Towards a Socio-Technical Ecosystem for Ethical Screening and Promotion of Mental Health and Wellbeing

Abstract

This concept paper delineates the design of a socio-technical ecosystem for ethical screening and promotion of mental health and wellbeing, building on the convergence of digital technologies with modern human-centred design methods. Access to individuals' health and wellbeing data will enable the generation of actionable insights with different degrees of granularity, for the benefit of individuals, care providers, and business organisations. Critical to the success of the ecosystem are proactive involvement of all stakeholders, the definition of incentives to encourage engagement, and the promotion of consistent narratives as public institutional messages. The article posits working hypotheses, including the idea that creative externalisation of health and wellbeing data, augmented by advanced physico-digital interactivity, can sustain positive psychological and behavioural change. The theoretical underpinning consists of the integration of existing frameworks across wellbeing, behaviour change, and sustainable business. The article defines a research agenda for expanding socially-inclusive dialogue on data governance and policy implications.

Keywords. Mental health; mental wellbeing; health screening; digital technologies; predictive analytics; portable electronic devices.

Statements and Declarations

The research was proposed and initiated by FC and initially developed in collaboration with GS. DHF's contribution focussed on visual representations of dynamic ecologies and relevant metaphors for creative externalisation of health and wellbeing data, as well as on the definition of the theoretical underpinnings. MN's contribution focussed on the aspects of the mental health and wellbeing ecosystem relevant to business organisations. The first draft of the manuscript was written by FC, and all authors commented on versions of the manuscript prior to submission. All authors read and approved the final manuscript. Given its conceptual nature, this article is not underpinned by any primary data. No funding was received for conducting this study. The authors have no competing interests to declare that are relevant to the content of this article.

Introduction

Innovation for mental health and wellbeing has attracted significant attention in recent years due to its potential for promoting development and growth of individuals, organisations, local communities, and society. It has been estimated that workplace interventions towards improved employee mental wellbeing in the UK, including the implementation of screening initiatives and care management programmes for those at higher risk of developing more severe conditions, can result in significant net profits for employers. Promotion of mental wellbeing at work, including risk assessment and stratification, combined with provision of personalised information, seminars, and workshops for employees, has been estimated to lead to a net profit of over £340,000 per year in savings for a typical business with 500 employees under the assumption that two thirds of the staff engage in the interventions. Such a profit is driven by reduced costs associated with assessment and treatment of mental health conditions, by lower rates of absence from work, and by a reduction in lost productivity due to suboptimal workforce performance [1-2]. The negative societal and economic impact of recent global events such as the 2007-2008 financial crisis and the COVID-19 pandemic has further highlighted the importance of achieving higher degrees of individual and collective resilience within social and productive systems.

In addition to the relevance of employee mental wellbeing to business operation and productivity, increasing prevalence of anxiety, depression, and – more generally – mental ill-heath has often highlighted infrastructural and capacity limitations of support and care services [3]. Opportunities have been identified for digital technologies to augment existing support and care workflows, for example to increase efficiency and improve access to mental health services in primary care settings [4]. However, the potential of digitally-enhanced systems for streamlining workforce wellbeing service access at scale – beyond basic functionalities provided by common self-assessment and self-management mobile software applications – is yet to be fulfilled. Recent research has highlighted opportunities for the development of innovative solutions, enabled by modern technologies, to enhance employee wellbeing [5-8]. Separate studies have considered opportunities for mobile health innovators to contribute to the development of digital mental health ecosystems [9]. However, despite the useful insights generated, these independent lines of research have failed to converge and delineate the design of a socio-technical ecosystem complex enough to address simultaneously challenges faced by care service providers, employers, and individuals.

The reasons for this lack of convergence are more user-centric than technological in nature, and are often associated with a lack of involvement of designers and design researchers together with end users (public and care professionals) in the design and development of digital solutions [10]. Whereas end user involvement has been documented, little information has been provided regarding the nature and scope of the engagement throughout the development process. For this reason, there is often little clarity regarding benefits associated with designers and health professionals taking the lead in scaffolding and facilitating the generation of innovative design concepts with significant end user and stakeholder involvement. This issue is frequently compounded by preconceptions around mental health conditions and by the associated social stigma, which can further reduce engagement of the public with support services and can therefore limit the benefits associated with provision of early-stage mental wellbeing support [11]. This combination of factors can result in a significant missed opportunity with reference to individuals who, if their signs of psychological distress could be detected and flagged at an earlier stage, could receive additional support before more debilitating symptoms manifest themselves [12].

It can be argued that challenges for care providers and business organisations associated with mental ill-health can be conceptualised within the same human-centred systems design framework. In recognition of the relevance to mental health of system-level interdependencies within organisations and communities, recent research has targeted emotional, physical, and psycho-social dimensions of health and wellbeing. A need to consider multi-scale interdependencies within large-scale social systems when designing for innovation towards individual and community wellbeing is illustrated, among others, by research on agent-based computational modelling of community mental healthcare processes and of population wellbeing. Such research aims to improve care and support service quality and to reduce financial burden on taxpayers [13]. The adoption of system-level perspectives has been advocated for the evaluation of public health interventions [14], and interdependences between business and society are well documented [15]. Nonetheless, based on the current literature, it can be argued that no unified framework has, so far, been presented for addressing the needs and requirements of different stakeholders including the public, care providers, and business organisations. A unified approach towards integrating portable electronic devices and modern predictive analytics capabilities within a socio-technical ecosystem to enable monitoring and promotion of mental health and wellbeing on a large scale is lacking. On the other hand, ongoing research and development have contributed to the establishment of a mature knowledge base to provide the foundation of such an ecosystem; this is particularly notable with reference to research on emerging as well as more established technologies for monitoring and promoting individual and community wellbeing in domestic, workplace, and broader social settings [16-19].

This article outlines the theoretical and methodological underpinnings of an ecosystem comprising individuals, care providers, business organisations, and government authorities, aimed at large-scale ethical monitoring and promotion of mental health and wellbeing. Central to the ecosystem is a commitment to ethical practices in gathering and managing mental health and wellbeing data across communities, including self-reports and data collected via continuous passive monitoring of individuals' bio-signals, while rigorously adhering to privacy regulations and achieving clarity in relation to data ownership. The ecosystem, to be designed, implemented, and evaluated in coordination with all stakeholders, will streamline information exchange via a digital platform envisaged for collection, integrity assessment, integration, storage, and analysis of health and wellbeing data. It is expected that the ecosystem will contribute to more efficient and equitable access of individuals to mental health support and care services by further increasing the efficiency of existing triaging processes, among others. In the first instance, the ecosystem will streamline detection of mild-to-moderate anxiety and early-stage depression, with a view to flagging individuals at higher risk of developing more debilitating mental health conditions, so their consultations with care professionals can be prioritised. From a sociological perspective, mental health has received significant attention in recent research [20-21]. Studies have focused on improving the understanding of the impact that factors such as age, sex, gender, ethnic background, and socio-economic status can have on mental ill-health, as well as on "the stigmatizing consequences of mental illness as a social status" [22:129]. It is anticipated that successful implementation of the proposed mental health and wellbeing ecosystem will have a beneficial impact on sociological research around mental health. Streamlined ethical sharing of health and wellbeing data across the ecosystem stakeholders can, in fact, facilitate the identification of factors affecting mental health and wellbeing across the population and can point to disparities in terms of access to support and care services. More broadly, crowdsourced data collection has been identified as a promising way of facilitating the achievement of positive impact of the behavioural sciences on policy-making [23]. This is based on the observation that behaviour often exhibits a high degree of specificity in relation to context, that testing of

new solutions in specific settings is required for successful innovation, and that crowdsourced data collection can enable the implementation of financially-sustainable and scalable data collection strategies. For these reasons, it is expected that the development of the proposed ecosystem will create ideal conditions for strengthening positive impact of the behavioural sciences on policy-making in relation to mental health and wellbeing.

The potential of digital technologies in support of mental health and wellbeing screening is illustrated by the availability of portable electronic devices and mobile software applications and by the data streams that they generate, either passively (using embedded sensors including accelerometers and gyroscopes) or following purposeful user interaction. Large-scale collection, integration, and analysis of data from wearable bio-sensing devices measuring sympathetic nervous system activity and tracking user behaviour, combined with analysis of social media data relating to communication patterns and content, have the potential to enable evidence-driven triaging of mental health conditions [24]. This, in turn, can increase the efficiency of support and care services and facilitate fairer access to resources. Nonetheless, if large-scale adoption of remote screening technology is to be achieved, systemic changes are required within healthcare organisations, and consistent narratives need to be put in place for facilitating continued engagement of the public, of individuals in need of mental health and wellbeing support, and of care professionals [25].

Existing mental health screening and diagnostic methods typically rely on in-person one-to-one interaction between individuals in need of mental health support and care professionals. Whereas reliance on telephone and video-conferencing technology for remote consultations can partly address the negative environmental impact associated with exclusive reliance on in-person interaction, it cannot provide a financially-sustainable large-scale deployment solution unless combined with efficient triaging [26]. The proposed ecosystem is envisaged to fill this gap, in line with the concept of 'Healthcare 5.0', which encompasses "real-time patient monitoring, ambient control and wellness, and privacy compliance" [27:84486] based on a combination of artificial intelligence, 'Internet of Things', 'big data', as well as high-bandwidth and high-availability networking technologies. It has been suggested that health information technology can enable the collection of more objective behavioural health management data and can underpin more effective mental health and wellbeing screening than traditional approaches relying on questionnaires administered in primary care and educational settings [28]. There have been reports of questionnaire-based methods overestimating socially-desirable behaviours, medication adherence being one example, and it has been recognised that the quality of data collected using such questionnaires ultimately rests on accurate recollection of past events by the respondents, which is often limited [28]. Nonetheless, if large-scale mental health and wellbeing screening strategies enabled by modern digital technologies are to be developed, changes for all stakeholders will be required.

Considering the ethical challenges involved in the adoption of digital interventions for mental health and wellbeing, policies and frameworks have been developed to address issues of privacy, transparency, and user trust in modern technologies [29-31]. Such issues are of direct relevance to ongoing research aiming to understand barriers to user engagement with digital technologies in support of mental health and wellbeing [32]. A recent report on attitudes to digital mental health technologies by the Medicines and Healthcare products Regulatory Agency (MHRA) [33] has highlighted the importance of several factors influencing perceptions and attitudes of the public regarding digital innovations in support of mental health and wellbeing. Such factors include the following: integration within wider support and care services; endorsement from authoritative organisations such as the UK National Health Service (NHS), MHRA, and the National Institute for Health and Care

Excellence (NICE); the inclusion of a human element in addition to digital interaction, with emphasis on empathy; digital technologies and information provenance; arrangements for anonymised data sharing, preferably with public universities and research organisations as opposed to commercial entities; proportionate regulation to minimise the negative impact of scams, commercial advertising, and exploitative attempts at taking advantage of individuals who feel vulnerable; clear terms and conditions; granular user control over the data being shared; clarity regarding responsibilities when problems arise; evidence of feasibility and effectiveness, including success rates and relevant metrics, ideally relying on standardised evaluation frameworks for enhanced transparency. Recent work by the Alan Turing Institute has concentrated on 'assurance' as a "process of building trust and justified confidence in a system or technology through engagement and communication" [34:1], with the aim of developing trustworthy digital mental healthcare. A framework and methodology were presented, underpinning the definition of principles and guidelines towards the development of trustworthy digital innovations. Particular attention was paid to fairness (balanced distribution of risks and benefits across user groups) and to explainability in relation to the use of predictive analytics, considering the importance of such aspects for establishing public trust in innovations enabled by modern technologies.

The concept of 'mental health ecosystem' is not new. Recent research has focussed on identifying opportunities and challenges for digital innovators with reference to the development of new mobile health tools to promote mental health [9]. The emphasis has been on improving the alignment between the innovation strategies and the perceived relevance and benefits of the innovations to the users. For this reason, it has been recommended that the use of co-design methods, underpinned by insights from behaviour theory, be prioritised, with a view to lowering barriers to uptake of the innovations and to fulfilling the user needs in line with users' values and expectations. Whereas the digital mental health ecosystem proposed in [9] has an emphasis on mental healthcare provision, the focus of the socio-technical ecosystem the design of which is delineated in the article is on empowering individuals in relation to their own wellbeing and on enabling large-scale mental health screening and preventative interventions. For this reason, issues relating to screening and health anxiety [35] will need to be considered as part of the design of the ecosystem, in addition to the ethical issues discussed previously.

The following sections present the methods employed for identifying the key components of the theoretical foundations for this study, the theoretical framework underpinning the development of the mental health and wellbeing ecosystem, research aims, working hypotheses, the ecosystem and associated development strategies, and conclusions.

Methods

The methodology adopted for delineating the design of the proposed ecosystem is grounded in critical realism, which identifies five key stages in interdisciplinary research: (i) planning; (ii) disciplinary reflection; (iii) teamwork concentrating on developing understanding across discipline boundaries; (iv) knowledge integration; (v) interdisciplinary understanding of relevant structures and interdependencies [36]. The principle of 'epistemological pluralism' [37] has proven particularly useful in the context of this study, in recognition of the existence of different ways of 'knowing' and of generating knowledge about complex systems in which components refer to qualitatively-different contexts and domains. The mental health and wellbeing ecosystem discussed in this article is defined via the convergence of technical, semantic, semiotic, social, organisational, and ethical elements, each of which has been a subject of academic and broader professional discourse.

A scoping review of interdisciplinary literature led to the delineation of the proposed design framework. The review included recent developments in relation to semiotics, sense-making, cognitive load, social engagement, health beliefs, health behaviour change, corporate social responsibility, diffusion of innovations, explainable artificial intelligence for healthcare, and ethics in the processing and management of health and wellbeing data. Google Scholar was used to perform initial searches of scholarly publications across the relevant disciplines, relying on keywords that were iteratively refined based on the results returned. Initial keywords were selected with a view to maximising the likelihood of retrieving publications relevant to the different aspects of the ecosystem, and included a logical OR of the following: 'mental health and wellbeing'; 'digital technologies' AND 'health and wellbeing'; 'artificial intelligence' AND 'health and wellbeing'; 'data sharing' AND 'health and wellbeing; 'health and wellbeing' AND 'AI ethics'; 'health screening'; 'employee wellbeing'; 'corporate responsibility' AND 'sustainable business models'; 'visual ecologies'; 'sense-making through metaphors'; 'social engagement'; 'behaviour change' AND 'health and wellbeing'; 'diffusion of innovations' AND 'health and wellbeing'. Where required, the searches were extended to additional databases and digital platforms as part of a process of iterative refinement including consolidation discussions among the authors. Additional databases and platforms included Scopus, ACM Digital Library, Web of Science, and PubMed. Searches were restricted to publications written in English, and articles published within the last 10 years were prioritised. Considering the importance of ethical and regulatory issues in relation to the proposed ecosystem, additional public sources were considered beyond academic publications, most notably MHRA and the Alan Turing Institute regarding the use of software and artificial intelligence as a medical device. The definition of the keyword-based queries was refined in the context of scoping and iterative concept consolidation discussions among the authors. The authors' combined academic and professional expertise spans human-centred technology innovation, artificial intelligence, design for healthcare innovation, arts therapies, and business transformation. Such a convergence of expert knowledge across academic disciplines and professional practice enabled the development of the study model, building on established but thus-far disjoint theoretical frameworks, as well as the generation of innovative design concepts for the development, implementation, and sustainable deployment of the ecosystem.

Theoretical Framework

The proposed mental health and wellbeing ecosystem is meant to create the conditions for a positive change process to take place for individuals, engendering a sense of ownership and agency over health and wellbeing, and encouraging the engagement of individuals within communities defined by shared interests and goals. The change process will be facilitated by interactive capabilities accessed via digital and physico-digital interfaces enabling individuals to visualise and intervene on external representations of individual and community health and wellbeing data. The theoretical framework is the result of the convergence of sustainable business and wellbeing models documented in the management research literature [38] with behaviour change models, especially those that have proven beneficial in modelling mechanisms of change in relation to the adoption of digital healthcare innovations [39]. The Integrated-Change Model [40], the potential of which for the design of digital health programmes has been recently documented [41], is used in the following to elucidate key factors relevant to the ecosystem framework. Figure 1 displays key elements of the Integrated-Change Model ('Awareness', 'Motivation', 'Action', and 'Behaviour') together with factors influencing the change process, including change to attitudes and behaviour with reference to the adoption of digital health innovations. The middle row with boxes within the grey area represents an idealised linear sequence of transitions from 'Awareness' to 'Motivation', from 'Motivation' to 'Action', and from 'Action to Behaviour'. The thinner

arrows in the figure show which factors influence which of the four elements. The filled dots have been included to make it explicit that each factor can affect each of the elements. The directional flows in Fig. 1 illustrate the progression and interplay between the key elements of behaviour change, namely ‘Awareness’ → ‘Motivation’ → ‘Action’ → ‘Behaviour’. These arrows represent a sequential yet dynamic process. While the primary flow suggests a linear progression, it is important to acknowledge that nonlinear dependencies and feedback loops exist within this model. For instance, the ‘Awareness’ stage serves as the initial step, where individuals recognise the need for change. However, feedback from subsequent stages, such as experiencing barriers during ‘Action’, can prompt individuals to revisit and deepen their ‘Awareness’. The ‘Motivation’ stage is influenced not only by the preceding ‘Awareness’, but also by factors such as support or barriers encountered during ‘Action’ and ‘Behaviour’, which creates a bidirectional relationship. Finally, whereas ‘Action’ leads to tangible efforts towards change, sustained ‘Behaviour’ can reinforce ‘Motivation’ or reshape ‘Awareness’ through reflection on outcomes.

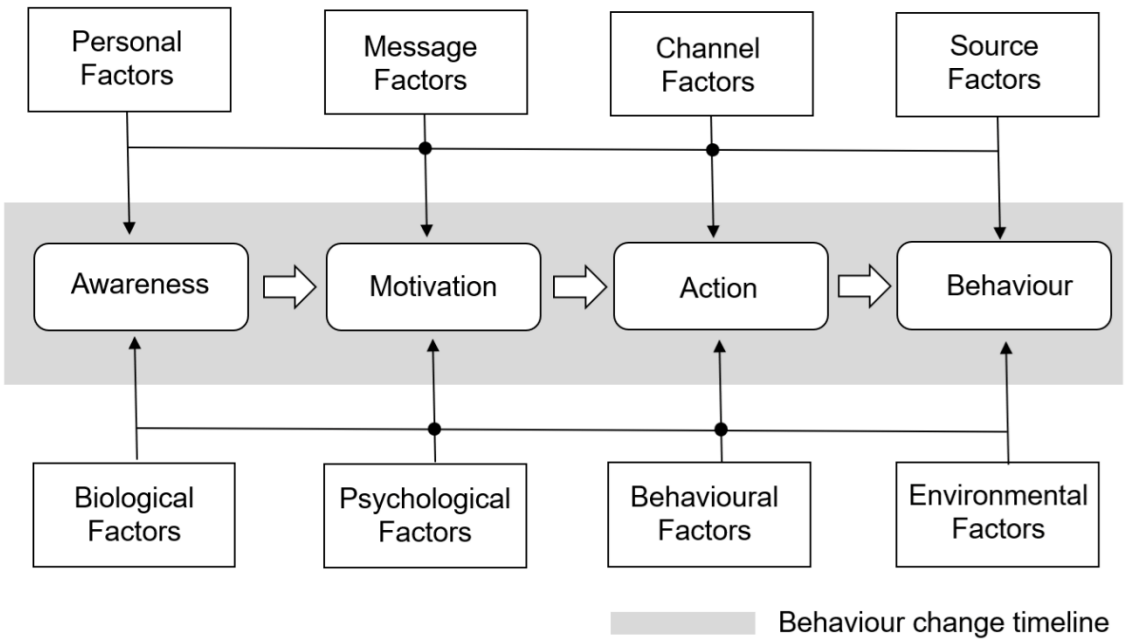

Figure 1. The Integrated-Change Model, adapted from [40].

A logic model of the proposed interactive change process is presented in Fig. 2, where precursors are formulated as willingness and availability to share health and wellbeing data across the ecosystem stakeholders, underpinned by awareness of anticipated benefits and trust in the ecosystem. For this discussion, ‘trust’ is defined as epistemic confidence, identity centrality, or a combination of the two. Epistemic confidence is the “degree to which someone feels a belief state approximates [...] clear contents, objective truth, and rational justification" [42:2], whereas identity centrality is the “degree to which someone experiences a belief state as part of their social identity" [42:2], where 'social identity' is defined as "a cluster of psychological states and behavioral dispositions that constitute someone as a member of an actual or potential in-group, or that an individual uses to achieve a desired social position" [42:2]. The definition and relevance to the ecosystem of the concept of ‘trust’, which plays a critical role in the framework as reflected in Fig. 2, is grounded in recent developments [40; 42-44].

Considering the different stakeholders involved in the ecosystem, it is expected that the role played by epistemic confidence and identity centrality in the context of the interactive change

process will depend on context. ‘Antecedents’ and ‘Contextual Factors’ have been separated from ‘Precursors’ in Fig. 2, to clarify that the latter are prerequisites to the use of individuals’ health and wellbeing data as input to the interactive change process within the ecosystem. In addition to health and wellbeing data externalisations augmented by accessible interactive capabilities, mediators of positive change include constructive and consistent narratives around mental health as well as employee benefits and incentives schemes. Recent research has highlighted a need for additional depth to the ongoing discourse across academics and practitioners, including HR professionals, with a view to identifying how employee benefits and incentives schemes can best be devised and embedded within existing corporate social responsibility programmes [45]. Care should be taken to mitigate risks associated with unintended effects, including potential negative impact on employee mental health. The convergence of such future studies with existing efforts to establish scientific tools for assessment of employee psychological, social, subjective, and workplace-related wellbeing [46] holds promise to feed into the development of the proposed mental health and wellbeing ecosystem.

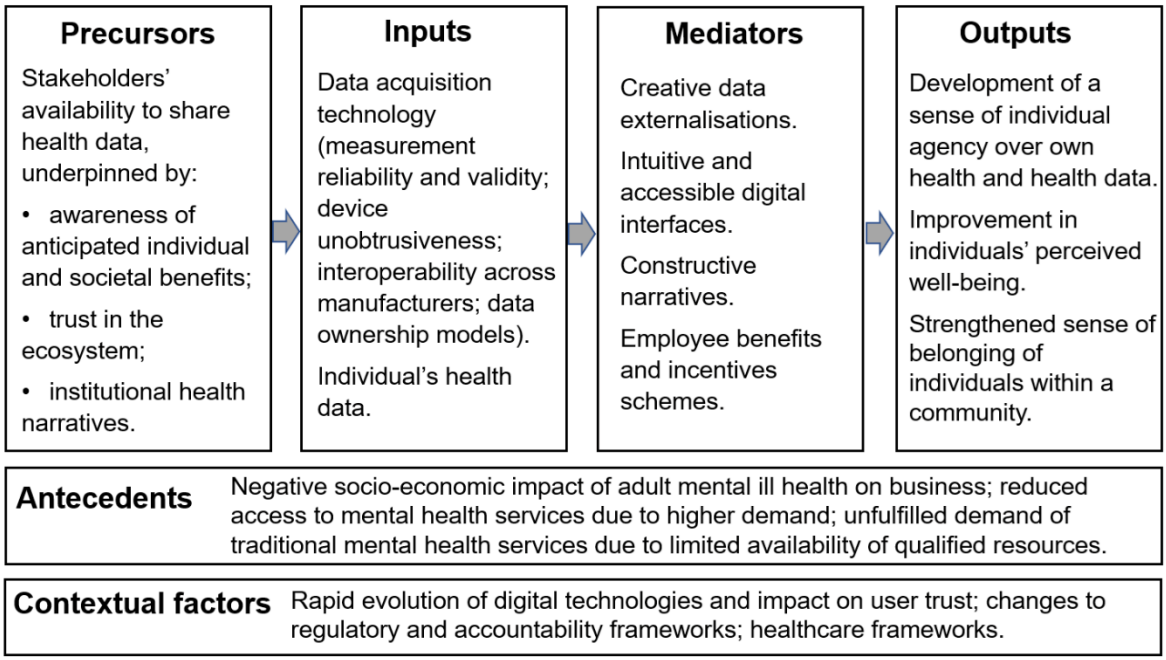

Figure 2. Logic model of the interactive change process to be enabled by the ecosystem.

Table 1 summarises key features of the interfaces providing access to the health and wellbeing data externalisations, mapped to behaviour change stages ('Awareness’, ‘Motivation’, ‘Action’, ‘Behaviour’), with reference to the interactive change process as presented in the Integrated-Change Model (Fig. 1). Individual characteristics relevant to the different behaviour change stages have been included in the table. Attitudes are generally determined by individual and contextual factors such as individual predisposition to the use of digital technologies and peer influence. Similarly, intentions can be affected by individuals’ attitudes and peer influence. Table 2 reports a list of factors from the Integrated-Change Model affecting individuals’ willingness and abilities to engage with different features of the proposed physico-digital interfaces.

In the context of the Integrated-Change Model, the ‘Action’ stage encompasses the processes and capacities required to move from motivation to pragmatic behaviours. The inclusion of

'Willingness to overcome barriers' with reference to this stage reflects the active effort that individuals must make to address obstacles that arise when planning or enacting behaviours. Barriers, in this sense, are seen not as static, pre-existing factors but as dynamic challenges that individuals encounter and address during the action-taking process. For example, accessing appropriate resources or engaging with others to resolve these barriers may depend on an individual's willingness and capability to engage actively. Similarly, 'Capability of interacting with individuals and groups' is categorised under 'Action' because it directly influences the ability to execute planned behaviours in a social context. Whereas 'capability' might traditionally be seen as a preceding factor (or skill), it is treated as part of the 'Action' process in the context of this framework because the application of capability is what enables individuals to translate plans into real-world behaviours. This categorisation emphasises the dynamic and iterative nature of actions, particularly in collaborative and group-based contexts, integral to taking meaningful steps towards change.

A schematic representation of functional relationships between individuals' health and wellbeing data, data externalisations, and features of the interfaces is provided in Fig. 3, with emphasis on functionalities to facilitate access to information and advice and to encourage engagement of individuals within communities.

Behaviour change stage	**Individual characteristics**	**Interface feature**
Awareness	Cognizance	Signposting of information and advice
	Knowledge	
	Risk perception	
	Perception of interactive cues	Inclusive access to interactive functionalities
Motivation	Attitude	-
	Social influences	Capability of interacting with individuals and groups
	Self-efficacy	Inclusive access to interactive functionalities
	Intention	-
Action	Willingness to overcome barriers	Signposting of information and advice
	Willingness to plan	Capability of interacting with individuals and groups
	Willingness to enact	
Behaviour	Interest in own wellbeing data	Functionalities for individuals to track changes to their own wellbeing and behaviour over time
	Interest in community wellbeing data	Functionalities for individuals to track changes to data originating from multiple users over time

Table 1. Features of the interfaces to health and wellbeing data externalisations, mapped to behaviour change stages and to relevant individual characteristics.

Factor	**Interface feature**
Biological	Design to enhance accessibility
Psychological	
Behavioural	
Environmental	

Personal	Signposting of information and advice
Message	Capability of interacting with individuals and groups, with an option for anonymity
Channel	Interactive access to data with varying degree of granularity
Source	Reliance on authoritative channels for signposting of information and advice

Table 2. Factors influencing individuals' willingness and abilities to engage with the proposed interfaces to creative externalisations of health and wellbeing data, extracted from the Integrated-Change Model.

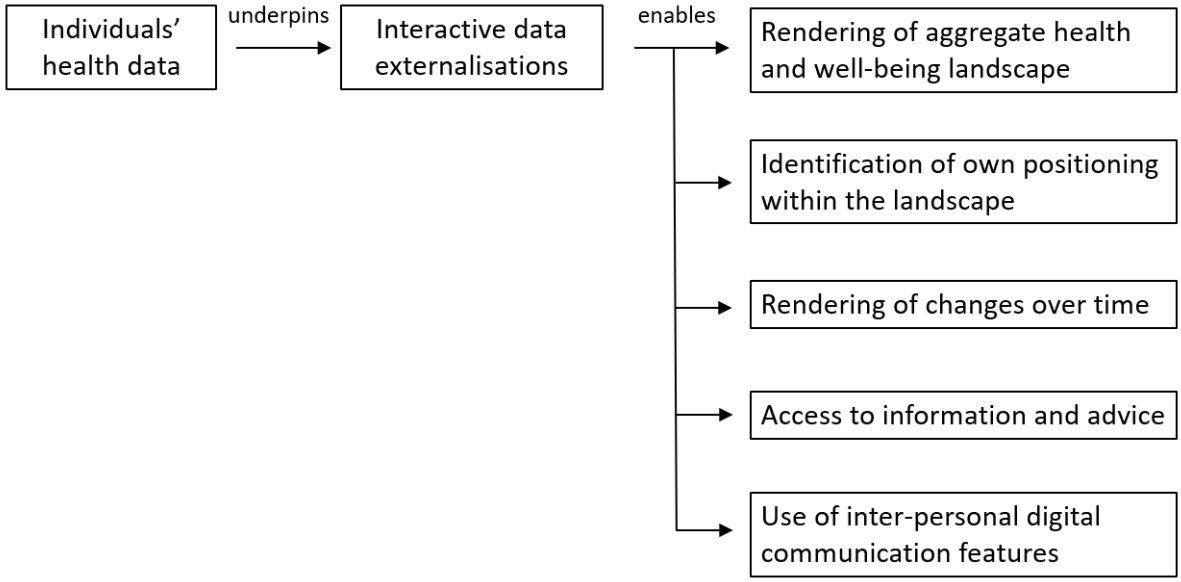

Figure 3. Schematic representation of how individuals' health and wellbeing data will underpin key functionalities enabled by interactive data externalisations.

The factors listed in Tab. 2 are the same as reported in [40] as 'Preceding Factors' and 'Information Factors': 'Personal Factors', 'Message Factors', 'Channel Factors', 'Source Factors', 'Biological Factors', 'Psychological Factors', 'Behavioural Factors', and 'Environmental Factors'. 'Message Factors', 'Channel Factors', and 'Source Factors' are information-specific and refer to communication between individuals and across communities. Examples of relevant factors with reference to the mental health and wellbeing ecosystem and the associated physico-digital interfaces to the proposed creative externalisations of health and wellbeing data include the following: individuals' circumstances affecting engagement within communities, e.g. limited time due to work or family commitments ('Personal Factors'); the content of communication between individuals ('Message Factors'); the communication channel(s) employed, e.g. face to face as opposed to the use of digital technologies between individuals, and Web interfaces regarding individuals accessing health information and guidance ('Channel Factors'); information provenance, e.g. authoritative organisations in relation to the provision of health and wellbeing advice ('Source Factors'); individuals' health as a result of genetic predisposition to specific conditions ('Biological Factors'); individuals' self-efficacy in relation to management of own wellbeing ('Psychological Factors'); individuals' degree of engagement within local communities ('Behavioural Factors'); availability of local initiatives promoting individuals' engagement within communities ('Environmental Factors').

Research aims

The conceptual modelling presented in this article aims to promote individuals' engagement with health and wellbeing by enhancing awareness and by fostering a sense of agency over personal wellbeing while encouraging community participation. Design of creative externalisations of live multimodal health and wellbeing data streams is envisaged, together with the definition of dedicated engagement strategies to engender a sense of ownership of personal health data. Further engagement of individuals within local communities is expected to lead to benefits for both individuals and communities, and to underpin sustainable operation of the ecosystem via continued engagement of individuals in the proposed ethical health and wellbeing data sharing programme. Nonetheless, strategies for promoting engagement should also consider the involvement of community leaders and influencers, including organisations representing minority groups.

Business organisations will be empowered with scalable ethical methods of monitoring employee wellbeing and of tailoring interventions towards increased productivity and improved workforce resilience. Gaps have been identified in terms of ethical and regulatory frameworks to cover collection, storage, exchange, and processing of individuals' health data (including the use of inferential algorithms for screening purposes) with reference to smart healthcare applications, particularly in the context of prospective real-time patient monitoring and management systems enabled by emerging technologies [27]. For this reason, addressing regulatory gaps in data governance is a key aim in relation to the development of the ecosystem, along with identifying effective health and wellbeing data sources and integration strategies. Finally, the research seeks to streamline ethical exchange of health and wellbeing data across organisations, and to develop metrics and algorithms for monitoring health and wellbeing changes over time, thereby enhancing the integration and effectiveness of care services. The research aims are summarised below.

A1. Promote individuals' engagement, community collaboration, and community empowerment. To increase individuals' awareness of (and contribute to engendering a sense of agency over) personal wellbeing, at the same time promoting the engagement of individuals within their communities. To engage with organisations representing local communities, including minority groups, with a view to encouraging further the promotion of the ecosystem.

A2. Design externalisations of mental health and wellbeing data. To identify relatable health and wellbeing data experiential strategies to enable meaningful and sustained engagement of individuals, to facilitate objective assessment of personal and community mental health, and to streamline access to peer and specialist support.

A3. Empower businesses. To provide business organisations with ethical, cost-effective, and scalable methods of quantifying and monitoring employee wellbeing, and of tailoring interventions to increase employee wellbeing and business productivity.

A4. Address regulatory gaps. To address current regulatory gaps regarding the governance of individuals' and organisational data as well as data exchange between care providers and business organisations, thereby identifying ways of implementing changes to existing policies and regulations.

A5. Select and integrate health and wellbeing data sources. To identify what streams of individuals' health and wellbeing data (including data from bio-sensors, mobile software applications, and self-reports) and what data integration strategies are best suited for maximising benefits to individuals, communities, business organisations, and care service providers.

A6. Streamline exchange of health and wellbeing data. To facilitate responsible exchange of individuals' health and wellbeing data within integrated care services as well as between care services and business organisations, with a view to supporting the operational integration of care and support services.

A7. Develop algorithms for monitoring health and wellbeing changes. To generate equitable metrics (and algorithms relying on them) to enable tracking of health and wellbeing changes over time at individual and community level.

Working hypotheses

The working hypotheses underlying the design and development of the ecosystem are discussed in this section with reference to relevant theories and models.

OW. Overarching Working Hypothesis. A health and wellbeing data sharing programme can be designed for equitability and trust, to underpin a socio-technical ecosystem comprising individuals, care providers, and business organisations, enabling ethical screening and promotion of mental health and wellbeing for the benefit of individuals and communities.

Considering the complexity of the proposed ecosystem and the interdisciplinary character of the research, the overarching working hypothesis is best broken down into multiple hypotheses relevant to different aspects of the ecosystem and to different beneficiaries of the innovation. A list of working hypotheses and relevant theoretical and methodological underpinnings is provided below.

H1. Empowerment of individuals, community collaboration, and community empowerment. Individuals can benefit from awareness and engagement with their health and wellbeing data as well as from engagement with local communities in terms of improved wellbeing. Community leaders and influencers can be involved in programmes to support the sustainable operation of the ecosystem. *Theories, models, and methods*: Sense-Making Theory [47]; Theory of Social Engagement [48].

H2. Employee wellbeing. Access to aggregate anonymised workforce health and wellbeing data can enable businesses to develop targeted interventions to improve employee wellbeing and productivity. *Theories, models, and methods*: Corporate Social Responsibility [49].

H3. Health data and preventative care. Large-scale collection and integration of personal health data can support national healthcare services and integrated care providers in implementing prevention and early-stage interventions. The primary aim is to reduce costs associated with diagnosis and treatment of severe and chronic mental health conditions. *Theories, models, and methods*: Diffusion of Innovations [50-51].

H4. Sustained participation. Creative and aesthetic externalisations of health and wellbeing data, augmented with advanced physico-digital interactivity and combined with benefits and incentives structures, can foster active and sustained participation in the data sharing programme. *Theories, models, and methods*: Sense-Making Theory [47]; Semiotic Models [52]; Cognitive Load Theory [53]; Affordance Theory, recently reviewed in relation to information systems [54].

H5. Data integration. Collection, integrity assessment, and integration of individuals' health and wellbeing data can be scaled up to local, regional, and national level. *Theories, models, and methods*: Diffusion of Innovations [50-51]; Corporate Social Responsibility [49].

H6. Actionable insights. Actionable insights can be generated from individuals' health and wellbeing data with different degrees of granularity, to monitor and promote the health and wellbeing of individuals and communities. *Theories, models, and methods*: Diffusion of

Innovations [50-51]; explainable artificial intelligence for healthcare [27]; validation methods for machine learning models in medicine [55].

H7. Monitoring of health and wellbeing changes. Modern predictive analytics techniques can underpin real-time monitoring of health and wellbeing changes at individual, community, and societal level, based on quantitative metrics suitable for streamlining equitability assessment. *Theories, models, and methods*: Diffusion of Innovations [50-51]; explainable artificial intelligence for healthcare [27]; validation methods for machine learning models in medicine [55], contributing to the ongoing programme for change to the UK regulatory framework for software and artificial intelligence as a medical device [56].

The mental health and wellbeing ecosystem and strategies for its development

A schematic representation of the proposed ecosystem is provided in Fig. 4, where roles are presented for individuals, business organisations in their capacity as employers, healthcare providers and integrated care teams, and government authorities. Integrated care teams comprise professionals with complementary knowledge, skills, and experience – they often include Nurses, Occupational Therapists, and Psychology specialists working alongside Social Workers, Physiotherapists, physical health Occupational Therapists, and General Practitioners. Arrows in the figure reflect flow of information or causal relations**,** as relevant.

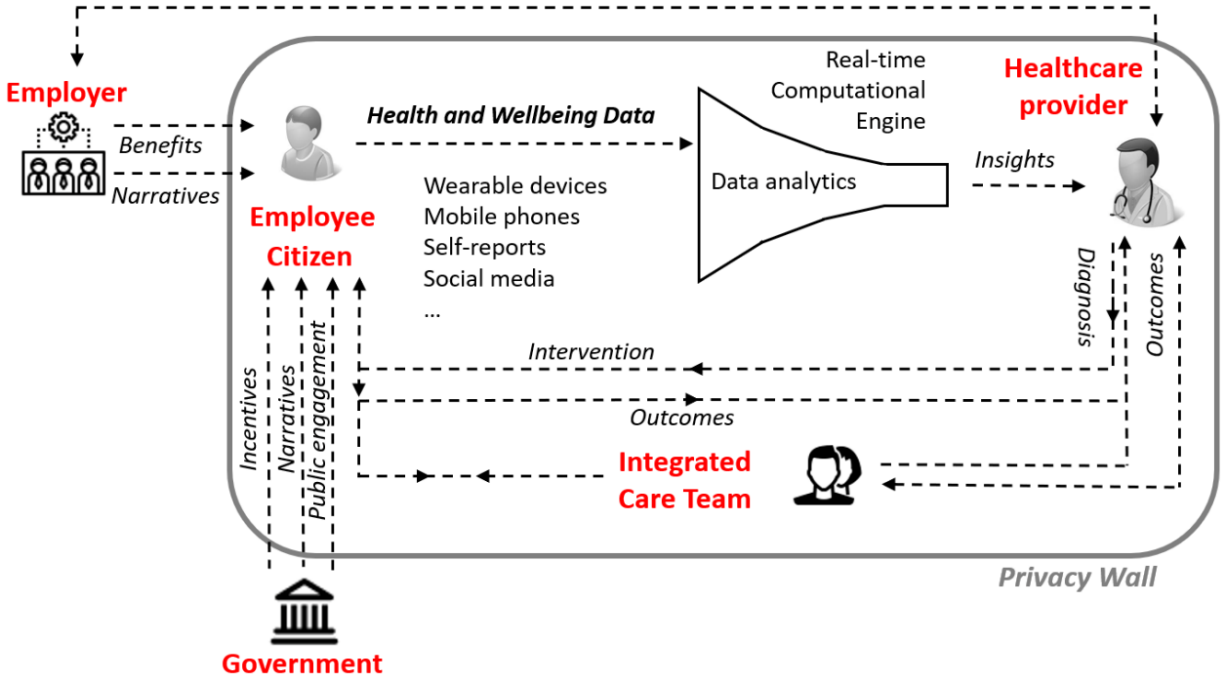

Figure 4. Schematic representation of the proposed socio-technical ecosystem.

The operation of the system will rely on three Pillars, as outlined below.

- *Pillar 1*. An employee engagement programme, including the provision of suitable incentives and benefits schemes.
- *Pillar 2*. A public engagement programme to favour engagement of individuals in digitally-enhanced mental health and wellbeing screening.
- *Pillar 3*. A scalable Information Technology (IT) infrastructure to enable the collection and integration of data across a range of sources including portable electronic devices, smartphone software applications, social media communication, and self-reports.

	Stakeholders	Development stage

Pillar 1: Engagement, incentives, and benefits schemes	Designers and design researchers; employers; government; healthcare staff	Programme implementation
Pillar 2: Constructive and consistent mental health narratives	Designers and design researchers; behaviour change specialists; healthcare staff; government organisations	Programme conceptualisation
Pillar 3: Scalable IT infrastructure integrated with healthcare systems	Designers and design researchers; technology developers	Technical development
	Designers and design researchers; AI researchers and data scientists; healthcare systems; government authorities; policy-makers	Programme implementation

Table 3. Development stages and relevant stakeholders with reference to the three Pillars of the mental health and wellbeing ecosystem.

Table 3 provides additional detail about development stages and relevant stakeholders with reference to the development of the three Pillars. The adoption of an interdisciplinary approach is a key requirement for the successful development of this research programme. Development priorities in relation to the three pillars are outlined below. It is recommended that designers and design researchers be involved across the three Pillars at the relevant development stages. This will create favourable conditions for the consolidation of the conceptualisation programme, and for the innovations to be aligned with user values, needs, and requirements as well as to the expectations of the different stakeholders.

Pillar 1: Engagement, incentives, and benefits schemes

Identifying operational mechanisms to encourage continued engagement of individuals with the ecosystem and with its data sharing programme will play an important role in the development process. The role of strategies incorporating multifaceted sense-making through metaphors [47] has been investigated in the domain of wellbeing data visualisation, and successful health and education research has been conducted relying on metaphors based on visual ecologies [57-58]. Visual metaphors representing social ecosystems can offer scope for expressing ‘dynamic landscapes' of live metrics, for example relying on symbolic biospheres, in such a way that position and movement of individuals’ health and wellbeing data representations within the landscape can symbolise significant personal wellbeing milestones and challenges, informed by health and social paradigms and based on personal goals. Ways of incorporating population-level metrics within the interactive externalisations of individual health and wellbeing data will be investigated during the development of the ecosystem, so that personal data can be contextualised within continuously-evolving geographic community representations. This component of the ecosystem ultimately builds on the hypothesis that simple contextualisation of health and wellbeing data within a collective 'landscape' can engender a sense of social connectedness and ultimately improve individual and community mental health. Work to develop this Pillar will include the definition of suitable employee incentives and benefits schemes, as well as the identification of methods of integrating employee health and wellbeing assessment workflows within appraisal and annual review

processes. It is expected that the involvement of designers and design researchers, starting with the Pillar 1 conceptualisation stage, will facilitate the employment of generative research methods and co-design practices and will create ideal conditions for the user needs to be accurately identified and translated into actionable system requirements.

Pillar 2: Constructive and consistent mental health narratives

The promotion (by government authorities, care providers, and business organisations) of constructive and consistent mental health narratives for public consumption will be important for addressing issues of stigmatisation that can negatively impact individuals' perceptions and attitudes towards the ecosystem. The narratives should be devised as public institutional messages, with the dual aim of encouraging individuals' stronger agency over their own wellbeing and of inviting the development of additional interventions by business organisations to foster employees' health and wellbeing in addition to performance assessment. By embedding such narratives into every aspect of the ecosystem, from design to policy advocacy, the research programme will foster a holistic, inclusive, and empowering approach to health and wellbeing for individuals and communities. Communication strategies implemented by national governments and employers should therefore be devised with active participation of public, patient, clinical, healthcare management, and third-sector stakeholders. Examples of narratives to be considered include those focussing on modern integrated views of wellbeing along mental, social, and physical dimensions [59], as opposed to others with more explicit clinical connotations – for example, with reference to diagnosis of anxiety, depression, and other mental health conditions. It is recommended that designers and design researchers be involved at the development stage, so their expertise can feed into the definition and implementation of iterative testing and design refinement strategies. The emphasis should be on ecosystem tools and interfaces, with the aims of enhancing accessibility and inclusivity and of facilitating collaboration between end users and technical teams.

Pillar 3: Scalable IT infrastructure integrated with healthcare systems

The operation of the ecosystem is to be underpinned by an IT infrastructure and suitable digital platforms, including features to enable secure data storage, data processing, and generation of actionable insights. The infrastructure and the digital platforms should be developed for scalability and cost-effectiveness in coordination with user groups and stakeholders; the emphasis should be on addressing both systemic and infrastructural barriers to deployment, including those associated with limited interoperability across hardware and software providers. The benefits of data-driven health and wellbeing insights for individuals, care professionals, carers, business managers, and healthcare management professionals will be maximised thanks to the adoption of digital interfaces designed for interpretability and ease of use, to replace existing dashboards that often require a degree of technical competency for efficient use. Dedicated interfaces will streamline access to health and wellbeing data with different degrees of granularity for research and government organisations, for example to generate epidemiology and public health insights in support of policy-making. The ability to quantify, track over time, and display informative visual representations (based on interpretable metaphors) of health and wellbeing changes at individual and community level – potentially, also at the level of individual support and care services – is expected to facilitate the task of making sense of health and wellbeing data, often complex in nature. Approaches have been proposed for secure storage and analysis of individuals' health data relying on federated machine learning techniques and associated information systems architectures. Such approaches typically rely on storage and processing of data within local computational nodes, combined with shared availability of machine learning models built using data aggregated from across the system [60]. These methods and

techniques hold potential for addressing privacy concerns while at the same time enabling the generation of a large-scale evidence base. At the implementation stage, designers and design researchers are expected to play an essential role in evaluating the success of the system in real-world scenarios, relying on data-driven insights for further refining tools and interfaces. Their continued involvement will support the adaptability and long-term sustainability of the ecosystem.

Both the data externalisations and the associated interactive features are to be designed with involvement of the public and patients, and in coordination with key stakeholders including managers and healthcare staff. Attention will have to be paid to suitable degrees of granularity for access to health and wellbeing data by individuals and organisations, as well as to the circumstances where such access is appropriate. Similarly, the possibility of negative affect states being transferred across members of a community [61-62] via individuals' interactions with the data externalisations will have to be considered when designing the interactive features.

The availability of aggregate anonymised data about employee health and wellbeing will facilitate the employers' task of implementing tailored support strategies. Access to such data holds additional potential for helping job applicants in selecting the most suitable prospective employers, for example based on statistics about the average degree of mental health and wellbeing corresponding to different business locations. Care service providers are expected to benefit from the ecosystem in terms of more efficient management of early signs of individuals' psychological distress, before conditions exacerbate and require more sustained reliance on care services. Finally, the practice of ethically sharing individuals' health and wellbeing data that fulfil reliability and validity requirements is anticipated to streamline the exchange of information and insights across integrated care teams consisting of multiple service providers. This, in turn, will contribute to more efficient delivery of – and more inclusive access to – support and care services.

An initial pilot study should be conducted to understand opportunities and barriers to engaging the public in mental health and wellbeing screening interventions relying on ethical sharing of individuals' health and wellbeing data across the ecosystem stakeholders. The involvement of diverse groups of individuals in a human-centred design programme is encouraged. This will create favourable conditions for promoting engagement with the ecosystem across the population, with emphasis on under-represented and under-served communities. Attention should be paid to minority ethnic groups, members of the LGBTQ+ community, and individuals residing in disadvantaged geographical areas or otherwise less likely to have access to mental health screening services due to socio-economic status**,** age or sex. Further development should focus on the role to be played by business organisations and care providers within the ecosystem, on regulatory and policy-making implications, and on developing the underpinning technological infrastructure.

Conclusions

This concept paper has introduced a comprehensive socio-technical ecosystem framework to enable ethical mental health and wellbeing screening on a large scale, with a view to promoting health and wellbeing for individuals and communities. The convergence of individuals, care providers, and business organisations, supported by government authorities and building on a shared willingness to contribute personal and institutional health and wellbeing data, has been proposed as a key enabler of the ecosystem, with anticipated benefits in terms of streamlined ethical collection, integration, and sharing of health and wellbeing data. Reliance on predictive numerical models will enable the generation of

actionable insights to be shared across stakeholders with different degrees of granularity, with anticipated benefits for individuals, communities, care service providers, and business organisations. It is also anticipated that streamlined ethical health and wellbeing data exchange across the ecosystem stakeholders will benefit sociological discourse around mental health by providing an integrated knowledge base. Such a knowledge base will support the identification of inequities across the population in terms of mental health and wellbeing outcomes as well as access to support and care services. Whereas the focus of this study is on the UK health service provision, the generalisability of the proposed ecosystem framework is underlined by the recommended engagement of all stakeholders throughout the design process: this underpins the adaptability of the framework to different economic, regulatory, and cultural environments. By integrating ecological design principles, the framework emphasises the importance of iterative engagement with local stakeholders within complex human-technological environments. The proposed engagement is to include policy-makers, community leaders, and end users, taking into consideration the characteristics of the interactive digital and physical environment. The goal is to maximise the alignment of the ecosystem components with the specific needs and values of the user population. For instance, in low-resource settings, adaptations could focus on leveraging cost-effective digital tools and on prioritising interventions that address systemic barriers such as limited healthcare access. On the other hand, in high-resource settings, the framework might emphasise advanced analytics and personalised interventions while adhering to the relevant regulatory requirements. Additionally, cultural adaptations can rely on the embedding of local norms, languages, and beliefs into the design and delivery of digital tools to foster trust and engagement. Tailoring implementation strategies to varying contexts will enhance the generalisability of the framework and its anticipated positive impact in terms of improved global mental health outcomes.

The theoretical underpinning of the ecosystem is the result of the coalescence of existing wellbeing and sustainable business frameworks, combined with health behaviour change models. Equally, the framework relies on the systemic integration of disjoint services and information sources, enhanced using predictive analytics and underpinned by a robust data governance framework. Working hypotheses have been presented, with emphasis on the engagement of individuals with health and wellbeing data, facilitated by creative externalisations of multimodal live data streams augmented with advanced physico-digital experiences, to enhance individual and collective engagement as well as agency rooted in shared interests and goals. Proactive involvement of all stakeholders from an early stage has been proposed with the aim of nurturing a conducive environment that will maximise the public, organisational, and healthcare benefits of the ecosystem. A research agenda based on the ecosystem framework has been proposed to enhance transdisciplinary socially-inclusive discourse. Addressing ethical considerations in the development of complex health systems, the governance of personal health data, and policy implications will be key to advancing mental health and wellbeing screening to the highest ethical standards, with a view to maximising positive societal impact.

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Abbreviations

IT: Information Technology

LGBTQ+: Lesbian, gay, bisexual, transgender, queer or questioning, intersex, asexual, and more.