FEASIBILITY OF USING AN APPLICATION-BASED TOOL TO SCREEN FOR DEMENTIA IN THE HAI DISTRICT OF TANZANIA

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1. Introduction

What is Dementia?

Dementia is a syndrome of chronic neurodegeneration, characterised by progressive memory loss and cognitive decline[1]. Dementia is typically a condition of older people, although not a normal aspect of ageing[1, 2].

Cognitive decline in dementia manifests not only as memory loss, but also as problems with orientation, language, concentration and problem solving[2]. Additionally, patients may also experience psychological phenomena – such as hallucinations, delusions, depression and aggression – and as the condition progresses, neurological symptoms[3]. Each of these domains can significantly impact upon an individual's ability to independently complete their activities of daily living, and in fact a marked reduction from baseline functioning must be shown in order to discriminate between dementia and a milder cognitive impairment by the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) citeria[2, 4].

The risk factors, pathophysiology, presentation and progression of dementia differ according to the aetiological disorder underlying it, however determining this is often difficult and mixed causes are common [Figure 1, Table 1][1]. The most prevalent causative disorder is Alzheimer's disease (AD), which accounts for 60-70% of cases [Figure 1][2, 5]. Although no curative treatments are currently available for AD or other non-reversible dementia subtypes, there are multiple pharmacological and therapeutic interventions, which may help to ease symptoms of the condition, and therefore allow patients a prolonged period of independence and greater involvement in care[6].

Figure 1: The commonest causes of non-reversible dementia[5]

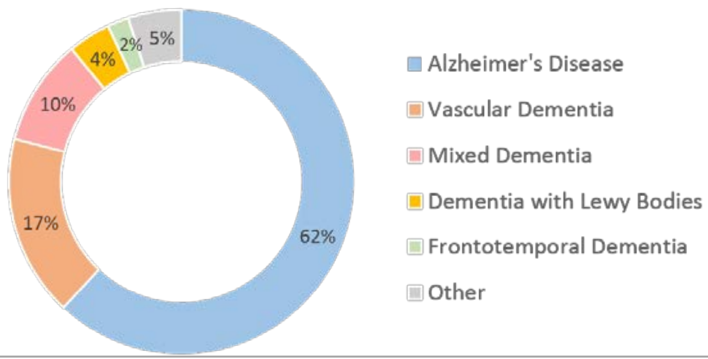


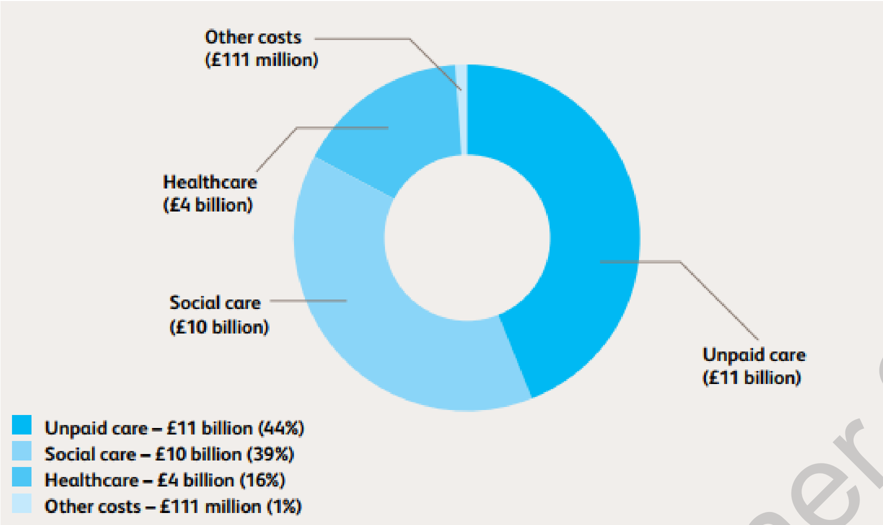
Table 1: Summary of dementia subtypes[3]

Dementia Disorders	**Presentation**	**Pathophysiology**
Alzheimer's Disease	▪ Amnesia ▪ Aphasia ▪ Apraxia ▪ Agnosia ▪ Disorientation ▪ Impaired visuospatial function ▪ Impaired executive function	▪ Beta-amyloid plaques ▪ Tau protein tangles
Vascular Dementia	▪ Focal neurological abnormalities ▪ Poor attention ▪ Impaired executive function ▪ Seizures ▪ Cardiovascular events ▪ Stepwise decline	▪ Long-term deterioration of small vessels ▪ Multiple small infarcts
Lewy-Body Dementia	▪ Fluctuating cognitive impairment ▪ Poor attention ▪ Hallucinations ▪ Parkinsonian signs	▪ Deposition of alpha-synuclein proteins within neurones
Fronto-Temporal Dementia	▪ Personality changes ▪ Behavioural disturbances ▪ Aphasia ▪ Young onset	▪ Mixed causes - Degeneration of the frontal and temporal lobes

WHY IS DEMENTIA IMPORTANT?

Worldwide, dementia is in the top five causes of disability in the over 75s[7]. It is associated with a significantly increased mortality, high morbidity and high rates of care-giver burden[1, 5, 8, 9]. Additionally, as the condition progresses, increased care needs, reduced independence and associated comorbidities act as significant drains on health resources[5]. Cumulatively, the annual economic impact of dementia in the UK is estimated to be over £25 billion, and the global impact $1 trillion [Figure 2][5,10].

Figure 2: Estimated UK cost breakdown of dementia, 2013[5]



When considering the implications of dementia alongside predictions of a 181% increase in global prevalence from 2015-2050, it is alarming to imagine the ramifications[10]. Without a way to cure this syndrome, health and social resources - which in many places are already stretched to capacity - will somehow have to restructure, or assemble the expertise and funding needed to deal with the mounting demand[11].

Dementia in Sub-Saharan Africa

Epidemiology

Globally, there is a demographic transition in which an increasing number of people are living into old age (60+)[11]. This trend is most marked in low and middle income countries (LMICs), and none more so than in Sub-Saharan Africa (SSA), where the elderly population is growing more rapidly than anywhere else worldwide[10-12]. Reflecting this ageing population, the prevalence of non-communicable diseases (NCDs) is increasing in LMICs, and it is in these countries that 71% of those with dementia are expected to be living by 2040 (a rise from 57% in 2010) [12]. A considerable contribution to this increase will be from SSA, where dementia prevalence is projected to double every 20 years[11, 12]. The ongoing increase in SSA's dementia incidence is considered to be implicitly connected with the concurrent epidemiological transition both directly, as a result of an ageing population, and indirectly, secondary to the 'westernised' behavioural and lifestyle shifts which accompany such a transition and act to increase known risk factors such as cardiovascular disease[11, 13].

Research

Previously, infectious diseases have been considered the greatest challenges to health in low income settings. However, due to widespread appreciation of the demographic transition, and its influence on disease profiles, it is now acknowledged that NCDs also have a major impact upon mortality and morbidity in LMICs, therefore creating a double-burden effect[11, 14, 15]. Perhaps due to the novelty of this understanding, NCD research in SSA considerably lags behind that of higher-income settings. Consequently, despite awareness of the current epidemic, there is a startling sparsity of dementia research from SSA, in particular the Eastern and Southern areas of the subcontinent[10, 11]. Furthermore, due to the scarcity of studies and inconsistent research methods, results thus far have been difficult to compare and often inconsistent, creating doubt over their reliability[13, 16].

Attitudes to Dementia

Prejudices, stigma, poor infrastructure and a low level of health literacy, all pose challenges to mental health research in SSA. Qualitative studies found that awareness of dementia is poor, with many dialects in SSA having no translatable term for the condition[11, 17]. Although carers and those living with dementia could describe symptoms of memory loss, dementia seemed to be viewed not as pathological, but as normal ageing[18]. Many attitudes towards the causality of dementia also reflected this, however some were more sinister, citing 'witchcraft' and 'punishments from God'[11, 18]. Views such as this, alongside a general lack of mental health awareness in developing countries, foster an environment of isolation and stigma which can reduce quality of life for patients and carers alike, as well as creating barriers to the research, identification and treatment of dementia.

United Republic of Tanzania and the Hai District

Tanzania, a country of 55 million, lies on the eastern coast of Africa[19].

Comparable to most countries in SSA, Tanzania is resource poor, with 1 doctor per 45454.5 of the population, compared to 1 for every 354 in the UK [Table 2][11, 20]; mental health and geriatrics are particularly poorly served[21-24].

Table 2: World Health Organisation's most recent figures comparing health resources in the UK and Tanzania (per 1000 population). Adapted from Global Health Observatory data repository tables[20, 22].

	Physician Density	Nursing and Midwifery Density	Pharmaceutical Personnel Density
UK	2.825	8.421	0.868
Tanzania	0.022	0.416	0.035

The Hai district is in Northern Tanzania, in the Kilimanjaro region. The district contains a demographic surveillance site (DSS) through which there are regular targeted censuses, monitoring the largely rural population and providing data for research; the most recent census was done in conjunction with this study. This population is relatively stable, as people in the district often remain there lifelong as sustenance farmers, working on local farms and living from their produce.

Healthcare in the district is provided by three small hospitals as well as local dispensaries or health centres in most villages. However, due to unreliable supply of drugs and lack of disposable income, very few people have prolonged stays in hospital or regular medication.

Dementia Detection

Why is it Important to Screen for Dementia?

With no cure for dementia, many public health initiatives focus on early diagnosis of the condition[6, 25]. A timely diagnosis leads to earlier intervention, preserved functioning and consequently, improved quality of life for patients and carers alike[6, 25]. However, formally diagnosing dementia is a lengthy and skilful task, often reserved for old-age psychiatrists[26]. Simple tools, with good predictive properties are therefore needed, in order to give researchers and lesser-trained healthcare workers a quick and dependable method with which to assess patients' cognitive function and base further clinical or epidemiological decisions[25, 27]. In high income countries (HICs), these are often used in primary care as a gateway tool for referral. However, in LMICs, where resources are too scarce to provide a comprehensive service, screening tools may have higher value, as they may be the only diagnostic tool available[25]. This 'task-shifting' approach to screening is recommended by the World Health Organisation (WHO) as a way of optimising healthcare resources in LMICs in order to scale-up mental health facilities[11, 28].

Current Dementia Screening Tools

Currently, the majority of our knowledge on dementia stems from research carried out in HICs, and as such, many diagnostic tools are based upon these findings[27].

Screening tools developed and validated on Western populations, such as the Mini-Mental State Examination, require basic levels of education, using questions that involve subtracting numbers and recreating geometric shapes[27, 29]. In areas where very few people attend formal schooling, and many have never been taught how to hold a pen, these questions are unrepresentative and often lead to inaccurate diagnosis[27, 30, 31].

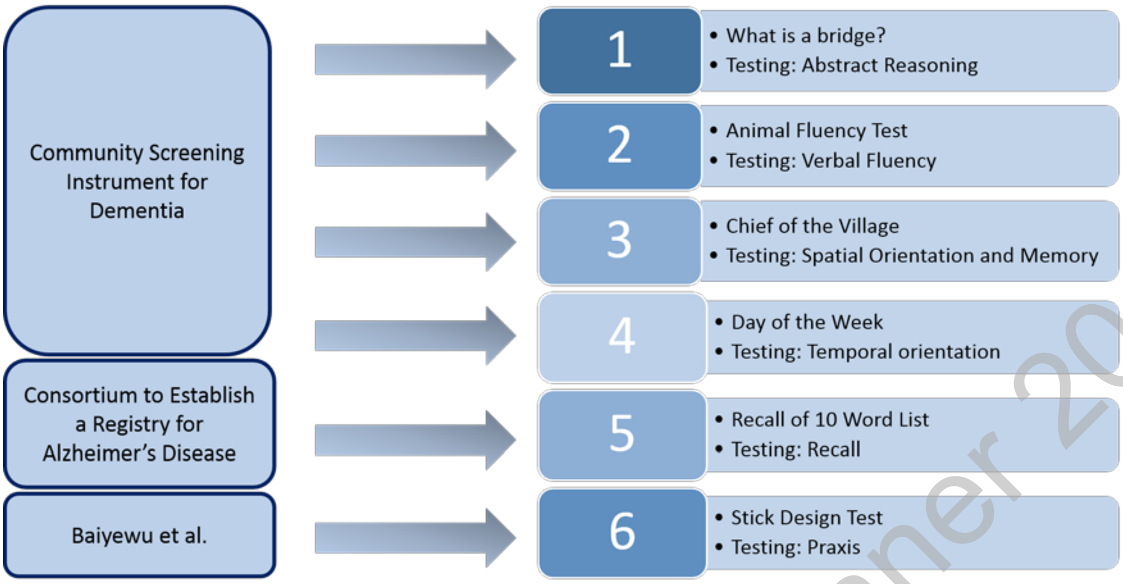
Similarly, assessing functionality using standard HIC tools is also innapropriate[32, 33]. The day-to-day activities of an older person in rural SSA are drastically different to those in HICs; literal translations of questions regarding daily activities are therefore unsuitable and accordingly, even those with a good level of functioning may score poorly, giving false positives and decreasing test specificity[31, 34]. It has therefore been necessary to develop screening tools which are culturally appropriate for low income settings[34].

Several validated tests now exist which have been developed specifically for use in LMICs. The Community Screening Instrument for Dementia (CSI-D) is one example[11, 35]; it was created as a cross-cultural tool to standardise dementia diagnosis in LMICs and therefore allow epidemiological comparisons[35]. It combines culturally-sensitive screening elements with a concomitant collateral history[35]. However, the test is lengthy and depends upon the presence of an informant, which is not always possible[30, 35]. Consequently, whilst this tool is excellent for research, its place in routine screening is questionable[30].

The 6 Item Dementia Screen for Africa (SIDSA) was created by the Identification and Interventions for Dementia in Elderly Africans (IDEA) study as a swift and simple screening tool which could be used in SSA without the need for an informant[30]. The pen-and-paper tool combines questions from the CSI-D, with the 10 word recall test from the Consortium to Establish a Registry for Alzheimer's disease (CERAD), and finally Baiyewu's praxis test [Figure 3][30, 36]. The tool showed no educational bias in low-literacy settings, and was found to take an average of 10 minutes[27, 30].

A brief and culturally-sensitive instrumental activities of daily living (IADL) questionnaire, was later developed and validated by the team to accompany the SIDSA cognitive screen. This gave a combined tool with greater utility as a clinical decision aid[33].

Figure 3: The origin and function of the SIDSA questions[30]



Applications as Screening Tools

In this research, we follow on from the work of the IDEA study, and assess the feasibility of converting the screening tool into an application (app) for smart-devices. By updating the screen in this way, we hope to increase the quality and sustainability of care to patients, allowing assessment methods to be routinely updated in line with current best practise, and offering decision-making support to those with minimal psychiatric training. The potential for new technologies to aid those with dementia in LMICs is also recognised by the WHO Global Action Plan on Dementia, who promote increased investment in the field[11, 37].

Smartphone apps have been shown to improve access to healthcare and be an effective way to monitor chronic health conditions; for example, Jongstra et al used their iVitality app to monitor patients' cognitive function at home, reducing the need for face-to-face consultations[38-40]. In rural, resource-limited areas such as SSA, apps similar to this could transform primary healthcare. Point-of-care tools on smartphones have previously been demonstrated to be effective in resource-poor environments, and with smartphone ownership, and mobile-cellular network coverage increasing, it is realistic that healthcare apps could be widely used in LMICs to aid the diagnosis and management of dementia[40-43].

Applications to screen for dementia are already in circulation; 'MOBI-COG' and the 'Cognitive Assessment for Dementia – iPad version' are both brief tools designed as dementia screens[44-46]. The 'Mobile Cognitive Screening' app is however much longer, with 33 questions assessing 8 cognitive functions[47]. The 'Cambridge Neuropsychological Test Automated Battery' tool is also extensive, as it assesses functionality and simultaneously screens for other neurodegenerative diseases such as Parkinson's disease[48]. Unfortunately, all of these apps were designed in high-literacy, high income countries, and as such are not suitable for use in SSA. Thus, the aim of the current study is to create a brief, app-based screening tool designed for use in LMICs.

2. Study Aims

Aims

- To screen all adults aged ≥60 throughout twelve villages in rural Tanzania using an app-based version of the SIDSA screening tool[49].
- To establish the feasibility and construct validity of using an app to allow non-specialists to screen for dementia in SSA.

Objectives

- To train a team of 12 Tanzanian enumerators (rural healthcare workers) to screen the elderly (≥60) population of their village for dementia, using an app.
- To establish the acceptability of the app by gaining feedback from those delivering and receiving the screening.
- To evaluate the construct validity of the app by comparing screening scores to known dementia risk factors, and findings of a further dementia assessment by DSM-V criteria.

Hypothesis

That the use of this decision-support app will both correlate with dementia risk factors and be acceptable for use in SSA.

3. Methodology

Overview

A census of twelve rural villages was carried out by local enumerators using an app on a computer-tablet. As a continuation of the census, those aged 60 and over were asked to partake in a dementia screen. Stratified samples of those screened in two villages – Kimira and Sanya Station – were then randomised to take part in a further cognitive assessment and feed back on the acceptability of the app. At the end of our allotted research time, 182 individuals had been screened, 93 selected for further assessment, and of these 84 were seen.

Sample

As part of the large-scale IDEA-DePEC (Dementia Prevention and Enhanced Care) study, a sample from each of the twelve villages screened will be followed up for further cognitive assessment. However, due to time restrictions we were only able to see a smaller sample of these participants. We therefore selected two villages to focus our research on; this reduced the selection bias which would have arisen had we attempted to visit all twelve villages, and just seen those most accessible in each.

Setting

All villages were within the Hai district of Tanzania, which lies on the southern slopes of Mount Kilimanjaro; from these, two focus villages were selected following local advice. Factors considered included which villages would be hard for future assessors to access without a car, and which would be the toughest to reach once the rainy season began – villages filling these criteria were prioritised. Our study took place in Kimira, a largely Chagga tribe village, and Sanya Station, a village mostly inhabited by Maasai and considerably less affluent than Kimira.

Figure 4: Visiting houses in Kimira (left) and Sanya Station (right)

PARTICIPANTS

Anybody identified as being aged 60 or over in the census was thereupon consented to take part in the cognitive screen. Of those screened, 100% who scored as having likely dementia, 50% of possible cases and 10% of those who screened negative, were randomly selected for further assessment.

In each of the two villages, randomised participants were located by the local enumerator and requested to visit the local healthcare centre or dispensary along with a relative. For those who were unable to attend due to mobility difficulties, home-visits – accompanied by the enumerator – were arranged.

DATA COLLECTION

A large team of people were involved in the collection of data for this study. Twelve enumerators – one for each village – were responsible for the census and initial screen of all participants. An enumerator is a well-respected local within each DSS village, who works with researchers to gather data. They are an invaluable asset as they are accustomed to the geography and culture of the villages, and as well-trusted members of the community, they also help to dispel any mistrust locals may have towards the research team.

All enumerators received two sets of training, refreshing their knowledge of dementia and introducing them to the screening app on the tablets. These courses were delivered in a group setting, thereby standardising the procedure. Training was led by Dr S. Paddick, Aoife Colgan (MRes student) and myself, and lasted for 2-3 hours per session.

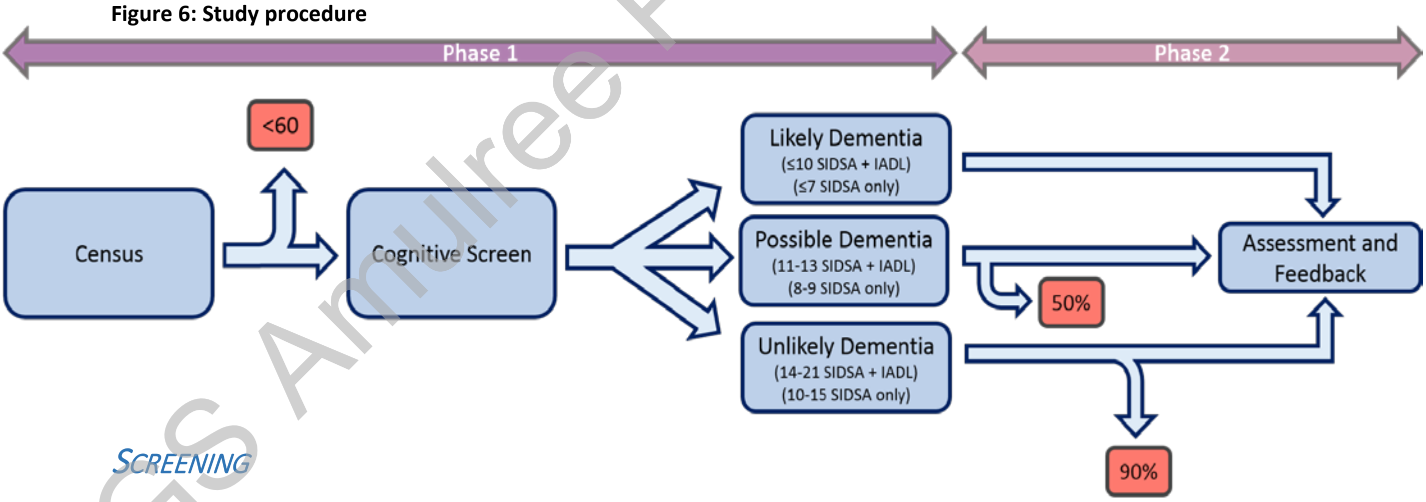
Census and screening data were uploaded weekly from the 12 tablets onto the Kilimanjaro Clinical Research Institute server. Thereafter, an independent statistician stratified participants according to score and provided a randomly generated list to be seen in phase 2 of the study, the further cognitive assessments. Screening scores were omitted from this list in order for phase 2 to remain blinded. The sampled participants' names and their corresponding study numbers were subsequently given to the appropriate enumerator, who would invite them to attend a designated centre for further cognitive assessments and an opportunity to feed back on the app.

Figure 5: Enumerator training for the screening app and tablets

Unfortunately, exceptionally heavy rains – the worst in 12 years – created barriers to patient turnout; people were unwilling, and in many cases unable to walk to the health centres due to flooding and thick mud. Additionally, the prematurity of the rains resulted in the farming season beginning early, thus participants understandably prioritised their farming work over attending our appointments. When it became clear our strategy was not yielding enough participants, we ceased inviting people to the health centres, and instead began to review people in their homes. Adopting this method, study numbers began to increase, and repeated attempts to see absent participants were made throughout the duration of the study, with the exception of those who did not consent once approached. Nevertheless, flooding and work commitments still prevented 100% coverage.

My role within the data collection was to oversee the 12 enumerators, provide their equipment and ensure that they understood how to use the app. I mobilised the screening process, uploaded the resultant data each week, and continually managed the schedule of participants to be seen in phase 2 – which was then carried out with the help of two local doctors and a nurse for translation.

Figure 6: Study procedure



SCREENING

For those aged 60 and over, wherever consent was gained, screening was carried out by enumerators in conjunction with the census; demographic data were therefore consistently recorded. Establishing an accurate age for older persons in rural Tanzania can be difficult, owing to a prevailing lack of formal birth certificates. However, older adults there – if not aware of their year of birth – are usually aware of their age during key historical events. All enumerators were therefore equipped with a year-event table, detailing significant occasions in Tanzanian history, as confirming age this way is a recognised practice for research in the area[50].

The app-based screen was carried out in the participants' homes, and comprised of the SIDSA cognitive screen and – whenever an informant was present – the 3 question IADL functionality assessment. The results of each section were combined to give the overall score, upon which participants were then stratified. Where both the SIDSA and IADL were completed, a maximum score of 21 was available, however this was reduced to 15 if the IADL questions could not be completed. Scores of 7 or less in the SIDSA indicated that a participant was likely to have dementia.

The screen also included an appraisal of the participants' subjective opinion of their memory, and questions to rule out delirium.

Further Cognitive Assessment

Phase 2 was carried out by the two research students and two Tanzanian doctors (later one doctor and one nurse) who were able to translate between English and Kiswahili. Before beginning data collection, the procedure was rehearsed with a UK psychiatrist to establish a thorough understanding of each question's purpose and to standardise technique, thus minimising interviewer bias and maximising inter-rater reliability.

Phase 2 assessments comprised of a clinical history, taken from both the participant and their relative, bedside cognitive tests, and a neurological examination. In line with DSM-V criteria, provisional diagnoses of dementia or – where there was doubt concerning the number of cognitive domains affected, timescale of decline, or the degree of functional impairment – mild cognitive impairment (MCI) were then considered. As the assessments were student led, diagnoses could only be provisional; case notes will however be independently reviewed by an old-age psychiatrist to allow formal diagnoses to be made.

The assessment was guided by a proforma, broken down into many sections [Figure 7], which allowed a comprehensive picture of each participant to be assembled. All of those involved were blinded to the participants' screening score, therefore reducing bias when determining the construct validity of the screening app.

Figure 7: Proforma justification

Demographics

- Data such as gender, age, occupation, literacy and level of education were collected.
- These can be used to identify patients and are also key for epidemiological studies assessing trends in dementia.

Risk Factors

- Contribute to dementia risk.
- Health complaints give an insight into general frailty.
- Many of these factors can be difficult to assess in this setting, due to a lack of formal diagnoses, however notes were taken of any undiagnosed complaints.
- Lifestyle practises such as alcohol intake and smoking habits were also recorded, although cultural norms such as chewing, rather than smoking tobacco and drinking locally brewed beers and spirits of non-standardised strengths hindered assessment.

Structured Interview, Mental State Examination (MSE)

- A set of standardised questions were devised to give insight into psychological functioning, and allow completion of the MSE.

Geriatric Depression Scale (GDS)

- If symptoms of depression were suspected, the GDS was completed to consider the possibility of depression-related pseudo-dementia.
- Questions were translated into Kiswahili in the proforma to guarantee both standardisation between interviewers, and a culturally sensitive approach to a commonly stigmatised issue.

Cognitive Assessment

- The SIDSA was included in this assessment alongside further cognitive tests assessing attention, working memory, orientation and coordination to give a more detailed summary of cognition.

Collateral History

- Each participant should have been accompanied by a close relative.
- Those with dementia may often appear well, and confabulation may mask memory loss. Collateral histories are therefore important to support diagnoses and give further details as to the time scales and severities of memory impairments.

Delirium Assessment

- Delirium should be ruled out before dementia is diagnosed.
- The proforma included the Confusion Assessment Method to assess for delirium.

Physical Examination

- Basic physical paramaters such as height and weight were measured – these may be unreliable when scales were used on uneven ground during home visits.
- Grip strength was measured to assess frailty, although the study had only one dynamometer and therefore it was not always possible to share this between the two sets of assessors.
- Blood pressure was measured as an indicator of cardiovascular disease – a known dementia risk factor.
- Neurological examinations were carried out to check for signs of Parkinsonism, previous strokes or cerebellar ataxia, as these may give indications towards dementia aetiology and subtype.

Feasibility Questionnaire

Feasibility questionnaires were given out to all enumerators and phase 2 participants. These assessed key feasibility domains [Figure 8].

Figure 8: Likert-style questions for enumerators (grey) and participants (red) by domain assessed.

User Friendliness of App and Tablet Device

- The tablet was simple to use
- The app was simple to navigate
- The instructions given for the app were suitable and easy to understand
- The font size was big enough

Question Simplicity and Understanding

- The questions assessing dementia were confusing
- The questions assessing memory were confusing

Practicalities

- It was hard to consistently find an informant for the dementia assessment
- It was difficult to keep the tablet charged

Timing

- It took too long to complete the memory questions after the census
- The assessment took up too much of my time

Acceptability and Future Use

- I prefer using this app to a paper questionnaire
- The app would be useful for my work in the future
- Having the app would make me more likely to assess someone's memory in the future
- I was happy for the enumerator to use the small computer whilst talking to me
- I preferred my census information being recorded and my memory being tested using the small computer, rather than with pen and paper
- If the small computer was used in health centres to assess memory in people over 60, that would be good

The questionnaires were written in English, then translated into Kiswahili by a member of the team, as her knowledge of the study allowed the intention behind each question to be kept clear. The majority of questions used Likert-style responses and consequently did not need back-translating into English. However, the few qualitative responses written in Kiswahili were kindly translated into English by a Tanzanian medical student upon completion of the data collection. Using someone independent to the study for this reduced assumptions and bias when interpreting answers.

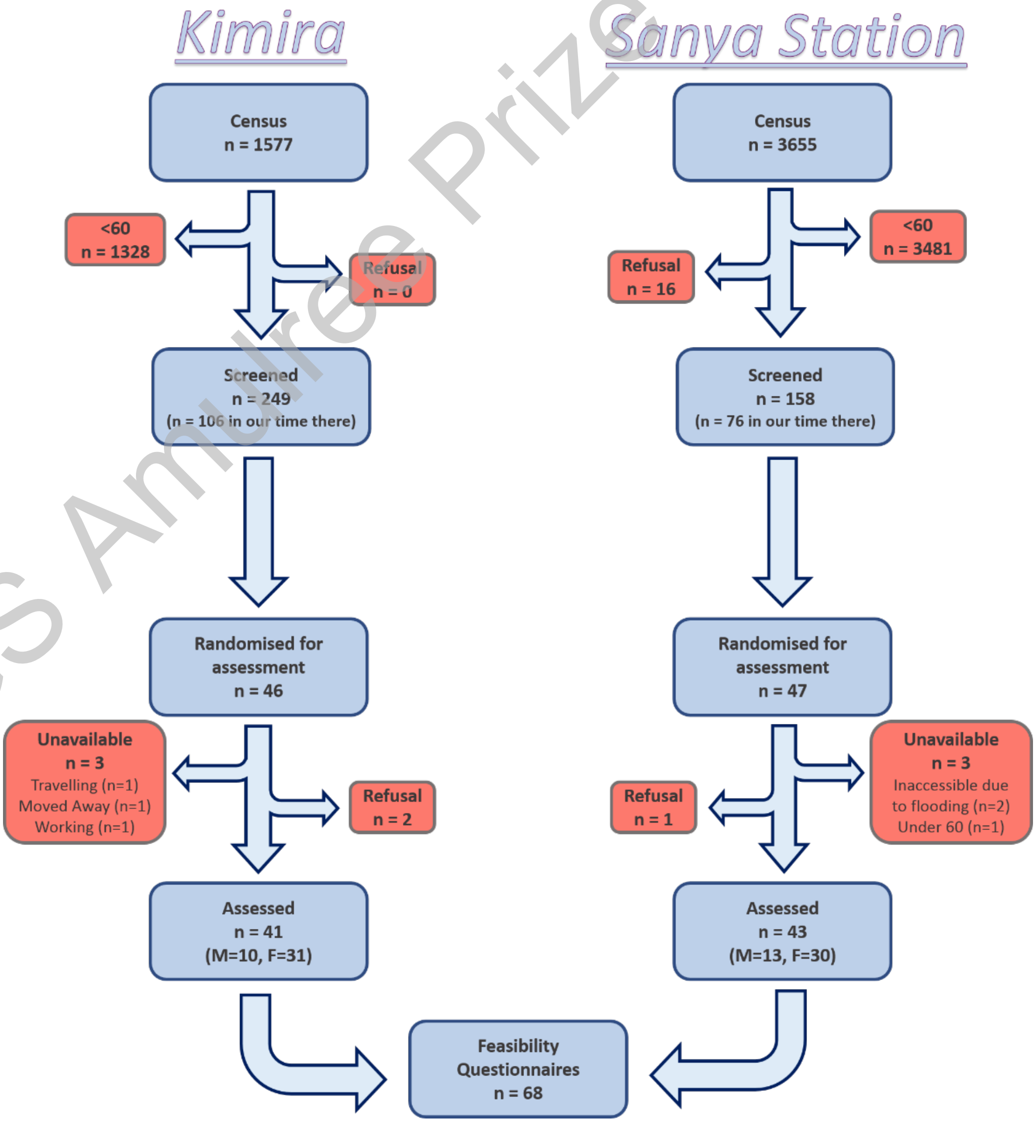
All forms made it clear that responses were anonymised and thus encouraged people to answer truthfully. Questions were preferentially answered by participants, however if they were unable, a relative was asked to complete the questionnaire in lieu. For those who could not read or write, questions were verbalised and answers recorded by one of the local doctors assisting with interviews. Enumerators completed their feasibility questionnaires in their own time, roughly 4 weeks into their screening progress, thus allowing a period to become accustomed to the app.

4. Results

Study Sample

In the census of the study's two focus villages, 5232 people were accounted for, and of those, 423 were aged 60 or over. In the largest ever cognitive screening process in SSA, all older persons were approached for screening and 96% consented. Due to a limited time frame, it was not possible to delay phase two until after completion of phase 1, thus those seen were a sample of the 182 screened before 1st May 2018. 93 were selected to enter these second stage assessments, and data was collected for 90.32%. Of those seen, 68 (80.95%) completed an acceptability questionnaire to assess the feasibility of the app [Figure 9].

Figure 9: Formation of the study sample



DEMOGRAPHICS

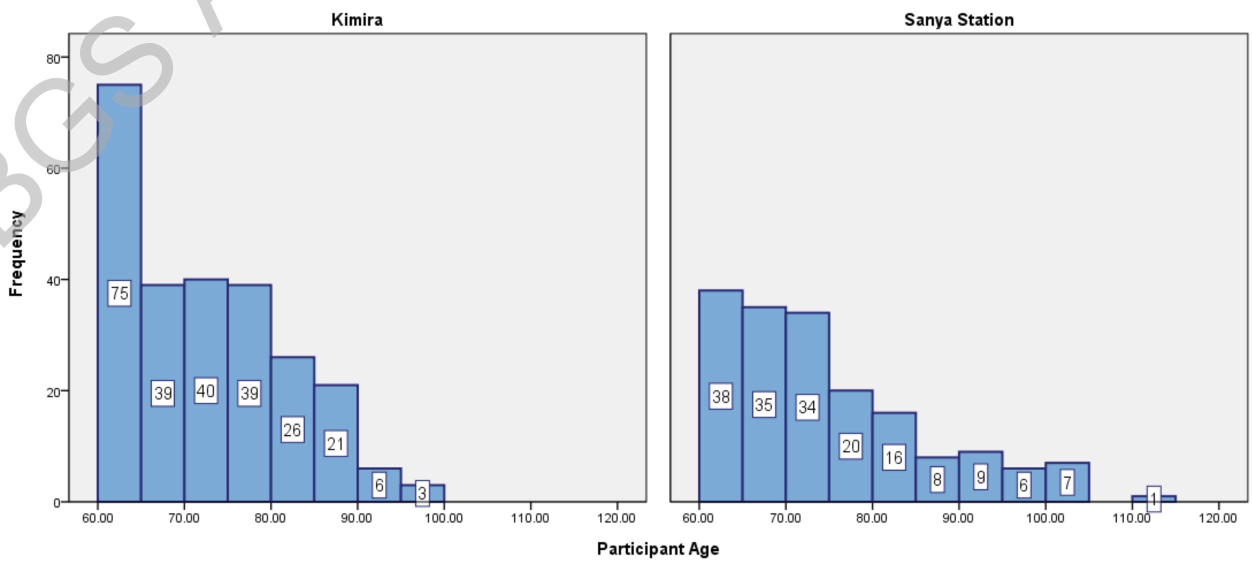
Preliminary analyses of the data collected were performed to establish the demographic makeup of the two villages. Differences between the two populations were investigated and showed a significant difference between the average number of years spent in education ($p<0.001$, $U=1662386.500$). Kimira also had a significantly larger proportion of villagers aged 60 or older ($p<0.001$, $X^2=180.324$), although the eldest resided in Sanya Station [Table 3, Figure 10]. In spite of the 14 year range difference, the composition of each village's ≥60s was similar; the median age for both locations was 70, and the upper and lower quartiles (UQ, LQ) were just 1 year older in Sanya Station than Kimira (LQ=65 UQ=80, LQ=64 UQ=79 respectively).

In both villages, as expected, females made up the majority of the elderly population, but there was no statistical significance to this skew ($p=0.279$, $X^2=1.172$ Kimira and $p=0.268$, $X^2=1.228$ Sanya Station) [Table 3].

Table 3: Village demographic data for Kimira and Sanya Station

		Population (%)	Mean Age	Number aged ≥60 (% of village population)	Mean years of education
Kimira	Male	767 (48.64)	32.53	111 (7.04)	5.47
	Female	810 (51.36)	33.96	138 (8.75)	5.39
	Combined	1577 (100)	33.27	249 (15.79)	5.43
Sanya Station	Male	1861 (50.92)	21.48	68 (1.86)	2.80
	Female	1794 (49.08)	22.21	106 (2.90)	2.59
	Combined	3655 (100)	21.84	174 (4.76)	2.70

Figure 10: Age breakdowns of those aged 60 and over in Kimira and Sanya Station



SIDSA Screening Scores

Using cut-off scores previously validated for the pen-and-paper version of the SIDSA screen, 85 people (20.88%) were classed as likely to have dementia, 47 (11.55%) were classed as possible cases, and 275 (67.57%) unlikely to have dementia [Figure 11][49]. When Chi-Squared tests were used to analyse this classification, significant differences were found between the proportions of the two villages within each category (X^2=15.115, p=0.001) [Table 4]. Nevertheless, the median screening scores for both villages were equal, at 11/15 [Figure 11].

When analysed by age group, SIDSA scores showed a negative trend, however the pattern of this cognitive decline differed considerably between villages [Figure 12].

Figure 11: SIDSA screening scores by village

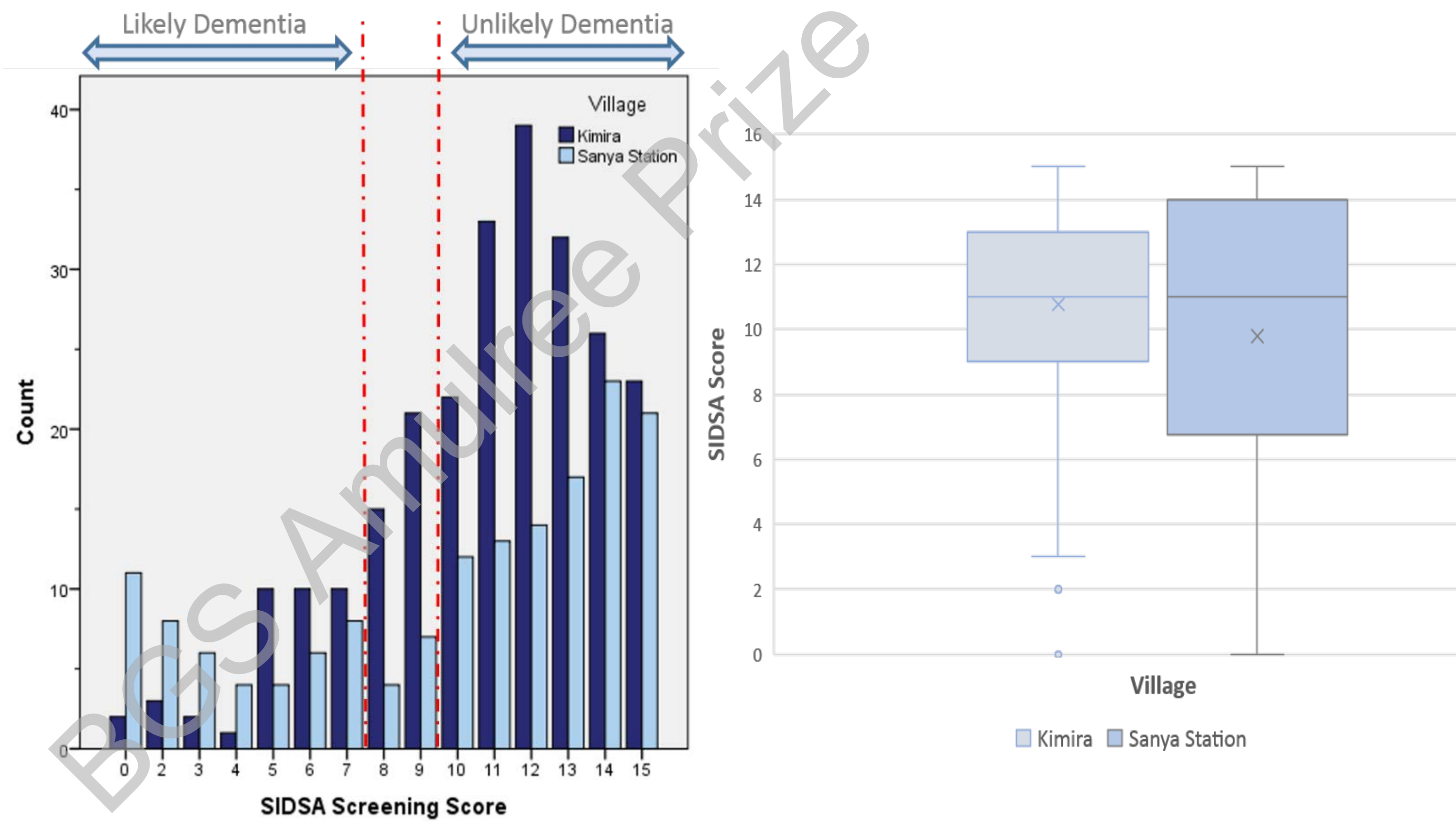
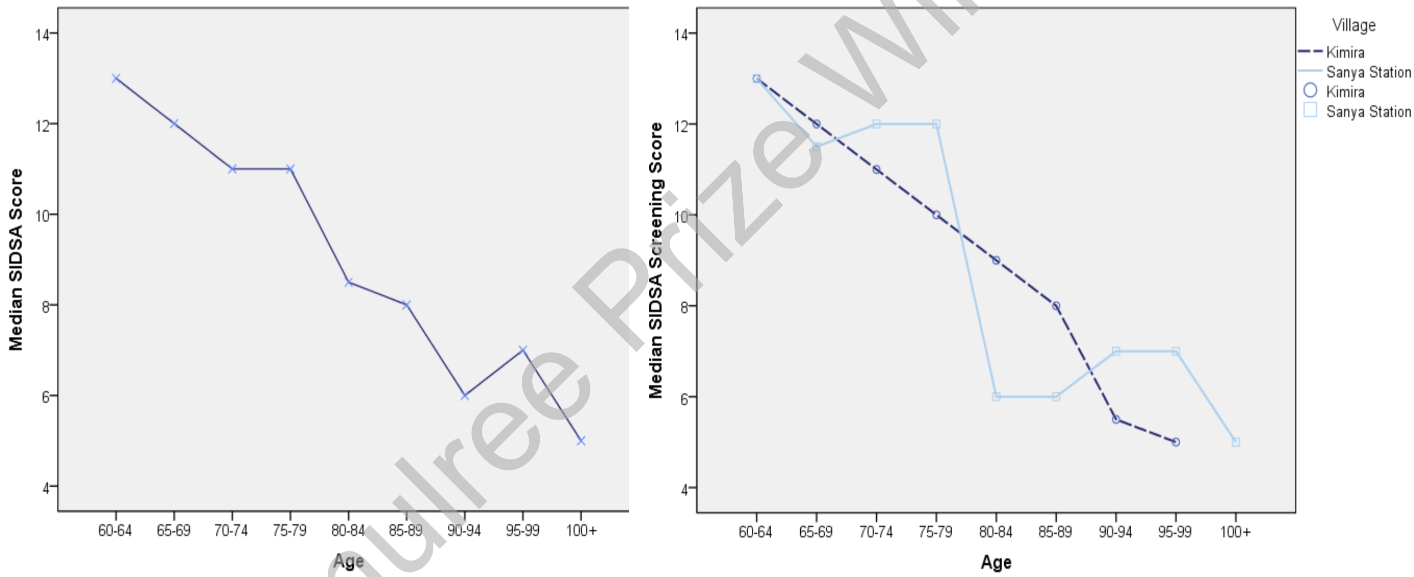


Table 4: Comparison of scoring categories between villages

		Proportion (%)
Unlikely Dementia	Kimira	70.281
(10-15)	Sanya Station	63.291
Possible Dementia	Kimira	14.458
(8-9)	Sanya Station	6.962
Likely Dementia	Kimira	15.261
(0-7)	Sanya Station	29.747

Figure 12: Median SIDSA screening scores by age category for the villages combined (left) and separately (right)



CONSTRUCT VALIDITY

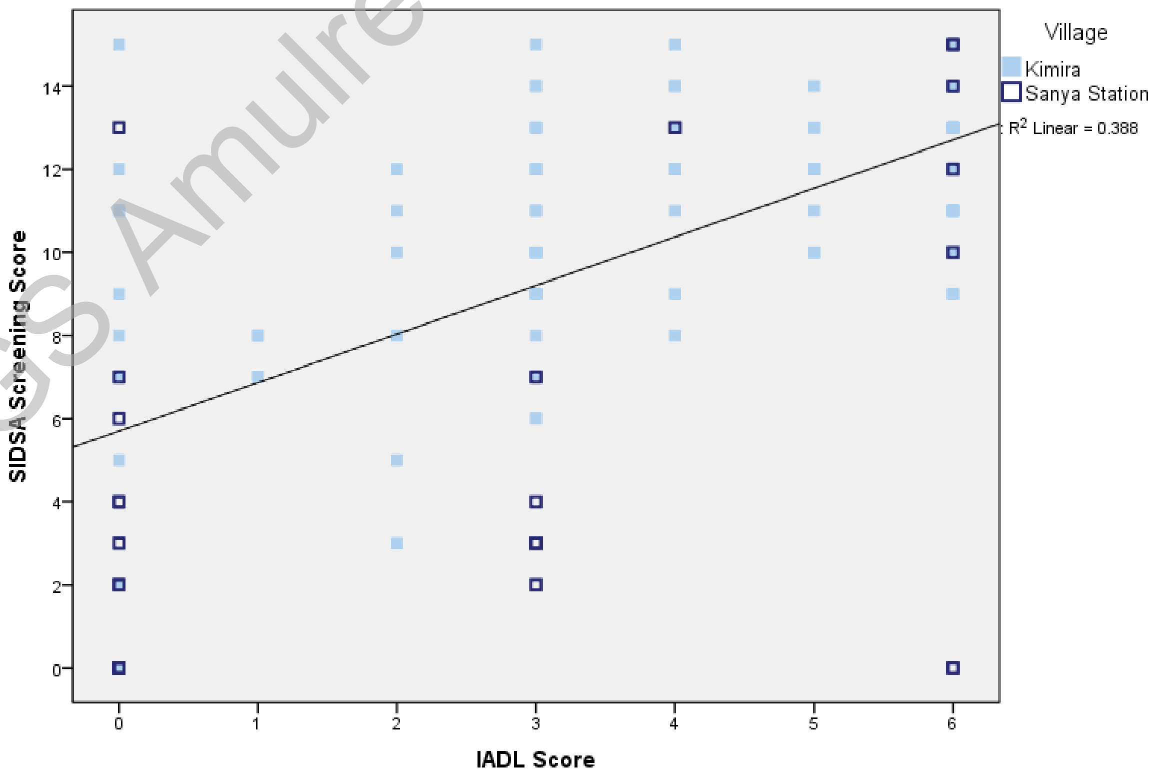
Phase 1 Correlations

In order to be feasible for future use, the app must be a valid way to screen for dementia. Analyses of the data from phase one were therefore carried out to establish correlation between screening scores and factors known to be associated with dementia; ageing, low educational levels, and female sex were all shown to be significantly associated with a poorer SIDSA score on the app [Table 5]. Informants were available for 159 participants, and their report of functionality correlated strongly with SIDSA scores [Table 5, Figure 13].

Table 5: Correlation between screening SIDSA score and other screening variables

	N =	*Correlation Coefficient*	*P Value*
Age	407	-0.479	<0.001
Education	406	0.394	<0.001
Sex	407	-0.120	0.015
IADL Score	159	0.609	<0.001

Figure 13: A closer look at the correlation between IADL and SIDSA scores for each village



Phase 2 Correlations

Focused investigation of the sample seen in phase two, showed that poor performance in cognitive tests assessing registration and recall, attention, working memory, orientation, reciprocal coordination and frontal lobe functioning, along with a provisional diagnosis of dementia or MCI were all also significantly associated with a lower SIDSA score [Table 6].

Table 6: Correlation between screening SIDSA score and further cognitive assessment performance

Cognitive Test	*N =*	*Domains Assessed*	*Correlation Coefficient*	*P Value*
3 item registration	83	Registration	0.377	<0.001
Days of the week backwards	77	Attention, Working Memory	0.634	<0.001
Days of the week forwards	43	Alertness	0.328	0.032
Time of day	84	Orientation	-0.358	0.001
3 stage command	73	Comprehension	0.227	0.053
Motor Task Demonstration	84	Praxis	0.176	0.110
Alternating Hands	84	Reciprocal Coordination	0.543	<0.001
3 Step Motor Sequence	84	Frontal Lobe Functioning	0.437	<0.001
3 item recall	79	Delayed Recall	0.303	0.007
Provisional Dementia or MCI Diagnosis	84	Global Assessment	-0.348	0.001

As a final measure of construct validity, scores for questions assessing the same cognitive domains in phases 1 and 2 were compared. Delayed recall showed a significant correlation, however the correlation co-efficient was poor for both orientation and praxis tests [Table 7].

Table 7: Correlation between questions on the SIDSA and further assessment, testing matching domains.

Questions		*Domains Assessed*	*Correlation Coefficient*	*P Value*
Screening App	**Further Assessment**			
Day of the week	*Time of day*	Orientation	-0.261	0.016
Matchstick shape	*Motor task demonstration*	Praxis	0.191	0.092
10 word list	*3 item recall*	Delayed recall	0.349	0.002

FEASIBILITY

Practicality

As a novel concept for dementia screening in SSA, and a tool designed to facilitate task shifting, the screening app must be acceptable to participants, whilst also being simple and practical to employ. Enumerator feedback on the training and user-friendliness of the device showed that application of the tool was serviceable by these non-specialists [Table 8]. Furthermore, 98.5% of participants asked were impartial or happy for the electronic device to be used to guide their screening, although 41.2% found the questions confusing. Feasibility was challenged by inconsistent electricity supply, as 25% of enumerators found regular charging of the tablets to be difficult, despite being given external battery packs [Table 8].

Table 8: Frequency of enumerator responses to questions assessing the practicality of the screening app.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The tablet was simple to use	3	5	4	0	0
The app was simple to navigate	2	4	6	0	0
The questions assessing dementia were confusing	0	2	4	5	1
The instructions given for the app were suitable and easy to understand	3	6	3	0	0
It was difficult to keep the tablet charged	0	3	3	4	2

Time Taken

After exclusion of entries which were not 'finalised' (this step stops the timer, but does not occur automatically upon completion) within 90 minutes of beginning, the mean time taken to complete the census alone was 3.16 minutes, and 21.98 minutes for the census-screen combination [Figure 14]. Although 77.9% of participants felt that this was acceptable, 91.7% of enumerators reported that the screen was too time consuming [Figure 15]. The process did however become more rapid throughout the study, with the mean census-screen time in the last three weeks of screening (20.22 minutes) significantly quicker than in first three weeks (27.16 minutes) ($p<0.001$, $t=5.245$).

Figure 14: Times taken to complete a census and screen.

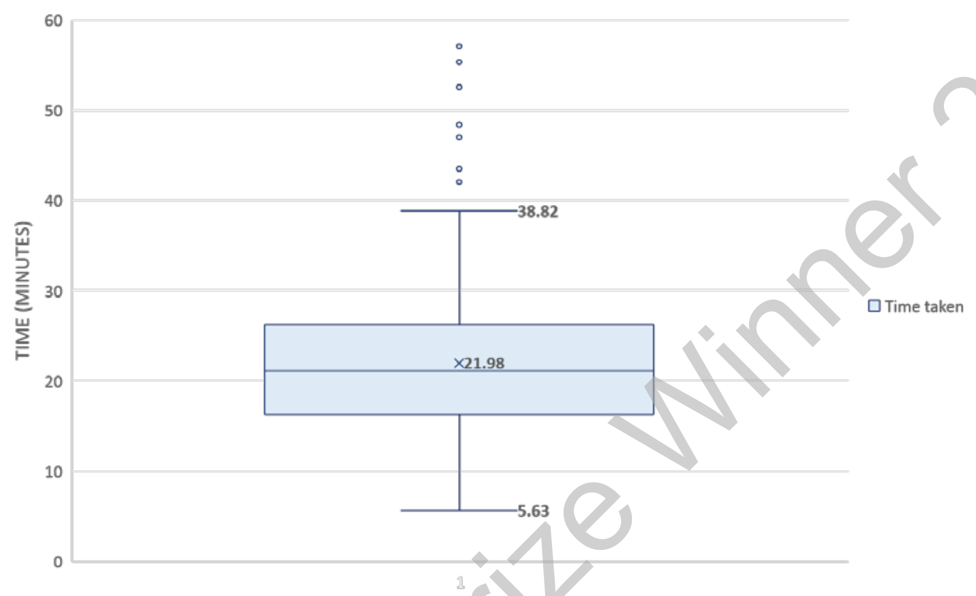
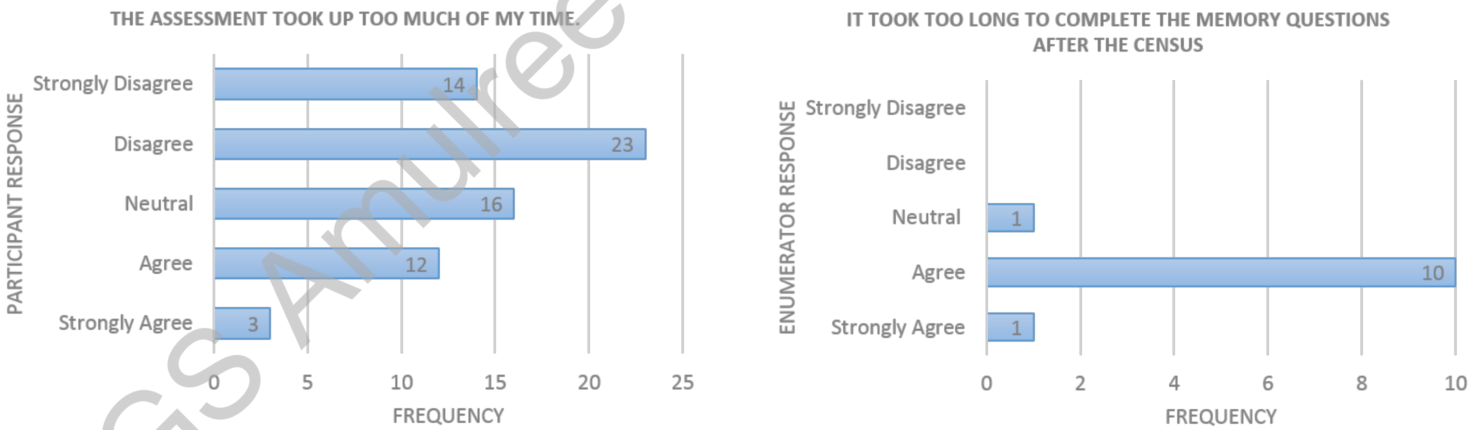


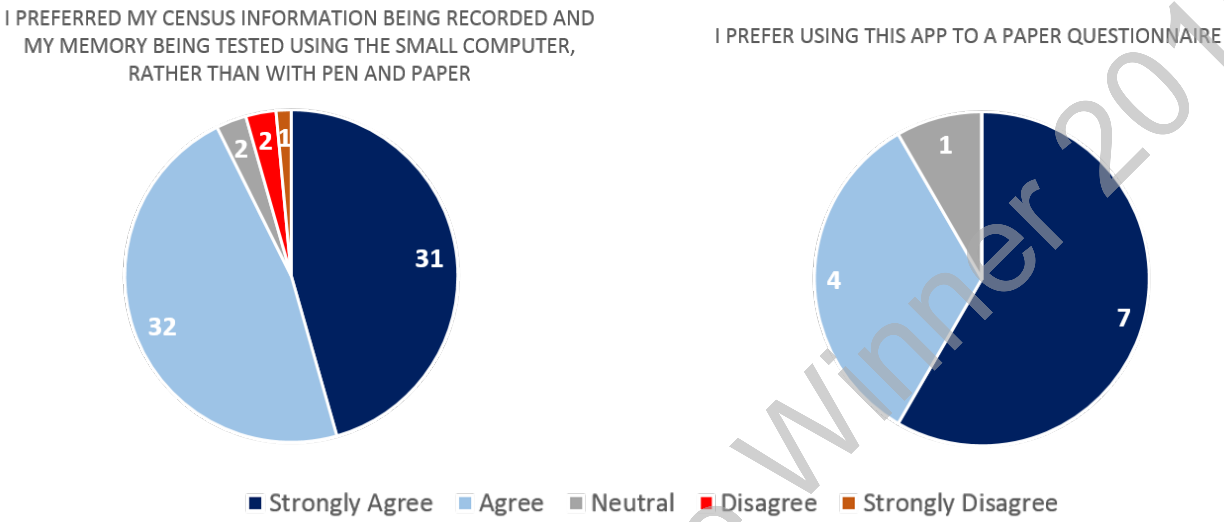
Figure 15: Acceptability of the length of the screening process.



Future Use

A fundamental aspect of the feasibility of the IDEA screening app is its prospect for future dissemination and use. The app received a positive response from those involved, with 11/12 enumerators and 63/68 participants preferring the system to the customary pen-and-paper style assessment [Figure 16]. Additionally, all participants concurred that the device would be beneficial for use in health centers when assessing an older person. Crucially, all enumerators stated that the app would be useful for their future work and that it would make them more likely to evaluate memory.

Figure 16: Participant (left) and enumerator (right) screening preferences

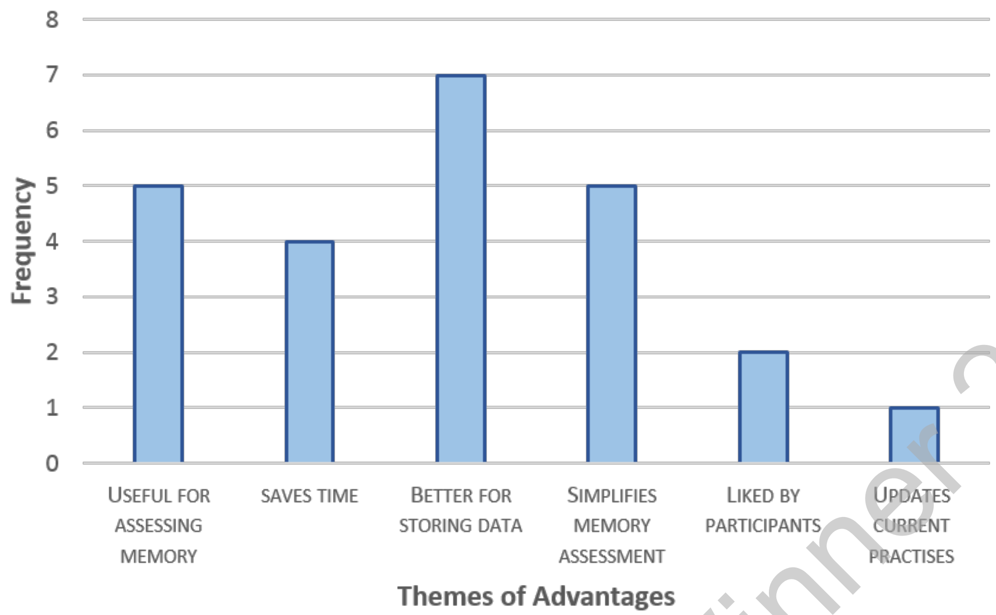


Improvements

All those who filled out a questionnaire were invited to highlight issues, or suggest improvements to the app. 49 participants (72.06%) did not complete this, however from those who did, 2 focal themes emerged. 26.32% thought serial screening of the elderly would be of benefit; a further 47.37% recommended that the app should be part of a more encompassing health service, in which the elderly are given drugs for other health issues – eyesight was of particular concern to 44.44% of these.

Contrary to participants, all enumerators gave qualitative feedback. 100% listed two advantages of the app, the most common of which was the benefit of storing patient data on the tablet [Figure 17]. Challenges faced and areas for improvement centred on the difficulty of completing the screening in the rainy season; 50% of the enumerators found that access to participants' houses was difficult and 50% also reported that multiple visits were needed to each house, as participants were often away on the farms.

Figure 17: Enumerator reported advantages of the app



5. Discussion

Village Demographics and Screening Scores

Within the two focus villages, the mean level of education in Kimira was significantly higher than that of Sanya Station. In an educationally biased tool, it could be expected that this difference would result in a significantly lower average score in Sanya Station. The median score however for each village was exactly equal (11/15), therefore reaffirming previous studies which have found the SIDSA to show no educational bias[27, 33].

A further significant demographic difference between the two villages in question is the proportion of their populations aged 60 or above. Sanya Station has 4.76% of its population currently living above this marker, and therefore conforms to current life expectancy projections for SSA; these show that by 2020, 5% of the population will be 60+ years old, with 2018 figures marginally below this[11]. In Kimira however, 15.79% of its population are aged ≥60, a statistic which is not predicted to be the average for SSA until 2085, and in fact is closer to the equivalent 2016 statistic for over 65s in the UK (18%)[11, 51]. Although the reason for this difference cannot be certain, possible contributing factors include greater wealth (attributable to the farming of cash crops such as coffee alongside sustenance farming), higher levels of education, and improved housing in Kimira when compared to Sanya Station.

Surprisingly, despite the greater number of older people in Kimira, it produced significantly fewer screen-positive cases than Sanya Station. This may be a result of the distribution of ages within these samples. The greatest difference in population size was in those aged between 60 and 65, a range which encompassed 75 people in Kimira, compared to just 38 in Sanya Station. Due to the positive relationship between dementia and age, it is the category in which we would expect the lowest prevalence of dementia. Therefore, despite Kimira having 1.43 times the number of over 60s than Sanya Station, one would not expect to see the number of likely dementia cases also differ by this factor. Moreover, Sanya Station has a significantly poorer education profile and is home to 71.88% of the ≥90s in the study – those expected to have the highest rates of cognitive impairment.

DEMENTIA PREVALENCE

Current figures estimate the prevalence of dementia worldwide to be 5.2%[10]. Literature regarding the prevalence of dementia in SSA varies greatly; it was previously assumed to be lower than that in HICs, however more recent studies have shown figures to be more analogous, and meta-analysis estimates the current prevalence in SSA to be 6.38%[11, 13, 16].

In 2013, Longdon et al investigated the prevalence of dementia in the Hai district and found it to be 6.4%[16]. The current study showed 85 (20.88%) people to have levels of cognitive impairment suggestive of dementia. The variance between these figures may initially suggest that the tool has poor specificity and is identifying many false positives – a feature which leads to misuse of resources and therefore greatly impacts upon a tool's feasibility in resource-poor settings, however there are several key differences in the studies. Longdon's study investigated those aged 70+, therefore discounting cases aged 60-69, the age range which makes up the majority of this study[16]. The study was also carried out 5 years ago; with the prevalence of dementia in SSA expected to double every 20 years, and the most significant rates of increase expected to be in the East of the continent, it should consequently be expected that numbers in the Hai district will have increased within this period[11, 16]. Furthermore, when raw screening data is analysed for the study, the screen positive rate for the first phase was 15.36% – much higher than the final prevalence figure and more akin to that in the current study[16]. Differences remaining may result from the use of a different screening tool – the CSI-D – which as mentioned, relies upon informant presence, therefore losing those potential screen positives without this[16]. A final point to highlight is that when an alternate set of diagnostic criteria, produced specifically for LMIC use, were applied to Longdon's study, prevalence figures rose to 21.6%[52]. Numerous studies using standard HIC diagnostic criteria may have therefore been drastically underestimating the effect of dementia in this setting, and perhaps screening results using culturally-appropriate tools – such as the one in this study – may give a more accurate picture.

Construct Validity

The SIDSA screening questions have previously been validated as a pen-and-paper tool[30]. The screen was found to perform well, with an area under the receiver operating characteristic curve (AUROC) of 0.990 and 0.919 for Nigerian and Tanzanian outpatients respectively, and that of 0.888 for those in the community [27, 30]. Accordingly, the app is also expected to be a valid measure of cognitive decline. However, validity cannot be assessed until all cases have been reviewed and formally diagnosed by a psychiatrist, preferably with an interest in dementia. Construct validity was therefore analysed as a temporary measure of the app's performance.

Within the screen, a low SIDSA score was shown to have a strong relationship with poor functioning, as classified by a low IADL score. The IADL questionnaire was first developed as a battery of 11 questions (AUROC=0.896 when used alone, 0.937 with SIDSA), but has subsequently been refined and re-validated into a shorter 3 question tool (AUROC=0.878); this was included in the app, alongside the SIDSA, in order to increase the accuracy of the screen[33,53]. Unfortunately, due to the early planting season, many informants were not present to report upon the activities of the participant. This segment of the tool was therefore only carried out on 39.07% of those screened, reducing the reliability of the SIDSA-IADL correlation, and the overall accuracy of the screen.

Demographic data showed links with SIDSA scores. Both increased age and low educational attainment – features which the literature has repeatedly shown to be risk factors for dementia – significantly correlated with poor screening performance[11, 52, 54]. The link between dementia and females has also been well recorded in SSA studies, showing a 2-8 times increased risk, however no significant association was seen in this study[11]. Dementia's association with sex is thought to be at least partly due to the greater life expectancy of women and hence really a relationship of old age[11, [55, 56]. In this study the mean age for women was <2 years older than that of men, which may be responsible for the lack of significant association.

Performance in the further cognitive assessment was found to be largely correlated with SIDSA scores. A poor score in most domains assessed carried at least a moderate association with a lower SIDSA score, as did a provisional diagnosis of dementia or MCI given by one of the two research students. The screen therefore appears to be a valid measure of cognitive decline.

SIDSA scores correlated particularly well with tests assessing sequencing (frontal lobe function), attention and working memory. This suggests that the questions assessing these domains in the app are accurately detecting deficits, and that these questions may be the most sensitive tests, detecting shortfalls which occur early in cognitive impairment.

Conversely, no significant correlation was found when comparing the screening scores to comprehension and praxis tests in the further assessment. Failure in these tests likely indicates a severe loss of cognitive function. It is therefore plausible that even those who achieved the lowest scores in the SIDSA, had not yet developed cognitive impairment severe enough to be reflected in the failure to complete these tests. This theory is further confirmed by specifically comparing the performance in praxis tests across the screen and the phase 2 assessment; performance in Baiyewu's matchstick test – a test which is known to be sensitive to decline in several visuoconstructional cognitive processes – was not correlated with performance in the much simpler motor demonstration task of phase 2, suggesting that those who struggled with the former were still able to complete the latter. Although this may mean that the SIDSA cannot differentiate those with a cognitive function poor enough to indicate a likely dementia from those with the most extreme cognitive impairments, this is not the role of a screening tool and so does not impact upon its feasibility.

Feasibility

Culturally-sensitive healthcare apps have previously been developed in SSA; Musyimi et al found that an app-based depression screen was feasible and useful in Kenya, whilst screening apps for hearing loss, and apps for HIV care-research were found to be acceptable in rural South Africa[57-59]. No previous studies however have assessed the feasibility of smart-technology screening apps within Tanzania, or investigated their use for detecting dementia. Furthermore, in many previous studies, app-based tools were delivered by trained healthcare workers, whereas this study was designed to investigate whether an app can be used by rural enumerators with no formal mental health training, in order to facilitate task-shifting and allow optimal use of health resources[37, 57, 58].

Response rates for the feasibility questionnaires used in this study were 80.95% and 100% for participants and enumerators respectively. However, only 22.62% of participants screened gave qualitative feedback responses, therefore making them a less reliable representation of overall attitudes. Nevertheless, almost 50% of the responses given focussed on the wish for treatments for other health issues, and similar findings were also seen in other SSA studies, in which people sought help to improve overall wellbeing rather than to cure dementia symptoms[11, 18]. The frequency of this feedback therefore suggests that it is likely to be valid and representative of the study population as a whole.

The study's marker of feasibility was 70% positive feedback for each domain. For the majority of questions assessing participant views, this quota was met and surpassed [Table 9]. The exception to this was the first question, which assessed the ease of understanding of the screening questions. On reflection, the phrasing of this question could have been improved, as it read 'The questions assessing memory were confusing'. Those with advanced dementia are expected to find some elements of the screen confusing and therefore this may have skewed results. It would have perhaps been a more accurate measure of feasibility had the wording been slightly adjusted, for example reading 'I understood what the memory questions were asking me to do', or focussing more on the language used.

Unfortunately, achieving the 70% positive feedback target was slightly rarer in the enumerator feedback [Table 9], though this may be due to the small sample size (n=12), as each enumerator was responsible for 8.33% of feedback, therefore one disagreement considerably swayed final statistics. However, undeniably low feedback came from the question evaluating attitudes towards the timescale of the screen; here none of the enumerators were satisfied with the speed of the test (one was neutral). Theoretically, the screen should take no longer than the equivalent pen-and-paper test (average 10 minutes). In practise however, the app-based screen was found to take almost 19 minutes on average. This suggests that despite the training delivered and the time given to become accustomed to the device, enumerators were still not fully comfortable with the apparatus. Nevertheless, the improved time taken between the first and last weeks of the study suggest that a shorter duration could be just a matter of practise. Additionally, in a real-world clinical setting, the app would not follow a census, and would not include an assessment of subjective memory impairment; these questions are designed for research purposes. Thus, the screen would be quicker to complete following their removal. Timing therefore, does not pose a long-term threat to the feasibility of the app.

A further point for consideration, is whether the acceptability of the time taken is likely to have been skewed by enumerators comparing the app to other screening tools to which they are accustomed (sphygmomanometers for example). These tools are quick to employ and give immediate results, however do not offer a fair comparison to a mental health screening tool.

Table 9: Summary of feasibility results

		Enumerator Positive Response >70%?	Participant Positive Response >70?	Feasible?
User Friendliness	*Tablet*	Yes	N/A	Yes
	App	Yes	N/A	
	Satisfactory instructions	Yes	N/A	
	Big enough font	Yes	N/A	
Practicalities	*Informant*	No	N/A	No
	Charge	No	N/A	
Question Simplicity and Understanding	*Understandable*	Yes	No	?
Timing	*Concise enough*	No	Yes	?
Acceptability and Future Use	*Preference to pen and paper test*	Yes	Yes	Yes
	Useful for future work	Yes	N/A	
	More likely to test memory	Yes	N/A	
	Acceptable	N/A	Yes	
	Good for use in health clinics	N/A	Yes	

Strengths

The study contributes novel ideas and findings to a distinct gap in the literature on dementia in SSA. It is patient-centred, and has real-world applications, acknowledging the ageing population and the mounting need for culturally-appropriate and resource-sparing screening tools.

Enumerator training for our screening tool was delivered as a group workshop session, thus standardising procedures and technique. The electronic equipment (tablets and portable battery packs) were also a standardised set brought from the UK, therefore eliminating discrepancy between smart-device models and ensuring that issues reported were of a true nature, and not due varying or sub-standard equipment.

Screening and census data were uploaded regularly from each tablet, minimising the potential loss of data, should any problems be encountered with the smart-devices. Furthermore, regular uploads allowed sensitive patient information to be removed from the tablets and stored instead on the secure, encrypted server of the local research institute. In a country with poor infrastructure, where internet safety is a novel concept, the ability to protect confidential patient information in this way was a crucial step in the ethical consideration of the study.

As screening for the study was done in conjunction with the census, all adults ≥60 in each village were invited to take part in the study. In Kimira, 100.00% of the elderly population consented, and 90.80% in Sanya Station. These coverage rates are excellent and consequently screening results are valid at a population level, with no selection bias. These screening assessments were all carried out within the home settings of participants. Assessing cognition within a familiar environment has been shown to give a much more accurate representation of optimal cognition and daily functioning, a further strength of the methodology of the study[60].

When conducting phase 2 of the research, multiple attempts were made to ensure that all those randomised were subsequently seen, and as many collateral histories as possible were gathered. For the duration of the research, repeated visits were made to absent participants' households, and regular contact was attempted by enumerators. Resultantly, 90.3% of those randomised were assessed, and of those, 80.5% completed a feedback questionnaire - substantial rates, likely to give valid results.

As questionnaires were delivered in phase 2 of the study – after the stratification of participants – the sample assessed had higher ratios of those likely to have dementia than at the population level. This thereby reflects the real-world clinical situations in which the app would be utilised, and although it may not represent the whole village's views, with the high response rate achieved, it does give an accurate view of those at whom the screen is targeted.

Limitations

Although this study was designed to be as robust as possible, residual limitations must be recognised.

Time constraints and adverse weather conditions hampered this research considerably. The study initiated screening in 12 villages, however only two were able to be followed up. Furthermore, heavy rains affected both accessibility and participant whereabouts, thus making it harder for enumerators to carry out screening. As a consequence of the slow pace and a limited time frame, phase 2 was forced to start before the completion of phase 1. Not only did this negatively impact upon the phase two sample size, which was much smaller than hoped, it also introduced a selection bias into the phase 2 assessments. Those who were most readily accessible were screened first; hence, it was a smaller sub-sample of these who then progressed to the second stage of the study, rather than a truly representative selection from the village population. Those rarely at home, or who are easily isolated from the rest of the village by floods, may have dissimilar opinions on the screening tool to the rest of the village and yet due to the sampling method, this will remain unacknowledged.

Language differences within the villages may have also reduced the validity of results. The app is in Kiswahili, and yet a small proportion of Kimira's elderly population, and a large proportion of that of Sanya Station, speak only in their tribes' native language (Kichagga and Maa), thus without a translator, these participants will have been unable to fully understand the questions. Furthermore, even those with a translator may receive unrepresentative scores; translation of the screening tool from English into Kiswahili was an intricate process, with many contributors helping to create an accurate translation and preserve the meaning of each question. Subsequent translations by relatives however are not subject to the same rigorous standards, leading to non-standardised questions and potential misinterpretation of answers.

A similar problem was experienced with the feasibility questionnaires. Many participants were unable to fill these out independently, due to illiteracy or uncertainty regarding the process. In these circumstances, the questionnaire was conducted verbally. Although it was stressed that questions must be read exactly, in order to maintain their integrity and minimise interviewer bias, there remained the chance for misinterpretation of answers which could introduce error into the study. Moreover, in a verbal feasibility assessment, due to a lack of anonymity, participants may be more likely to alter their answers according to what they perceive the assessor wants to hear, thus creating response bias.

A crucial drawback to the study which must be acknowledged is the inherent selection bias in the feedback, as those with the most advanced cognitive impairments were unable to complete it. This effect was mitigated wherever possible, by gaining feedback from the participant's relative.

A final point to consider is that although a part of the largest dementia screening exercise in SSA, this study focuses on the populations of just two rural villages. Findings are consequently not generalisable to urban populations, or other LMIC settings.

6. Conclusions

Sub-Saharan Africa is undergoing a demographic transition, resulting in an ageing population and an increased prevalence of dementia. Identification of dementia by standard tools used in HICs is inappropriate and therefore more suitable methods must be devised. The aim of this research was to investigate the feasibility of using a smart-device based application to identify cognitive decline in the elderly populations of twelve villages within the Hai district.

Screening was successful in all twelve villages, although time-constraints restricted feasibility assessments to just two. Construct validity analyses suggested that the app was a valid method of assessing for dementia and MCI. Scores reflected performance in working memory and sequencing tests very well, indicating a high sensitivity of the screen.

Feedback from those delivering and receiving the screen was largely positive, although the two groups' opinions differed on whether the test was easily comprehensible. Enumerators all said that the app would be useful for future work, although they were displeased with the length of time the assessment took and found it hard to keep the tablet charged.

Overall, it appears that the app is feasible for use in this setting. Slight changes however should be made; larger capacity battery packs and further training should be given in order to improve the battery life of the tablets and boost enumerator confidence with the device, thus hastening assessments. Translations in traditional tribal languages should also be available.

Future distribution of the app would provide a more secure, portable and lightweight alternative to paper tests, thus allowing assessors to collect more data and access those in the most rural locations, those too frail to leave the house or those afraid of the stigma of attending clinics. Furthermore, such smart-devices with internet connectivity would allow screening methods to be remotely updated in-line with current research findings, ensuring best practise for older patients' care. The success of the app in this initial study demonstrates the utility of task-shifting platforms in re-distributing healthcare workloads, thereby conserving resources and promoting other such programmes.

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