and programming skills to embrace this approach to inform the design and assess the impact of their interventions. We will engage academic, lived experience, and industry partners to produce outputs of value to each community. This will involve 1) the development of academic articles published in peer review journals to outline the technical and methodological contribution of our work, 2) the development of blogs and channels for those with lived experience to encourage feedback about common sticking points in tasks so we can better calibrate our task prompts, and 3) the production of white papers outlining our approach to interactive, user friendly modelling to reduce barriers to access and provide a business case in industry settings.

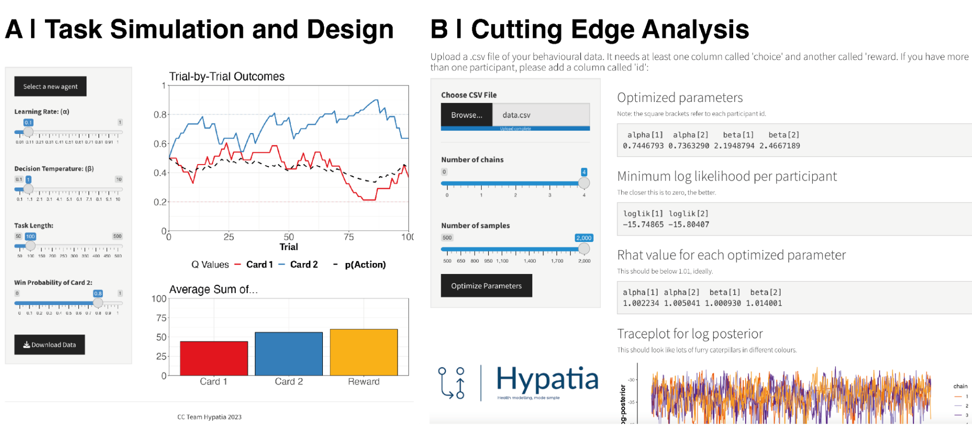

Figure 2. Hypatia Prototype. From simulation (A) to analysis (B), our prototype allows user-friendly task design and computational model use without the need for technical skills.

Gan, D. Z. Q., McGillivray, L., Han, J., Christensen, H., & Torok, M. (2021). Effect of Engagement With Digital Interventions on Mental Health Outcomes: A Systematic Review and Meta-Analysis. *Frontiers in Digital Health*, *3*, 764079. https://doi.org/10.3389/fdgth.2021.764079

Gega, L., Jankovic, D., Saramago, P., Marshall, D., Dawson, S., Brabyn, S., Nikolaidis, G. F., Melton, H., Churchill, R., & Bojke, L. (2022). Digital interventions in mental health: Evidence syntheses and economic modelling. *Health Technology Assessment*, *26*(1), 1–182. https://doi.org/10.3310/RCTI6942

Nair, A., Rutledge, R. B., & Mason, L. (2020). Under the Hood: Using Computational Psychiatry to Make Psychological Therapies More Mechanism-Focused. *Frontiers in Psychiatry*, *11*, 140. https://doi.org/10.3389/fpsyt.2020.00140

Yardley, L., Spring, B. J., Riper, H., Morrison, L. G., Crane, D. H., Curtis, K., Merchant, G. C., Naughton, F., & Blandford, A. (2016). Understanding and Promoting Effective Engagement With Digital Behavior Change Interventions. *American Journal of Preventive Medicine*, *51*(5), 833–842. https://doi.org/10.1016/j.amepre.2016.06.015