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Original Paper: Development and Feasibility of InDEx: A smartphone app and personalised text messaging framework to monitor and reduce alcohol use in ex-serving personnel

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Abbreviations

Term	Abbreviation
Application	app
Alcohol Use Disorders Identification Test	AUDIT
Behaviour Change Technique	BCT
Generalised Anxiety Disorder	GAD
Health Action Process Approach	HAPA
Information about Drinking for Ex-serving	InDEx
Patient Health Questionnaire	PHQ
Post-Traumatic Stress Disorder	PTSD
United Kingdom	UK

Abstract

Background: Self-reported alcohol misuse remains high among Armed Forces personnel even after they have left service. More than 50% of ex-serving personnel meet the criteria for hazardous alcohol use, however many fail to acknowledge that they have a problem. Previous research indicates that interventions delivered via smartphone applications (apps) are suitable in promoting self-monitoring of alcohol use, have a broad reach and may be more cost-effective than other types of brief interventions. There is currently no such intervention specifically designed for the Armed Forces.

Objective: This study sought to *i*) describe the development of a tailored smartphone app, personalised text messaging framework, and *ii*) to test the usability and feasibility (measured and reported as user engagement), of this app, in an hard-to-engage ex-serving population.

Methods: App development used Agile methodology (an incremental, iterative approach used in software development) and was informed by behaviour change theory, participant feedback and focus groups. Participants were recruited between May and June 2017 from an existing UK longitudinal military health and wellbeing cohort study, pre-screened for eligibility, and, directed to download either Android or iOS versions of Information about Drinking for Ex-serving personnel (InDEx) app. Through the app, participants were asked to record alcohol consumption, complete a range of self-report measures and set goals using implementation intentions (*if-then* plans). Alongside the app, participants received daily automated personalised text messages corresponding to specific behaviour change techniques, with content informed by the Health Action Process Approach, with the intended purpose of promoting the use of the drinks diary, suggesting alternative behaviours and to provide feedback on goals setting.

Results: 150 ex-serving personnel were invited to take part in the study, 31 (22.6%) of whom accepted and downloaded the app. Participants opened the InDEx app a median of 15.0 (IQR 8.5-19.0) times during the 4-week period (28-days), received an average of 36.1 (SD 3.2) text messages, consumed alcohol on 13.0 (IQR 11.0-15.0) days, consumed a median of 5.6 (IQR 3.3-11.8) units per drinking day in the first week, decreasing to 4.7 (IQR 2.0-6.9) units by the last week and remained active for 4.0 (IQR 3.0-4.0) weeks.

Conclusion: Personnel engaged and used the app regularly as demonstrated by the number of initialisations, interactions and time spent using InDEx. Future research is needed to evaluate the engagement with and efficacy of InDEx for the reduction of alcohol consumption and binge drinking in an Armed Forces population.

Keywords: Behaviour change techniques, smartphone app, mobile health, alcohol misuse, binge drinking, personalised text messaging, ex-serving, armed forces.

Introduction

Alcohol misuse is common in the United Kingdom (UK) Armed Forces and the prevalence is higher in the military than the general population [1–3], with the trend continuing after they leave service [1]. More than 50% of those who have left military service meet the criteria for hazardous alcohol use, defined as scoring 8 or above on the Alcohol Use Disorders Identification Test (AUDIT; [4]). This prevalence rate is almost double that found in the general population [5], and additionally, 47% of ex-serving personnel report binge drinking, defined as six or more units for females and eight or more units (1 UK unit = 8g ethanol) for males per session at least once per week [3].

Most people in the general population underestimate their drinking and do not perceive it as problematic, even when the level of consumption is potentially harmful to health [6]; young men are at particular risk of underestimating their drinking [6]. This pattern is similar among Armed Forces personnel, with less than half of hazardous drinkers recognising that they have an alcohol problem and seek medical help [7]. There is a culture of heavy alcohol use in the Armed Forces which may be encouraged or maintained by social determinants [8]; therefore, leaving service could provide an opportunity to initiate behavioural change in settings with less peer pressure to conform to social norms.

In the last decade, computer and web-based interventions (*e.g.* Down Your Drink [9]) have been harnessed to increase reach, provide real-time monitoring and personalised delivery [9,10]. More recently, the mode of intervention delivery has shifted from web-based, to mobile-based [11]. Mobile applications (apps) for use in health have proven to be an effective and successful method of providing patient-centric interventions which are based on real-time data and needs [12].

There are a large number of alcohol-related apps available to the general population, with a recent content analysis identifying more than 600 apps, of which 91 were identified as focusing on alcohol reduction [13]. It has been reported that many apps lack an evidence-base and make no reference to the scientific literature [13,14]. Recent research has found that the use of mobile apps in brief alcohol interventions has been shown to be effective compared to a traditional delivery method (*e.g.* face to face) [15,16]; however, the content of most existing alcohol smartphone interventions is based on public health guidelines regarding safe alcohol limits [13,17]. These alcohol limits may not be *perceived* as credible as they are viewed as state-sponsored and are often at odds with individual beliefs, prevailing social context and perception of consumption [17–20]. Many users do not maintain engagement with mobile health interventions [21]. Further, the majority of existing alcohol mobile apps emphasise longer-term health consequences which are seen as remote risks especially by young drinkers [14,16,22], a recent meta-analysis suggests that it may be more effective to focus on shorter term detrimental consequences in order to encourage individuals to reduce their alcohol consumption [23].

Most existing alcohol apps include self-monitoring (*e.g.* Drink Less [22], Drink Aware [24], One You Drinks Tracker [25]), whereby users are encouraged to regularly record and monitor (via visual graphics) their alcohol consumption within an app [22,26]. Self monitoring was found to be the most effective behaviour change technique (BCT) for reducing alcohol use; a BCT is defined as a specific, irreducible component of an intervention designed to change behaviour and a putative active ingredient in an intervention [27]. A recent review of computer and web-based delivered alcohol interventions suggested that provision of normative feedback, goal review and inclusion of the social

norms approach in combination were associated with better outcomes [23]. There is also evidence that text message interventions can be successful in encouraging people to change their behaviour [28,29] and further benefits may be gained by incorporating user input to further tailor the text messages. However, to the authors' knowledge, there is no published work that seeks to develop an alcohol reduction app for ex-serving personnel.

We are not aware of any mobile health app that seek to customise a brief alcohol intervention using personalised text messages. In this study, we describe the development of the *In*formation about *D*rinking for *Ex*-serving personal (InDEx) app, a tailored 4-week (28-day) intervention, specifically designed to target ex-serving personnel who meet the criteria for hazardous alcohol use, which is likely to impact on their functioning. The purpose of this study was to design an engaging, responsive and usable smartphone app that delivers personalised text messages and gathers alcohol usage data and to test the usability and feasibility, measured and reported as user engagement, of this app in an hard-to-engage ex-serving population. Our primary outcome measure was adherence with InDEx, measured by the number of weeks participants engaged with the app. Our secondary outcome measures were how many times participants used the app (*e.g.* utilisation of the drinks diary) and the proportion of participants using InDEx at the end of the study period.

Methods

Ethical approval was obtained from the local Research Ethics Committee at the University of Liverpool (reference: #0625).

Participants

Potential participants were eligible for inclusion if they had served in the UK military, were aged 18-65 years, owned an iPhone or Android device released after 2012, were willing to receive daily text messages, currently resided in the UK and were capable of providing informed consent. Those who had an AUDIT score of lower than 8 or greater than 19 were excluded as InDEx is focused on intervening among those drinking hazardously or harmfully, who are likely to be experiencing some shorter-term consequences of their drinking, yet unlikely to be seeking any treatment for this misuse. Those scoring above 20 or above on the AUDIT meet criteria for probable alcohol dependency and we felt that they may require more intensive treatment. Potential participants took part in the King's Centre for Military Health Research cohort study [2,30] and consented to receive further contact. Participants were asked to use the InDEx app for a period of 4-weeks (28-days) between May and June 2017. Providing informed consent, downloading the app and registering an account constituted enrolment in the study. Participants were compensated £40 for their time.

App Design and Development

Design and development of the InDEx app was undertaken on an Apple MacBook Pro, 2.5 GHz i5 Intel processor and 8GB RAM. Drifty Co IONIC Framework version 1 [31] was used as the cross-platform framework to enable iOS/Android deployments using Atom [32] as the development environment. See Supplement 1 for an infographic of the InDEx ecosystem.

A full description of the development process, including the InDEx app source code, is available in [33,34], a summary is provided hereafter.

Specification and Development

The development of the InDEx app was academic-led and supported by experts in smartphone app development, epidemiology, addiction psychiatry and military mental health. The content of the intervention incorporated effective components of previous electronic alcohol interventions (*e.g.* [23]) and with text messages informed by the Health Action Process Approach (HAPA). HAPA theorises that individuals work through a number of stages in order to change their behaviour, emphasising the motivational processes underpinning behavioural intentions, and the various processes that bring about behaviour change [35,36]. The delivery was split into three stages, based upon the HAPA model, with the content of the app and the text messages corresponding to each stage, for example goal setting was only introduced at stage 2 (and available for use in stage 3). The stages were:

- Stage 1: Normative feedback (defined below), action self-efficacy and self-monitoring
- Stage 2: Maintenance self-efficacy and action planning
- Stage 3: Recovery self-efficacy and coping planning

The features were grouped into modules. The following modules were developed;

1) Account Management: Participants can modify personal information (*e.g.* first name, last name, mobile number), password and app parameters (*e.g.* automatic log-out, clear local storage).

2) Assessment and Normative Feedback: Captures participants response to a set of questions (defined by the research team) and aggregates responses to produce an infographic representing the participant's alcohol consumption in comparison to the general population.

3) Self-monitoring and Feedback: Records alcohol consumption by participants and provides a range of visual (*e.g.* charts, figures, text) metrics to allow for monitoring of consumption.

4) Goal (setting and review): Participants can set goal(s) based on implementation intentions [37] methodology, visual feedback provides feedback on progress towards achieving goal(s) set.

5) Text Messaging (review): Provides a facility to review text messages sent to and from the InDEx central server system. Further, participants can rate automated text messages (5-star Likert rating).
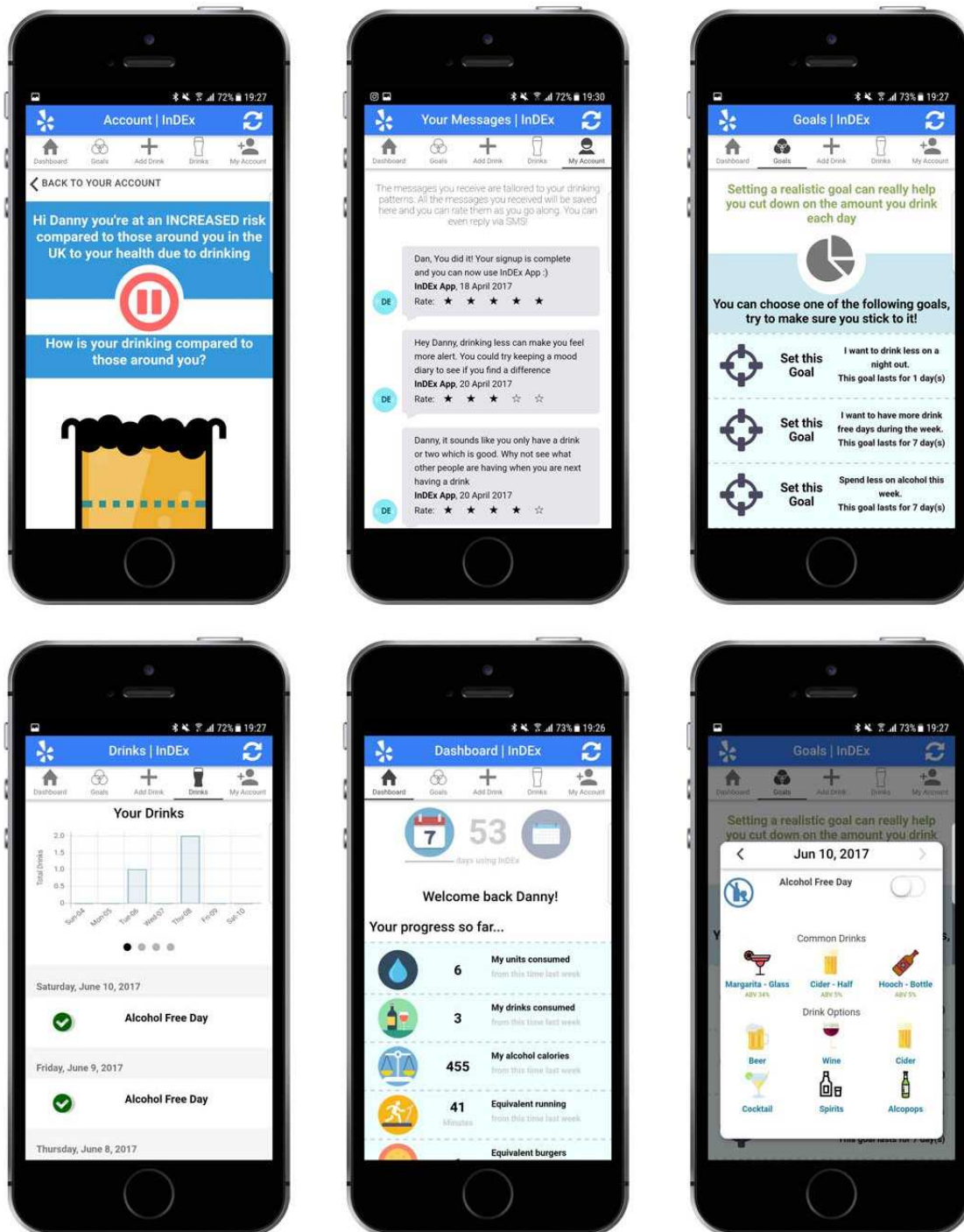
Figure 1. Example screenshots of interactions with the InDEx app (left to right, beginning at top): normative feedback, personalised text message history, set a goal, drink diary, dashboard and add a drink.

The app was developed using Agile development methodologies [38], in which an incremental design approach was employed, where each increment built upon the functionality of the previous. Each increment underwent rigorous testing by stakeholder/expert participants sourced from King's Centre for Military Health Research and University of Liverpool (*n*=17) to ensure software quality and usability. Stakeholders/expert participants were requested to provide feedback on usability, language, functionality and errors at each increment point. The development cycle would not progress until functionality and source errors were addressed.

To create an account, a participant was required to provide *first name*, *last name*, *email address*, *mobile telephone number*, *username*, *password* and *in-app informed consent*. All sensitive information such as *password* was encrypted using Bcrypt hashing algorithms (salt factor 10).

The app (see Figure 1 for example screenshots) was designed with limited storage capabilities to avoid concerns regarding confidentiality and privacy of data. Only the username and a secure JSON Web Token, denoting the user's time restricted session, were stored on the local device, with all other data being stored in temporary memory and accessible via Application Programming Interface calls. The app was also available for limited offline use.

Operating System Selection

In the UK, four out of five adults own a smartphone, among 18-44 year olds adoption is higher at 91% [39] with the majority (over 90%) of smartphones operate either on Google Android or Apple iOS. Based on this information, the InDEx was developed for use with both Google Android and Apple iOS enabled devices ensuring a wide spread of participants could be included.

Personalised Text Messaging

InDEx app is complemented by tailored text messaging which is used to provide prompts to use the diary, to suggest alternative behaviours and to provide feedback on goals. A bank of 180 tailored text messages was developed in line with delivery stages (defined earlier), which were informed by the HAPA framework and from discussion groups with ex-serving personnel further refining the messages (Table 1). Each message had the following characteristics: what day it would be sent, message content and a decision tree defining when it should be triggered. A participant would receive at least one text message each day, up to a maximum of two. The ultimate design and objective of each message was to prompt diary completion and to suggest alternative behaviour related to their individual alcohol consumption.

InDEx uses baseline and/contiguous measurements to inform the type of text messages a participant receives to provide a participant-centric approach. Baseline measurements are used to identify suitable messages, and as a participant engages with InDEx, continuous measurements are used to reflect current behaviour and attitude. For example, if a participant reports feeling depressed or anxious (measured by the Patient Health Questionnaire [40]), a message with suggestions for alternative behaviours to cope with these symptoms (*e.g.* going for a walk) is sent. The messages covered a wide range of topics to target beliefs and motivations with the primary aim of increasing the participant's awareness of their drinking habits and behaviours. The messages were divided into three categories: 1) tailored: personalised to drinking habits, baseline and/weekly measurements. 2) tailored and triggered: tailored to baseline and/contiguous measurements and a specific event occurring. 3) targeted (generic): sent on specific days to highlight inactivity, a new feature or to remind users about an issue. See Table 1 for examples of text messages.

The message bank and decision tree for sending text messages are available upon request from the corresponding author.

Text messages and two-factor authentication codes (used to verify participant's mobile phone number) were sent automatically using Twilio's Application Programming Interface via InDEx central command servers. No human involvement was required. All text messages sent to participants were

visible in the app (My Messages page), participants could rate any messages (rating scale 1-poor to 5-excellent) and provide text message responses which were stored and displayed to the user but not monitored by the study team.

Table 1. An example of the type of personalised text messages sent to an individual throughout their use of the app. Where parenthesis denotes personalised text fields, with reference to relevant Behaviour Change Technique Taxonomy.

Day to be sent	Type	Related Behaviour Change Technique (BCT)	Message
3	Tailored	Mental rehearsal of successful performance (BCT 15.2)	Hi {name}, try thinking that if I am at the pub this week and feel like drinking then imagine how fresh I will feel the next day if I do not drink a lot
8, 14, 21, 28	Tailored and triggered	Self-monitoring of behaviour (BCT 2.3)	Hi {name}, have you logged your drinks from last week? It's quick and easy to do, just go onto the 'drinks' tab in the app
8	Generic	Action planning (BCT 1.4)	Hi {name}, why not set a goal to reduce the amount you drink? It has been found to really help reduce your drinking, you can start now by clicking on the 'goals' tab in the app

Submission and Testing

InDEx was submitted to the Google Play and Apple iTunes App stores via Google Play Developer Console and Apple iTunes Connect, respectively. For testing of InDEx, a private testing group was created; whereby only those who had been given permission were able to access and download InDEx.

Measurement Reporting

All measurements were collected via *Assessment & Normative Feedback and Alcohol Reporting & Monitoring* modules, (Figure 2). The study team had no ability to modify or influence any measurement response.
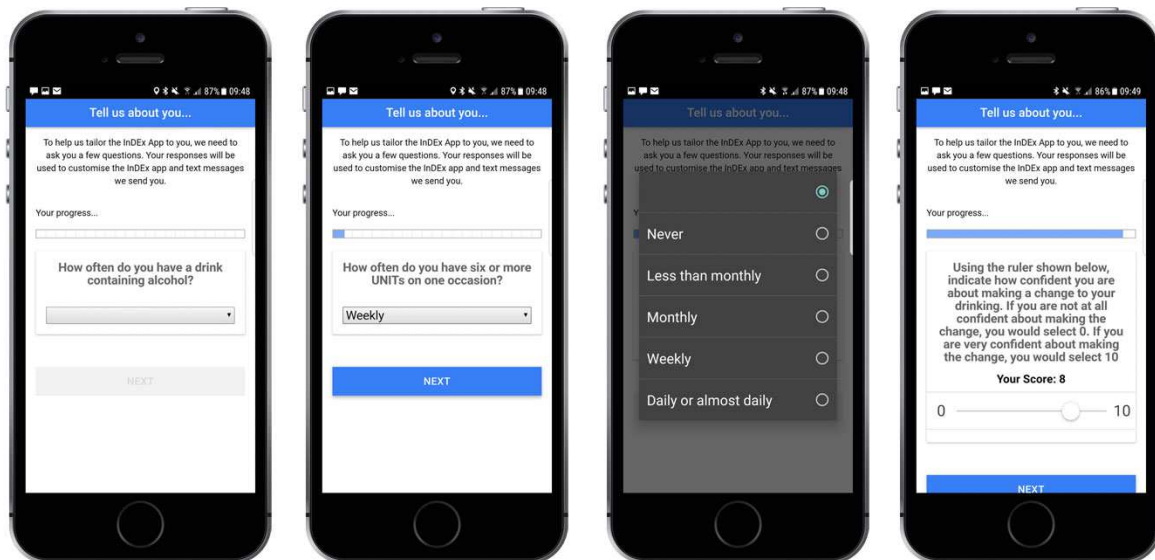
Figure 2. Example screenshots of the InDEx app measurement (questionnaire) module.

Baseline Measurements

Upon successful registration (referred to as 'day zero'), participants completed several baseline questionnaires which collected the following information:

1. Age and sex;
2. Alcohol consumption and alcohol use disorders via Alcohol Use Disorders Identification Test (AUDIT) [41];
3. Symptoms of anxiety using the two item Generalised Anxiety Disorder Scale (GAD-2; [42]);
4. Symptoms of depression using the two item Patient Health Questionnaire (PHQ-2; [40]);
5. Symptoms of were assessed using the five item Diagnostic and Statistical Manual of Mental Disorders Post-Traumatic Stress Disorder scale [43];
6. Readiness to Change and Self-efficacy Rules (score range zero to ten) [44].

Baseline measurement responses informed the type of text message a participant would receive. Although this was optional, the baseline measures were asked again upon completion of the study (day 28).

Weekly Measurements

Participants were asked on days *8*, *15* and *22* to complete the GAD-2, PHQ-2 and the Readiness to Change and Self-Efficacy Rules. Any response provided by the participant further informed the tailoring of the text messages, for example, a participant who scores low on the Readiness to Change Ruler is send supportive messages to encourage a willingness to change.

Reporting Alcohol Consumption

Participants could '*record*' alcohol beverage(s) or an '*alcohol free day*' via the *'Add Drinks'* tab, Supplement 2 illustrates the types of alcoholic drink a participant could record. Self-reported alcohol consumption is a standard method for assessing the efficacy of low-intensity interventions [13,16,22]. Participants could optionally provide volume, strength, price and calories; however, if no

information was provided UK standard data were used [45]. Further, participants could record who they were drinking with, where they were drinking and if consent was provided, their geographical position was recorded.

Engagement and Usability

We measured usability by frequency of engagement using a published procedure [46]: the number of times the app was initialised (*i.e.* started when not running in the background), the average session duration (*i.e.* time spent using the app, overall and for each page), the number of times a participant performed an interaction (*i.e.* synchronised data, added a drink, added a text message rating) and the number of weeks in which participants remained engaged with the app. User engagement was defined as having at least 3 client-server interactions in a 7-day period, other than receiving a text message and was used as a proxy for usability.

Participant engagement was tracked using Google Analytics for Mobile which recorded data when the participant was online or offline. It was not possible to confirm and/or track if a participant read the text messages except in cases where the participant provided a rating from within the app.

Clinical Monitoring and Risk Management

Prior to the study commencing, a risk protocol was developed and approved by the University of Liverpool Ethics Committee. Adverse health events were ascertained via automatic monitoring and reporting based on measurement responses and alcohol consumption. A clinician received all warning notifications, pre-defined by the research team for review. If the clinician felt that the event was clinically significant, participants were offered a call by clinician (those who declined, a reason was recorded) to discuss the adverse health event.

All participants, irrespective of an adverse health event, were provided with a signposting and pathways to local support and assistance via a 'Support' page within the app.

Data Analysis

We calculated descriptive statistics to estimate engagement and usability with the app which is used as a proxy for the feasibility of InDEx app (to address the Primary Outcome). Engagement statistics were reported as median and Interquartile Range (IQR), as the data was not normally distributed (evaluated using skewness and kurtosis values and visualising the data). Popularity of pages was inferred from summation of the total number of times each page was viewed by users, and pages were then ranked from highest to lowest number of views.

The average number of drinking days, drink free days, units consumed, units consumed per drinking day and alcoholic drinks per drinking day was computed across participants and reported as median and IQR. In this study, the number of binge drinking days, was computed per week based on the number of days participants reported consuming 6 or more alcoholic drinks (to address the Secondary Outcomes). Self-reported baseline and weekly measurements were presented as median and IQR, except for Readiness to Change and Self-Efficacy Rulers which were presented as mean and SD.

Analyses were undertaken using STATA SE 14.2.

Results

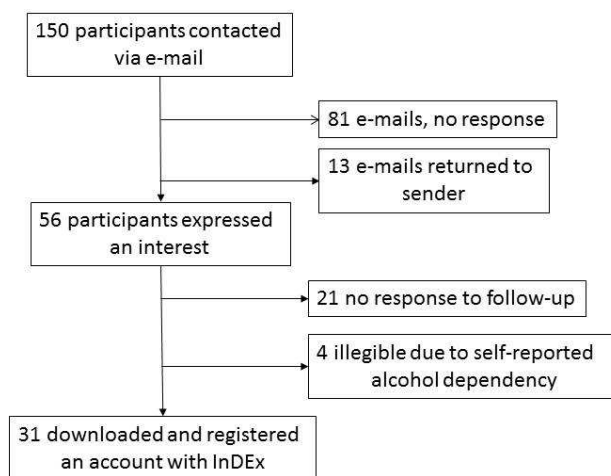### Recruitment, Study Enrolment and Participant Demographics

Figure 3: Participant flow through the study.

150 individuals were contacted via email, see Figure 3, in which 31 participants downloaded and registered an account with InDEx, of which 27 were male (87.1%) and 4 were female (12.9%), representing a registration rate of 22.6%. Of those who joined, 5 (16.1%) were aged 25-39 years, 6 (19.6%) were aged 40-44, 6 (19.6%) were aged 45-49, 6 were aged 50-54 (19.6%) and 8 were aged 55-64 (15.8%). Finally, most participants (*n*=26, 83.9%) reported serving in the military for 12 years or more.

Engagement

Participants used the InDEx app a median of 4.0 (IQR 3.0-4.0) weeks (Primary Outcome), initialising 15.0 (IQR 8.5-19.0) times over four weeks, engaging in 29.0 (IQR 20.0-40.5) sessions for a median of 48.8 seconds (IQR 35.1-73.1). Table 2 provides the engagement measures relating to the level of engagement and adherence. 23 (71.2%) of participants used the app every week (maximum 4 weeks), with 27 (87.1%) using the app in the final week. Table 3 describes the top ten pages viewed by participants, with the Dashboard (36.7%) page being the most popular.

Table 2: Engagement measure over the study period per participant.

Engagement Measure	Median	Interquartile Range
Initialisations[1]	15.0	8.5-19.0
Session count	29.0	20.0-40.5
Session duration (seconds)	48.8	35.1-73.1
Interactions[2]	223.0	182.3-303.5
Weeks active	4.0	3.0-4.0

1 App initialisation reflects the app being opened without a background session existing.

2 Defined as a participant performing a click event (*e.g.* add drink, log-out, change page, change drinks diary chart).

Table 3: Top 10 viewed pages within the InDEx app visited by participants within the study period.

Page	Total Views	% of views
Dashboard	4045	36.7

Drinks Diary	3031	27.5
Add Drink	1160	15.1
Account	390	3.5
Goals	379	3.4
Normative Feedback	244	2.2
Weekly Assessment	166	1.5
Login	148	1.3
Support	102	0.9
Your Messages	98	0.9
Other pages	766	7.0

Drinking Behaviours

Table 4 describes the frequency with which participants made a diary entry. Participants consumed alcohol a median of 13.0 (IQR 11.0-15.0) days, had 15.0 (IQR 13.0-17.0) drink free days and recorded 2.0 (IQR 1.0-4.0) alcoholic drinks per drinking day with a median of 4.7 (IQR 2.3-9.1) units per day.

Table 5 illustrates the drinking behaviour of participants over the study period. During week 1, participants reported a median of 2.0 (IQR 1.0-3.0) binge drinking days per week, with the result similar in week 4.0 (2.0; IQR 1.0-2.5). Further, reductions in units per drinking day from week 1 (5.6; IQR 3.3-11.8) to week 4 (4.7; IQR 2.0-6.9) and units consumed (week 1: 22.9; IQR 14.3-32.4, week 4: 15.9; 11.6-26.9) was observed.

Table 4: Number of drinking days, drink free days, units consumed and alcoholic drinks per drinking day across the study period (4-weeks). n=31.

Reported Alcohol Consumption	Median	Interquartile Range
Drinking days	13.0	11.0-15.0
Drink free days	15.0	13.0-17.0
Units per drinking day	4.7	2.3-9.1
Units consumed	79.4	58.4-117.3
Alcoholic drinks per drinking day	2.0	1.0-4.0

Table 5: Drinking behaviour of participants over the study period. n denotes the number of diary entries per week. Results provided as median (IQR), n denotes number of participants who recorded an alcohol event during the period.

Reported Alcohol Consumption	Week 1 (*n*=31)	Week 2 (*n*=30)	Week 3 (*n*=29)	Week 4 (*n*=31)
Drinking days	4.0 (3.0-5.0)	3.0 (3.0-4.0)	3.0 (3.0-4.0)	3.0 (2.0-3.0)
Drink free days	3.0 (2.0-4.0)	4.0 (3.0-4.0)	4.0 (3.0-4.0)	4.0 (4.0-5.0)
Units per drinking day	5.6 (3.3-11.8)	6.5 (2.3-9.1)	4.54 (2.3-8.9)	4.7 (2.0-6.9)
Units consumed	22.9 (14.3-32.4)	20.4 (14.6-25.0)	18.1 (12.7-26.3)	15.9 (11.6-26.9)
Alcoholic drinks per drinking day	2.0 (2.0-4.0)	3.0 (1.0-4.0)	2.0 (1.0-4.0)	2.0 (1.0-4.0)
Binge drinking days per week [1]	2.0 (1.0-3.0)	2.0 (1.0-2.0)	1.0 (0.0-2.0)	2.0 (1.0-2.5)

[1]Defined as having 6 or more alcoholic drinks in a session.

Measurement Responses

Table 6 summarises participants' baseline and weekly self-reported measurement responses. Participants had a baseline median AUDIT score of 11 (IQR 10-12), indicating hazardous alcohol use, with an average readiness to change score of 4.4 (SD 3.2) indicating some willingness to change. A small change in AUDIT score was observed for participants who self-reported for Day 0 (Registration) and Day 28 (Final Day) based on median score; however, they would still be classified as hazardous drinkers. Most participants did not report anxiety or depression symptoms (measured via GAD-2/PHQ-2) throughout the study.

Table 6: Self-reported baseline and weekly measurement responses.

Variable	Day 0 (*n*=31)	Day 8 (*n*=25)	Day 15 (*n*=25)	Day 22 (*n*=21)	Day 28 (*n*=22)
GAD-2					
Median (IQR)	0 (0-1)	0 (0-0)	0 (0-1)	0 (0-0)	0 (0-0)
PHQ-2					
Median (IQR)	0 (0-2)	0 (0-0)	0 (0-1)	0 (0-0)	0 (0-0)
AUDIT					
Median (IQR)	11 (10-12)	-	-	-	10 (8-12)
Self-efficacy					
Mean (SD)	6.7 (2.7)	5.9 (3)	4.9 (3.2)	6.3 (2.5)	4.5 (3.1)
Readiness to Change					
Mean (SD)	4.4 (3.2)	4 (3.3)	3.4 (2.8)	4.9 (3.2)	3.7 (2.7)

Text Messaging

A total of 1083 (mean 36.1, SD 3.2) text messages were sent. Participants were able to reply to messages but were informed that responses would not be monitored. There were 18 replies and 42 text message ratings, the mean rating of content suitability was 2.5 (SD 1.3), indicating a neutral rating for the content of those messages. One participant withdrew consent for receiving text messages on day 16 of the study.

Discussion

Principal Findings

The aim of this paper was to design an engaging, responsive and usable smartphone app that delivered personalised text messages and gathers alcohol usage data and to test the usability and feasibility, measured and reported as user engagement, of this app in an hard-to-engage ex-serving population. InDEx app has been developed using co-design between stakeholders and ex-serving personnel, with the results indicating successful user engagement and adherence. Results, based on the primary and secondary outcomes measures demonstrated that participants used the app for length of the study period, with two thirds of participants used the app every week and the majority were still using it in the final week (87.1%). These engagement measures suggest that participants were highly active in using InDEx during the study period and that it is feasible to collect alcohol consumption data from this population. On average, most participants reported drinking just under half the days in the study period, with participants reporting binge drinking on average two times a week. Reductions in units per drinking day and units consumed per week were observed across this 4-week study (yet the average number of drinks remained consistent), but it is not possible to determine whether this may be due to participants changing the size and alcohol content of their drinks in a small feasibility study.

In this study, the most frequently opened page was the *Dashboard*, the *Drinks Diary* page was the second most frequently accessed while *Add Drinks* was third. The top three most viewed pages accounted for 79% of all app views, which shows that most participants used the InDEx app primarily for monitoring drinks and the other features were not used as frequently. InDEx offered the ability to set a goal using *if-then* format, however participants used this feature rarely even after encouragement to set a goal via SMS text message and in-app prompts. This may be due to the sample not believing they have a problem, or they were unable to navigate to/set a goal, this will be explored further in future work.

We applied behaviour change theory [27] to create a smartphone app which incorporated a tailored text messaging framework in an attempt to engage with users who are usually hard to reach [47–49]. It is difficult to ascertain if, and to what extent, text messages encouraged alcohol reduction or app engagement. Future work is needed to assess the relationship between receiving a text message and engaging with the app. InDEx app takes advantage of a delivery method which circumvented the practical and psychological barriers by utilising digital technology. Participants were compensated for registering, but had no financial incentive to use the app for the study period; nevertheless, they spent a median of 4 weeks engaging with the app.

InDEx has features which do not feature in other currently available alcohol apps [16,17,22]. Firstly, it offers a user-centred, personalised design; the interactive features (*i.e.* normative feedback) of the app were generated through co-design discussions with stakeholders and ex-serving personnel and were developed using an iterative development framework to ensure that they were properly focused. The second major facet of the app was the use of BCTs in conjunction with data collected via the app to personalise the text messages sent to participants. These features exploit contemporary technology which, as our feasibility study suggests, has the potential to promote the acceptability of the InDEx and encourages users to engage with the app to record and thereby self-monitor their alcohol consumption. Third, InDEx is focused on reducing alcohol use among those

meeting criteria for hazardous to harmful alcohol use (who may not recognise they have a problem with alcohol), unlike other studies which have sought to support recovery for alcohol dependency (alcoholism) [20].

To the authors' knowledge, this was the first study to use text messages which were embedded in an app to specifically focus on improving engagement and alternative behaviour related to their individual alcohol consumption of ex-serving personnel. While several studies have sought to investigate the impact that text messages and tailoring can have on adherence, the combined use of the two within the framework of an online app has never been attempted before. We sought to describe the process of tailoring and the deployment of the app using digital technology.

Limitations

Notwithstanding the study strengths, our findings have some limitations. First, baseline, weekly alcohol consumption data was self-reported, albeit using reliable, consistent, and 'gold standard measurements'. As with all self-report measures, recall and social desirability biases may have impacted responses to be more favourable than if collected using objective methods, such as transdermal alcohol monitoring [50,51]. Second, participants were asked to use the InDEx app for 4-weeks. While the app appears feasible and acceptable to users based on engagement measurements during the study period, this study was not designed to ascertain the long-term benefits. Third, the sample size and design was appropriate for feasibility testing, but not for assessing efficacy of the app. Fourth, participants were recruited via the King's Centre for Military Health Research and offered an incentive to take part, resulting in a possible selection bias, as they have already consented to participate in a research study previously. Finally, we studied InDEx in isolation and did not directly compare it with other app-based interventions.

Conclusions

In summary, the results of this study suggest that the InDEx app was feasible to implement and acceptable to participants who typically engaged with the app for most of the study duration. It demonstrated to be potentially feasible as participants reduced alcohol consumption during the study period, but this needs to be specifically addressed in a Randomised Control Trial. Future research is needed to evaluate the engagement with and efficacy of InDEx for the reduction of alcohol consumption and binge drinking in an Armed Forces population.

Declarations

Conflicts

None declared.

Acknowledgments

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Supplements

Supplement 1: Infographic of the InDEx App Ecosystem

Supplement 2: List of alcohol types and categories included in the InDEx App.

Alcohol Category	Alcohol Type (measure)
Beer	Beer (Pint/Half), Shandy (Pint/Half), Ale (Pint/Half), Bitter (Pint/Half)
Wine	Red (Large, Medium, Small), White (Large, Medium, Small), Rose (Large, Medium, Small), Prosecco (Glass)
Cider	Cider (Pint/Half)
Cocktail	Bloody Mary (Glass), Screwdriver (Glass), Martini (Glass), Margarita (Glass), Cosmopolitan (Glass), Mojito (Glass)
Spirits	Cognac (Single, Double), Gin (Single, Double), Rum (Single, Double), Vodka (Single, Double), Tequila (Single, Double), Liqueurs (Single, Double), Sambuca (Single, Double), Sours (Single, Double), Others (Single, Double)
Alcopops	WKD (Bottle), Hooch (Bottle), Smirnoff Ice (Bottle)