Assessment and treatment of Post-traumatic Stress Disorder: exploring neurotechnological solutions in a digital world

Authors

Richard Laugharne: Psychoanalytica CIC; Cornwall Partnership NHS Foundation Trust; CIDER, University of Plymouth

Mohsen Farid: University of Derby

Christopher James: University of Warwick

Anirban Dutta: University of Lincoln

Christopher Mould: House of Opportunity (Charity)

Noelle Molten: Tech4Dev Consultant

Jonathan Laugharne: PAX Centre, Perth, Australia

Oliver Main: Torbay General Hospital

Rohit Shankar: Psychoanalytica CIC; CIDER, University of Plymouth; Cornwall Partnership NHS Foundation Trust

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Abstract

Post-traumatic stress disorder (PTSD) is an anxiety condition caused by severe trauma and characterised by nightmares, flashback, hyper vigilance and avoidance behaviour. These all lead to impaired functioning reducing quality of life. PTSD affects 2-5% of the population globally. Most sufferers cannot access effective treatment. These all lead to impaired functioning reducing quality of life. Eye movement desensitisation and reprocessing (EMDR) is a non-invasive brain stimulation treatment that has shown significant clinical effectiveness in PTSD. We describe a concept of a neurodigital tool for development to clinical practice . We will explore the evidence in using new technologies to measure sleep, geolocation and conversational analysis of social media to report objective outcome measures. If achieved, this can be fed back to users with data anonymously collated to evaluate and improve the tool. Coproduction would be at the heart of product development so that the tool is acceptable and accessible to people with the condition.

Introduction (1 page)

Post-traumatic stress disorder (PTSD) is an anxiety disorder precipitated by severe trauma and characterised by the following symptoms: nightmares, flashbacks, hypervigilance, avoidance of reminders and associated thoughts and feelings and an exaggerated startle response. These symptoms are persistent for at least a few weeks and impair functioning[1]. The prevalence of PTSD is between 2-5% of the population in World Health Organisation Surveys[2].

There are effective psychological therapies for PTSD, notably trauma focussed cognitive behavioural therapy and eye movement desensitisation and reprocessing (EMDR), both recommended by NICE in the UK[3]. EMDR (a non-invasive brain stimulation treatment) has been found to be superior to other therapies in reducing PTSD scores in meta-analyses[4,5]. However these therapies are labour intensive and expensive when delivered by clinicians.

In low-middle income countries (LMIC) mental health resources can be limited especially due to relatively few trained health professionals. However, the needs can be high, and PTSD common. In LMIC 76-85% of people with severe mental illness receive no treatment, and 75% of people with PTSD do not even seek treatment, possibly because they know little is available[2].

Self-administered EMDR therapy may be made available via the digital delivery of a smartphone application at a very low cost with little or no clinical supervision required. Likewise, trauma-focused CBT can be made available via smart phone application. Both applications will use machine learning and artificial intelligence to interact with the user and will provide the required support as they learn from the interaction with the user. The US Department of Veterans Affairs has developed an app called PTSD Coach[7] which has been evaluated in several countries[8-12]. Bilateral stimulation apps have been developed but have not been evaluated sufficiently yet[13]. This project seeks to help people with PTSD in situations with very limited mental health resources receive therapy through digital means and improve the quality of their lives.

We will do this by developing:

- A digital tool to help people suffering from PTSD access effective, personalised, holistic help with a smartphone or computer when clinical services are not accessible.
- A digital tool they can use with a friend, family member or treatment partner and can create a virtual peer-support community.
- A tool that uses smartphone and wearables data to unobtrusively monitor progress- data such as sleep monitoring, social media activity, geolocation and conversational analysis[14] - as well as conventional symptom scores and subjective feedback.
- A tool that uses machine learning and AI algorithms to assess the trauma the subject presents and provide clinically sound advice. It will also spot instances of possible harm the subject may experience.
- The tool is quality assured through the Nice Digital Framework and achieves ORCHA approval.

Description (1 page)

We want our tool to have the following properties:

- **Psychoeducation**: the tool will describe PTSD to users in a clearly understandable way and describe how this condition affects people and can be treated.

- **Diagnostic assessment**: do you have PTSD? It is important to help people to understand the difference between temporary distress caused by trauma which naturally resolves itself and longer standing PTSD symptoms that may require treatment.

- **Symptom rating scale**: if they do have PTSD, a symptom rating scale quantifies how much the condition is affecting them and gives a baseline to the level of distress suffered.

- **Choice of treatments and treatment delivery**: there are two non-pharmaceutical therapies recommended by NICE: eye movement desensitisation and reprocessing (EMDR) and trauma focussed cognitive behavioural therapy (T-F CBT). We aim to offer both treatments via the smartphone app intelligent enough to give users a choice of therapy. We will be able to measure the effectiveness of these therapies in different groups and situations.

- **Subjective measure of user satisfaction of the app**: the app will ask users to evaluate the app and its effectiveness in achieving its goals.

- **Repeating the symptom rating scale monthly**: this can be provided as easy to understand visualisation for the user to assess if the treatment is helping.

- **Behavioural and and other types of data will be collected**: the application will inform users of the need to collect behavioural, biometric, social (via social media) and other social activities such as geolocations. Users will be informed of the data that need to be collected and the app, which will be GDPR aware, and will request their approval to share the data.

- **Feedback to client**: the collected and computed data will be shared with the user in a variety of format using cutting edge user experience technologies (UX) to keep them informed of their progress. The app will also provide frequently ask questions (faqs) and will allow the user to make and receive answers to their questions when possible.

- **Building intelligent knowledge base**: as data is being collected, the app will build a language model and data warehouse that provide clinical insights about the types of trauma, user types, age, geographical locations, and other details, such as user eco-system. Such data will be used to build intelligence in the system and will help the clinical understanding of PTSD and other types of trauma which consequently could potential help to enhance treatment and other support modalities.

Solutions proposed (5 pages)

Literature, product and technology reviews

It is essential we have a good grounding on the evidence base of what works for people suffering with PTSD in the digital space. There are established literature reviews that underpin the NICE guidelines for treating PTSD[3] but the digital treatments are early in their development. A greater understanding of the neurophysiological underpinnings of EMDR may help us to develop better digital interventions.

We will conduct rapid literature reviews (registered on PROSPERO) in key areas for this product, including:

1. Neurophysiological understanding of EMDR effects.
   The neurophysiological understanding of EMDR can improve the delivery of the therapy. The review can generate testable hypotheses on how EMDR works to integrate traumatic memory into general semantic networks. Repetitive redirection of attention in EMDR can activate the brain's REM sleep system, leading to the activation of specific areas of the anterior cortex of the cingulate gyrus, facilitating its function as a filter. This integration is seen to lead to a subsequent reduction in both the strength of hippocampal-mediated episodic memories of the traumatic event as well as the amygdaloid-mediated negative affect of PTSD. It is suggested that another underlying mechanism of EMDR stimulation is activation of the lateral cerebellum. Also, inactivation of dentate nuclei in the lateral neocerebellum is shown to facilitate activation of the ventrolateral and central lateral thalamic nuclei. The activation of the ventrolateral nucleus is shown to lead to the activation of the left dorsolateral prefrontal cortex; further facilitating the integration of traumatic memory into general semantic and other neocortical networks. Furthermore, the posterior cerebellum and its metabolic connectivity to the precuneus are involved in the clinical efficacy of EMDR in PTSD. Previous work also found that higher cerebellar metabolism before treatment was associated with reduced clinical PTSD scores after EMDR. Previous work concluded that the posterior cerebellum and its metabolic connectivity with the precuneus have been found to be involved in the clinical efficiency of EMDR in PTSD. Here, the cerebellocortical circuit can be evaluated using neurophysiological testing with brain imaging for a mechanistic understanding of the EMDR effects [related work https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9027826/].

2. Biomarkers and PTSD. We will examine how digital sleep measurements correlate with EEG monitoring of sleep and relate to PTSD treatment response. We will examine the evidence for using geolocation and social-media conversational analysis as treatment outcomes in PTSD.
3. The effectiveness and safety of digitally delivered treatments for PTSD. There are established digital tools delivering T-FCBT and Bilateral Movement tools earlier in their development.
4. PTSD diagnostic and symptom rating scales.

We will also conduct product and technology reviews of digital tools for PTSD:

- Digital delivery tools for trauma-focussed cognitive behavioural therapies.

- Bilateral Movement tools.

Coproduction

Co-production is the process of enabling the experiences of people and organizations to contribute to the care and support of people. Digital applications, as products, need to reflect the general concept of co-production for the enablement, support and welfare and wellbeing of others. Therefore, implementing co-production as an essential foundation for any digital solution aiming to help people is paramount. It is essential that design of the project involves people with lived experience of PTSD from the beginning and incorporate their insights the digital application to be of value to its users. Coproduction will need to be integral to the design, the prototype, product implementation and development, product testing and eventually product roll-out.

We will create a narrative of the proposed system which engages user forums.

It will be important to understand the lived experience of patients with PTSD from different backgrounds, e.g. aetiologies and demographic, socioeconomic, etc.. Traumas leading to PTSD include serious accidents; physical or sexual assault, abuse, e.g., childhood or domestic exposure to traumatic events at work, including remote exposure, serious health problems, such as being admitted to intensive care, childbirth experiences, such as losing a baby, the death of a family member or a friend, , war, conflict and torture. We will seek one to three representatives from each of these groups to contribute to the design of the product.

We will seek to understand with our co-production partners:

- People's experiences of PTSD, coping and engaging with health care systems and community assets.
- Optimise any intervention built using the digital tool and its cultural content to address diversity of the PTSD groups.
- Human story; reinforcing positive identities/bonding social capital whilst bringing more diverse viewpoints (shifting thoughts, promoting curiosity and learning; bridging social capital).
- We will follow the MRC principles of developing complex interventions- support co-production partners to undertake a series of steps to identify the potential mental health benefits and develop a virtual cultural experience to improve people's PTSD symptoms.
- Investigate potential mechanisms of mental health benefits of the digital tool we produce..
- We will collect feedback (e.g., emotional activation, aesthetic engagement, interaction, social and cognitive stimulation, physical activity, sensory literature) from our co-production groups.
- We will focus on the lessons learnt to improve the tool performance as we publish new editions of the tool.

Measuring outcomes

We will measure the effectiveness of the tool in three ways:

1. Patient-focussed subjective feedback:

We will put the person at the centre of the analysis and ask them if they feel the tool has helped them with their problems. We will examine if their subjective experience is correlated with the other outcomes.

2. Validated diagnostic rating scales:

We will use validated symptom rating scales and ask users to complete at regular time intervals. We can chart these scores to both feedback progress to the user and inform the tool of its effectiveness.

3. Machine Learning, AI and Natural Language Processing: :

With the users' consent, we will use machine learning, AI and natural language processing tools to examine biometrics such as sleep, geolocation and actimetry to examine activity, and conversational data, i.e., textual analysis on social media use. We can feedback progress to the user and assess if these outcomes correlate with subjective and conventional measures.

The tool will collect a variety of anonymous data to examine patterns of effectiveness for different interventions, using biometric, demographic, socioeconomic andsocial interaction data. The data will be curated and fed into machine learning algorithms that will learn implied behaviors in the data and create models that will be used in the treatment of subjects based on their particular state. This will help inform continued development of the tool as well as in gaining insights into PTSD itself.

Biometrics for sleep: a risk matrix for the underpinning technology

We will examine the technology we want to utilise to provide innovative biofeedback and data analytics.

We will examine pulse oximetry and electrodermal activity (through smart-watches or smart-rings), voice and video recordings and ballistocardiography. We will assess these for technical feasibility, intellectual property (IP), regulation and for the business models to use.

Actimetry and geolocation for social activity:

PTSD often leads to social withdrawal and people staying at home where they feel safe. In using actimetry and geolocation we can measure correlates of behaviour and tell if people are able to go out more, this could contribute to an overall measure of their social functioning.

Language analysis for social media text:

We will use natural language processing utilising the following techniques:

- Sentiment analysis: the detection of positive and negative emotions, strength of emotion and sudden shifts in sentiment.
- Topic modelling to identify clusters of related topics.
- Named entity recognition to extract specific entities such as people, locations and events to identify patterns in events.
- Time series analysis: to analyse the temporal pattern of text data such as the frequency of certain topics or words over time. This can help to detect sudden spikes or drops in interest or activity.
- Network analysis: to build networks or graphs of related entities such as people, locations and events based on the co-occurance of these entities in text.

Product development for the proof of concept

We will need to develop a protocol for the proof of concept with a view to building a team and securing grants/investment for software engineering and integration, and also design a product that is acceptable and inviting for users with good human computer interaction (HCI).

Initially this will be a medical device which is initially UK based but we will be seeking an international applicability.

Feasibility

The pilot product will need to be tested initially for feasibility and this may need to be delivered in the UK where clinicians are present to enable a good evaluation. However, we will be always aiming to develop a product which can be used where clinicians are scarce and the device can be used by users alone or with a treatment friend who is not necessarily an expert.

We also aim to create an on-line capable community through the device which may develop into a peer support community.

Future work (1page)

Our future work is summarised in the Gantt chart in the appendix.

Phase 1

The development of the idea and concept: this was done at the Bedruthan Hotel in March 2023. The output will be a bid for N-Code funding in April 2023 and a paper on the concept to be submitted in April 2023.

Phase 2

If funded the following work will be undertaken over 12 months between September 2023 and August 2024:

- Work package 1: The literature, technology and product reviews and algorithmic developments.
- Work package 2: the coproduction work as described above.
- Work package 3: Product design and proof of concept.
- Work package 4: Implementation of the proof of concept, testing and evaluation.

The product will be co-developed in partnership with existing AI based behaviour monitoring specialists such as Augmented Insights Ltd. that has created a backend processing package looking for patterns in longitudinal human behaviour data.

These work packages will lead to a further paper being submitted for peer review and an application for further funding for phase 3.

Phase 3

This will take place over a two-year period, provisionally January 2025 to December 2026. This phase will include:

Product development

Agile development

A feasibility trial in the UK

Beta testing

Implementation in the UK

Application for quality assurance under the NICE Digital Framework and to ORCHA for approval under UK regulation and standards.

Phase 4

International marketing and roll out.

Discussion and conclusions (1page)

The strengths of our proposal include the vision of a low-cost treatment for people who have no access to clinicians to help them with their PTSD. If it works, it could help a lot of people and is scalable. It could democratise healthcare – getting help would not depend on having money to pay for it and access to expert clinicians, although the client would need to have a smartphone and other wearables. If the client does have the smartphone, it would be low resource and low maintenance solution. The exciting possibility is in using a smartphone, enhanced with the addition of a smart-watch or smart-ring data, to expand the measurement of the effectiveness of the intervention. With machine learning and AI technology the data collected can give the user and the research team real time personalised evaluations which can increase the effectiveness of the intervention. We can use big data to evaluate and feedback to the client how they are functioning.

The potential limitations include the need for users to trust our product and this needs to be built through the coproduction principle. If people are to use it, they need to trust us and the product and trust that their data is being used in their interests and for the public good. There is the challenge of translation to other languages. New translation technologies may need to be utilised. Developing the tool in commonly used languages will make the tool widely available, but we can explore if translation tools may make the tool more universal. There will be fear of risk, that the tool may make some people feel worse or even suicidal[15]. Our literature reviews and feasibility trials will need to cover these risks. We will need to use good implementation science and good marketing in order to ensure the tool is acceptable and accessible to people. Some professional associations may be reticent in approving digital tools and we will approach them to understand their concerns and address them.

We believe this is a great opportunity to leap into a new age of helping many people who could not access help in the past and utilise new technologies in AI, machine learning and big data. Fundamentally the limits of availability of therapists can be overcome which will democratise healthcare and create new capable communities in helping the poor and the sick.

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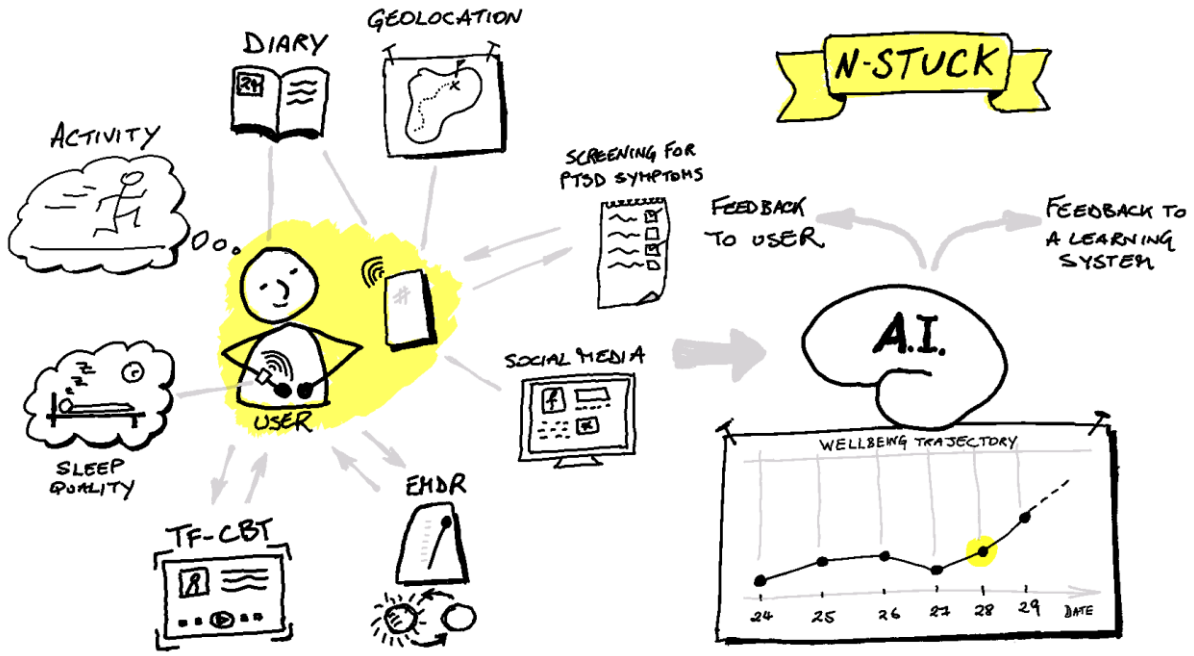
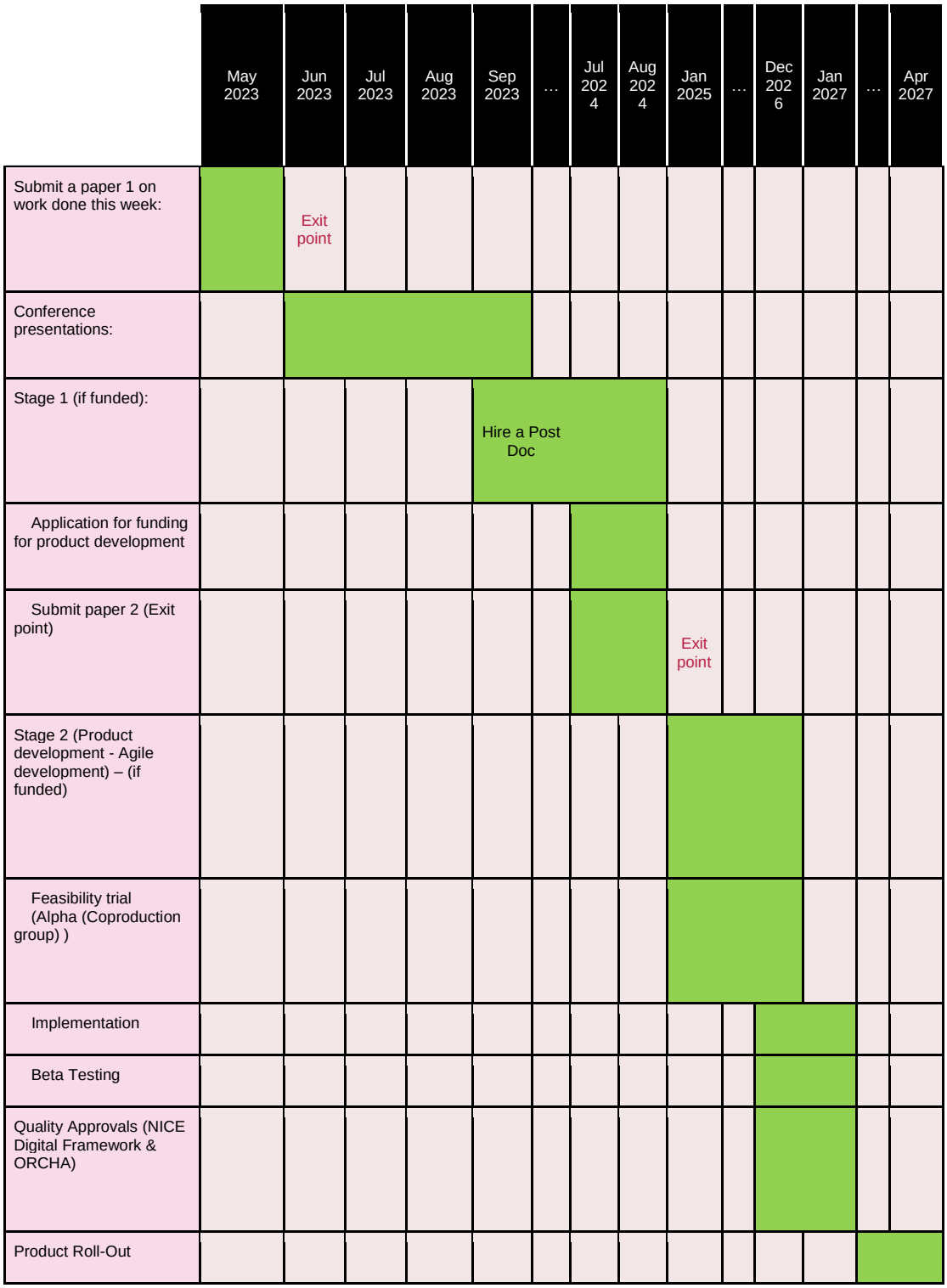
Appendices

Infogram



Gantt chart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Submit a paper 1 on work done this week:
Exit point
Conference presentations:
Stage 1 (if funded):
Hire a Post Doc
Application for funding for product development
Submit paper 2 (Exit point)
Exit point
Stage 2 (Product development - Agile development) – (if funded)
Feasibility trial (Alpha (Coproduction group))
Implementation
Beta Testing
Quality Approvals (NICE Digital Framework & ORCHA)
Product Roll-Out