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## **E-Health for Active Ageing; A Systematic Review**

Dr Timothy David Robbins<sup>a,b\*</sup>

Dr Sarah N. Lim Choi Keung<sup>a\*</sup>

Professor Theodoros N. Arvanitis<sup>a</sup>

A) Institute of Digital Healthcare, WMG, University of Warwick, Coventry, CV4 7AL

B) University Hospitals Coventry & Warwickshire NHS Trust, Clifford Bridge Road, Coventry, CV2 2DX

\* Joint first authorship

Corresponding Author: Professor Theodoros N. Arvanitis, [T.Arvanitis@warwick.ac.uk](mailto:T.Arvanitis@warwick.ac.uk)

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## **Abstract**

Enabling successful active ageing is an international priority to meet the challenges of increasing life expectancy. Digital strategies, such as telemedicine and e-health, offer the potential to deliver active ageing in a cost-effective manner at scale. This article aims to establish the extent to which the research literature considers e-health and telemedicine based active ageing interventions. A systematic review was conducted according to PRISMA Standards. Independently, two authors searched the Cochrane, EMBASE & CINAHL Databases, with subsequent independent extraction and semi-quantitative analysis. We report a considerable breadth in digital active ageing research, which is truly international in its scope. There is a diverse range of both interventions and technologies, including a reassuring focus on community-based interventions. Whilst there are a number of quantitative studies, sample sizes are small with a limited amount of statistical testing of the results reported. There is significant variation in the outcome measures reported and little consensus as to the most effective intervention strategies. Overall, whilst there is considerable breadth to the research published in the literature, there is a clear restriction in the depth of this research. There is little overall consensus. This lack of depth and consensus may be due to the need to recognize the important role of technical research elements alongside more traditional research methodologies, such as randomized controlled trials. Enabling both technical and clinical research methods to be recognized, in tandem, has enormous potential to support individuals, communities, clinicians and policy makers to make more informed active ageing decisions.

## **1 Introduction**

Life expectancy is increasing internationally, with World Health Organisation (WHO) estimates suggesting life expectancy increases of 0.9 years per decade for men and 0.8 years per decade for women. In developed countries, the increase in life expectancy has been even more pronounced [1]. Historically, this increase in life expectancy had been driven by reductions in infant mortality, however more recently this gain has been sustained by reductions in mortality from non-communicable diseases, which has specifically reduced mortality amongst older populations [2]. These changes have fundamentally changed population demographics internationally, resulting in increasingly ageing populations. The proportion of older people aged 65 and over is due to double between 2010 and 2050, with the fastest growing age group being those aged over 80 [3]. The WHO recognises that population ageing represents one of humanity's greatest triumph but also its greatest challenge. The challenge emerges from the potential for such ageing populations to place social and economic demands on communities and healthcare systems [4].

Enabling active ageing provides the opportunity for humanity to overcome the challenges of an increasingly ageing population, enabling ageing to be a positive experience for individual, communities and society as a whole. The concept of active ageing was first proposed in 1997 and incorporates previous concepts of healthy ageing that had restricted thinking too much towards healthcare provision [5]. Active ageing can be best described as a concept that "Applies to both individuals and population groups. It allows people to realize their potential for physical, social, and mental well-being throughout the life course and to participate in society according to their needs, desires and capacities, while providing them with adequate protection, security and care when they require assistance [6]." Active ageing can be achieved through a series of policy

interventions based around prevention, promotion and care. In particular, prevention of falls and infectious disease through vaccination, promotion of physical activity and social interaction, and care when necessary from both formal and informal care givers.

Matched to the increasing age of the population, is an increase in digital technology use by elderly populations; indeed elderly adults now represent the fastest growing population of adopters to internet and computer technologies [7]. There is clear potential therefore to adapt digital technologies, such as telemedicine and telehealth, to the challenge of enabling active ageing. A number of studies have considered exactly this approach [8-10]. However, the research literature lacks an overview of the importance of digital health approaches to enable active ageing. This paper systematically assesses the extent to which the research literature considers the role of digital interventions in active ageing in an international context. This approach is essential to guide and coordinate future research, as well as supporting policy makers, clinicians, communities and individuals to make the best possible active ageing decisions and interventions.

## **2 Methods**

### *2.1 Prospero Registration*

The systematic review was prospectively registered on the NIHR Prospero Database (Registration number: CRD42017080840).

### *2.2 Search Strategy*

The following search terms were selected following collaborative discussion between all authors: "Healthy Ageing" or "healthy aging" or "active ageing" or "active aging") AND (Telemedicine OR "Tele-medicine" OR telehealth OR "Tele-health" OR "Digital Health" OR "telecare" OR "digital" OR "E-health"). The databases used for identification of relevant articles were Cochrane Database, EMBASE and CINAHL. An initial screening of identified papers was performed, through review of title and abstract and removal of duplicates at this point, followed by full extraction of all articles considered to be of possible eligibility. The searches were conducted independently by authors Dr Tim Robbins and Dr Sarah Lim Choi Keung, who compared results of their independent searches. Any discrepancies were resolved through discussion amongst all authors.

### *2.3 Criteria for Study Inclusion/Exclusion*

For inclusion in the paper selection process, articles must include content relevant to both the active ageing and digital elements of the search strategy. Furthermore, articles must be peer reviewed and published in the English Language. There was no restriction on the type of article (e.g., conference paper, experimental study, review or comment article), nor was there restriction on the date of publication. Review articles were included to ensure capture of all relevant information within the research literature and to help identify specific

subsets of active ageing research areas where there had been sufficient original research articles to justify a review article summarising progress in that area.

#### 2.4 Data Collection and Analysis

Data extraction was performed to a pre-defined Microsoft Excel Pro-forma (see supplementary material), which had been pre-determined and piloted by both Dr Tim Robbins and Dr Sarah Lim Choi Keung. Data extraction was similarly performed independently by these two authors and results compared. Data was collected for the following variables: year published, article type, study type, country of study, study population, sample size, descriptor of e-health intervention, care setting, single centre or multi-centre, assessment of whether considering prevention/promotion/care, outcome measure, technology used and any evidence of statistically significance testing. The type of interventions under-examination for each article were extracted, categories were defined as outlined in Table 1. Multi-national studies were specifically assessed for any discussion around cross-boundary research challenges, including language barriers, dealing with diverse cohorts and information governance challenges. Data synthesis was performed semi-quantitatively, with the collated variables used to provide a measure of bias within the selected studies.

Category	Description	Article References
Clinical Information System	Information system for clinical use, includes electronic health record system-type functionalities.	[11]
Coaching	Intervention includes an element of coaching of the elderly person.	[12], [13], [14], [10]
Cognitive behaviour therapy	Interventions that target enable cognitive behaviour therapy.	[15]
Cognitive training	Intervention that targets cognitive functions to maintain cognitive abilities.	[16], [17], [18], [19], [20], [21]
Communication	Communication tools between healthcare professionals and patients or carers.	[22], [23], [15]
Decision Support System	Information system that includes functionality for decision support using algorithms and rules.	[11]
Education	Interventions that target education of patients, carers, etc. of various topics, such as use of digital tools, diet, self-care, etc.	[22], [24], [23], [25], [26], [12], [27], [28], [14], [29], [21], [30]
Ethics	Ethical considerations of technologies.	[31]
Gaming	Uses computer games, serious games and associated technologies.	[16], [17], [18], [20], [15], [32]
Information and Communication Technology (ICT)	Information systems and technology development, including design, methodology, implementation, evaluation etc. Also include aspects of computer science topics, such as human computer interaction, usability, etc.	[11], [31], [33], [34], [35]
Management	Focus on the management, coordination of e-health interventions and related elements, such as service delivery.	[36], [37], [24], [24], [38]
Physical exercise	Intervention that targets physical activity.	[17], [26], [20], [39], [40], [13], [30], [41] [42], [43]
Rehabilitation	Interventions targeting rehabilitation.	[32]
Social participation	Interventions that target social inclusion and participation, via technologies such	[22], [23], [44], [33]

	as social networking, sharing of experiences, etc.	
Telecare	Remote care technologies, such as reminders, alerts, communication with clinicians, sensors in the home or person, for monitoring falls, movement, etc.	[17], [45], [22], [24], [46], [20], [12], [47], [48], [49], [50], [51], [14], [10], [52], [53], [54], [42], [35], [36], [37]
Telehealth	Sensors to monitor vital signs, such as heart rate, blood pressure, physical activity to help support self-management mainly.	[22], [24], [55], [56], [26], [12], [51], [39], [40], [49], [51], [13], [14], [10], [44], [52], [57], [53], [54], [58], [43], [36]
Telemedicine	Technologies for direct intervention of the clinician, such as a remote consultation with patients, remote collaboration between clinicians, including integrated care.	[22], [24], [55], [11], [25], [51], [44], [59]

*Table 1 Descriptor definitions of interventions*

### **3 Results**

#### *3.1 Paper Identification*

A total of 140 papers were initially identified, using the search strategy described above. The PRISMA flow diagram [60] (Fig 1) demonstrates that 47 duplicates were excluded, with 53 full text articles extracted for review. A total of 51 of these articles were accepted for use in the final semi-quantitative synthesis described.

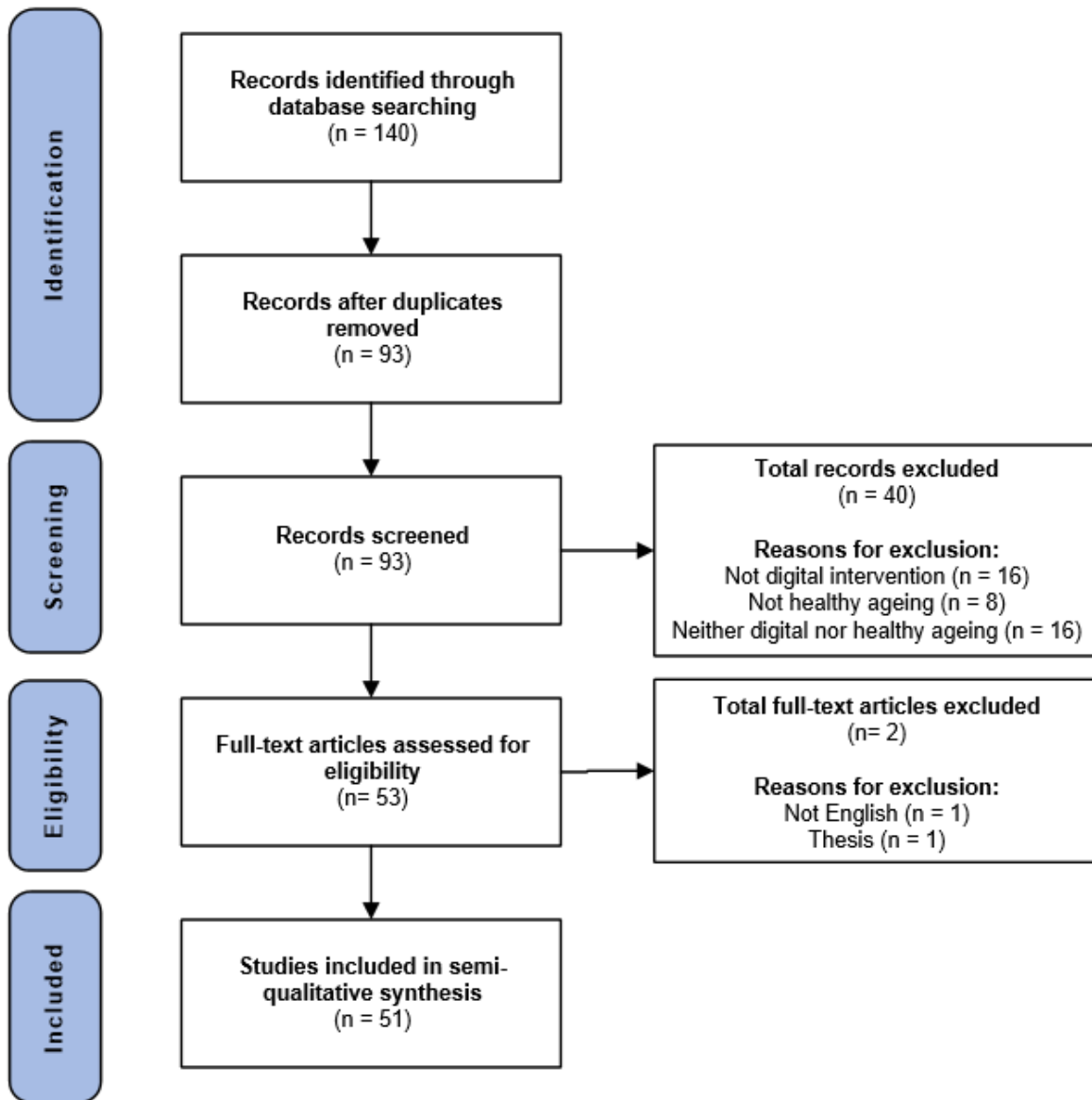


Figure 1 PRISMA flow diagram demonstrating paper extraction

### 3.2 Publication of articles over time

The first identified study was published in 2002, with an increasing number of studies published until 2016, where 13 studies were published (Fig 2). Five studies were published in 2017.

## Number of Articles Published Over Time

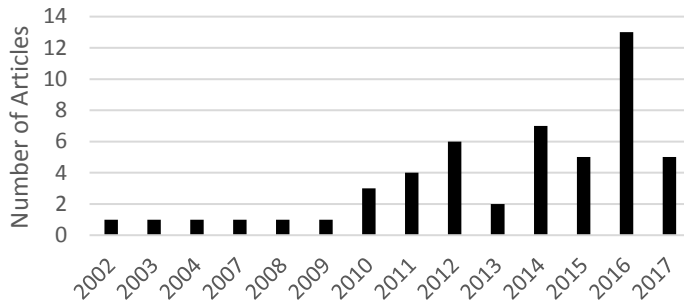


Figure 2 Number of Articles Published over Time

### 3.2 Study Type

Eleven articles reported experimental quantitative or qualitative studies, with 17 articles representing comment based articles (Table 2). There were 9 review articles described in further details below and 11 articles represented multi-centre studies.

Article Type	Number of articles	Article References
Comment article	17	[61], [11], [31], [52], [51], [32], [28], [59], [51], [44], [50], [36], [50], [24], [50], [36], [58]
Experimental Qualitative	1	[55]
Experimental Quantitative	10	[37], [42], [20], [54], [12], [27], [21], [41], [10], [14]
Intervention Descriptor	9	[17], [62], [57], [45], [30] [47], [16], [17], [30]
Observational / survey	7	[33], [23], [46], [26], [34], [56], [29]
Published Protocol	6	[10], [13], [19], [18], [35], [40]
Review article (non-systematic)	6	[15], [53], [22], [50], [49], [38]
Review article (systematic)	3	[39], [43], [48]

Table 2: Types of article reported in the literature

### 3.3 Study Population

The selected articles represented research from 20 different countries, with the most research in this area being published from the United States of America and The Netherlands. The articles had a mean average sample size of 300 participants with a median of 119 participants. Of the quantitative studies, 7 performed statistical significance testing of the results.

Forty-one studies explicitly described the study population under investigation, with 37 studies focused on older adults alone. Fourteen of these studies specified a specific age range to define older adults with the starting age for this category varying from 55 to 65. Two studies focused on interventions during middle age to enable healthy ageing later in life [19, 21]. Two studies focused on clinicians involved with the promotion of healthy ageing [28, 49] with a further study considering the role of researchers in enabling healthy ageing [32]. A single study considered the roles of carers [30].



### 3.3 Intervention Characteristics

Thirty-four (67%) studies considered health promotion, 31 (61%) considered preventative strategies and 27 (53%) studies considered care interventions. Sixteen (31%) considered all three domains of healthy ageing within the published study. More specifically the most common interventions discussed were telehealth,

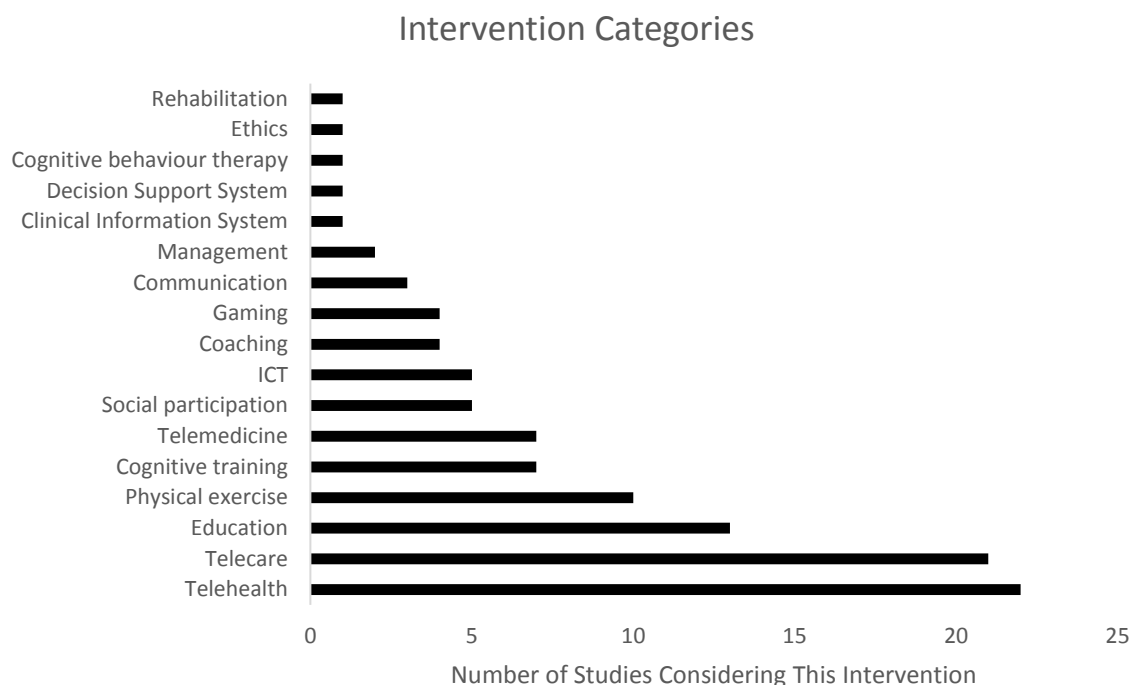


Figure 3: Number of each category of intervention reported in the literature

telecare and tele-education (as defined in Table 1 above). A smaller number of studies considered rehabilitation or cognitive behavioural therapy (Fig 3). Forty-six (90%) specified a specific location for the active ageing intervention, with 44 of those interventions focused on the community setting. One article specifically considered active ageing interventions in a rural setting [63], and a further article specifically considered active ageing interventions in the developing world [28].

There was a diverse range of technologies utilised for the digital interventions described in each study, with the most common technology being home computer delivery of digital content, followed by sensor-based interventions. A full breakdown of the technologies used in the studies is provided in Table 4.

Intervention technology	Number of Articles
Computer	19
Sensor device	8
Mobile device (incl. tablets)	6
Not specified	6
Telephone call	3
Wearables	2
Video technology/DVD	2
Augmented reality/virtual reality	1
Gaming console	1

Table 3: Interventions employed in extracted studies

Forty studies described a specific outcome measure, only 7 studies described a specific outcome measure directly relevant at the individual patient or person level, these patient based outcome measures are illustrated in Table 5.

<b>Clinically Relevant Outcome Measure at Patient Level</b>	<b>Article Reference</b>
Functional health	[49]
Aerobic capacity	[42]
Cardiovascular risk	[10, 12]
Cognitive functioning	[18, 21]
Personal wellbeing	[21]
Mood, mortality, dementia risk	[12]
Balance, reaction time	[47]

*Table 4: Outcome measures relevant at the individual patient level (measures have been grouped where they only occur in a single study)*

### 3.4 Multi-centre Studies & Challenges

Eleven studies described multi-centre investigations [10, 11, 14, 18, 19, 22, 28, 44, 46, 51, 62]. These were assessed for any discussion of challenges to implementation around language barriers, information governance or the challenges of delivering interventions across diverse cohorts. Two studies mentioned that their intervention was translated into different languages [10], in no study was this reported as a challenge. One study reported that differing structures of healthcare between different countries represented a challenge (Norway and The Netherlands compared to England and Spain) [46], whilst another study commented on the similarities of providing healthy ageing interventions between different international countries (comparing European Union Countries in general to Australia) [62]. Only one multi-national study considered the challenges of information governance [22].

### 3.5 Review Articles

Eight review articles were identified from the literature search. These were remarkably diverse in their subject matter, covering topics such as active ageing in developing countries [22], use of sensor data for supporting healthy ageing [49], creation of healthy environments for healthy ageing [50] and ensuring healthy ageing in the context of multi-morbidity [15]. There were 3 systematic reviews, two of which focused on promotion of physical activity [39, 43] and a further one, which examined the role of telecare in promoting independence [48].

## 4.1 Discussion

Meeting the challenges of an ageing population through successful active ageing approaches is an international priority. There is enormous potential for e-health strategies to support such interventions. The current state of the research literature demonstrates there is a truly diverse breadth of research. The research is diverse both in terms of the geographies studied (research from 20 countries and multiple international studies) and in terms of the interventions considered. It is reassuring that the vast majority of interventions focus on community based interventions and concepts around ageing in place [64], rather than on already

overburdened inpatient settings. There was further significant diversity in the types of technology used to deliver the interventions. Typically, articles consider multiple different intervention categories, with 17 distinct different categories identified.

Whilst the research shows considerable breadth of research, there is somewhat limited depth. There is a high proportion of comment-based articles, and many non-intervention based studies. Typically, there are (with a few exceptions [34, 37]) small sample sizes and limited statistical significance testing. Many of the studies fail to focus on a specific element of health promotion, frailty prevention or clinical care, rather combining all these elements together. There is often no clear definition of outcome measures. The multi-centre articles failed to address the challenges one would expect to encounter with such studies, focusing almost exclusively on the challenges of delivering interventions to individuals, rather than system wide changes in implementing transformative active ageing interventions. While active ageing is a relatively established area of research, it currently lacks clear consensus in terms of the most suitable outcome measures, or clear directions in terms of what the most successful interventions are likely to be. It could be suggested that the research is still at an exploratory stage, exploring broad ranges of different technologies, interventions and outcome measures in diverse populations but still at a small scale.

This review has highlighted barriers to the in-depth research and study of e-health based active ageing interventions. A likely barrier is that traditionally promoted research methodologies may not be the most suitable research method to apply to such research questions. Whilst 2 randomised control trials were reported in the research literature [21, 41], with a further ongoing trial reported [65] there was a range of other reported intervention approaches. These alternative research approaches included design papers [26, 45], technical reports [28, 35] and an ICT based ethical evaluation [66]. There was a clear distinction in the journals/conferences these different articles were published in, and something of a disjunction between the more traditional clinical based articles and technical based articles. It is essential that the technical and clinical elements of e-health active ageing research are able to combine in a smoother more collaborative fashion. An excellent example of this in action is in relation to the HATICE trial, where a design and development technical article was published [67] followed by a randomised controlled trial protocol [68] and subsequent publication of the ongoing research trial [65]. Whilst representing an isolated example, with the full trial reports still to be published, it is an important example for the research area of the successful merging and reporting of both technical and clinical research activities.

This systematic review has been completed according to PRISMA guidelines and benefits from the independent article identification, screening and extraction by two authors. The article is further strengthened by searches in three major research databases and the absence of a time-limited period of search. There are, however, a number of weaknesses; the most significant of which is the restriction of the search to English Language only journals, which has the potential to exclude valuable contributions from what we have identified already is a truly international research area. Furthermore, the research was restricted to peer reviewed articles, and given the identified importance of technical reports and technology evaluations it is possible or even likely such work has been missed. Identifying such reports, however, from the grey literature would be a truly enormous task. Such an undertaking only underscores further the importance of transitioning

to a research practice that recognises such research and research methodologies more prominently, alongside more traditional outputs, such as randomised controlled trials.

In summary, the application of digital strategies to enable active ageing represents an exciting area of international research, with diverse research approaches and interventions. There is currently a lack of clear consensus as to preferred outcome measures, or indeed the most fruitful intervention strategies. There is a significant disjoin between technical elements of this research and the more traditional clinical trial based interventions. Therefore to meet what is the WHO describe as “humanity’s greatest challenge” [6] researchers themselves need to challenge the existing approaches to publishing and sharing research and to work more collaboratively across disciplines and traditional research silos. The benefits of adopting such an approach will have truly wide-reaching effects as to how we live our lives and build our communities.

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