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To cite this article: Lydia Harkin, Clifford Stevenson, Emanuele Fino, Catherine Talbot, Avelie Stuart, Miriam Sang-Ah Park, Jennifer Lay, Dmitri Katz, Blaine Price & Daniel Gooch (21 Oct 2025): Older adults can re-appraise loneliness using a social connectivity app: a mixed method intervention study, *Aging & Mental Health*, DOI: [10.1080/13607863.2025.2572017](https://doi.org/10.1080/13607863.2025.2572017)

To link to this article: <https://doi.org/10.1080/13607863.2025.2572017>



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Older adults can re-appraise loneliness using a social connectivity app: a mixed method intervention study

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ABSTRACT

Objectives: Older adults face an elevated risk of social isolation, loneliness, and poor psychological health. This mixed methods study evaluates a trial of an intervention app designed to protect against loneliness by raising older adults' awareness of their social relationships.

Method: A 4-week online mixed methods randomised 2 (condition: app use vs waitlist) x 3 (timepoint: baseline, 2 week, and 4 week wellbeing) trial, with follow up qualitative interviews. Older adults ($N=99$, Mean Age = 68) completed a survey at three timepoints (baseline, two, and four weeks) reporting loneliness, depression, and anxiety. Forty-five post-trial interviews were conducted with the app users and analysed using reflexive thematic analysis.

Results: A significant interaction effect was found; participants using the app reported a significant reduction in depression scores between baseline and four-week follow-up. There was no significant effect on loneliness or anxiety scores. Interviews revealed ways app users were (1) Holding up a mirror to feelings about their social groups, (2) Re-appraising loneliness; and (3) Acting as analysts.

Conclusion: The digital intervention reduced reported depression by enhancing positive appraisal of social groups. Further work is required to understand how to overcome risks of reflection-based apps for loneliness.

ARTICLE HISTORY

Received 12 September 2024

Accepted 2 October 2025

KEYWORDS

Loneliness; depression; older adults; digital intervention; cognitive reflection

In Great Britain, approximately one in four older adults report feeling lonely (Health & Social Care Information Centre, 2007). This is often attributed to long term lifestyle changes such as retirement, ill health, driving cessation which typically increase social isolation and reduce access to social support (Ogrin et al., 2021). A four-year longitudinal study found that perceived social isolation increases the probability of experiencing mood disorders, depression and anxiety (Domènech-Abella et al., 2019). Similarly, a twelve-year cohort study of older adults suggested that, if loneliness were to be eliminated, then 11-18% of cases of depression could be prevented (Lee et al., 2021).

Loneliness is a cognitive process, experienced as negative, distressing emotions (van Winkle et al., 2017; Morgan et al., 2022) arising when the quality and/or quantity of relationships are appraised as unsatisfying. Poorer satisfaction with relationships typically arises during life transitions when individuals can experience changes to their social networks and lower available support (Harkin et al., 2024). Ageing related changes can corrode social networks,

leading to long term or chronic loneliness (Ogrin et al., 2021). Whilst older adults' loneliness is acknowledged as a challenge within society, there is no agreement for how to alleviate loneliness in older adults. Reviews of interventions evidence a range of approaches but often lack a guiding theoretical framework and are inconclusive regarding how to best address loneliness (Fakoya et al. 2020; Ibarra et al., 2020).

Digital interventions hold some potential in this field and are increasingly relevant as digitally literate populations age (Welch et al., 2022). Technology has advantages over traditional interventions due to its convenience of access and ability to promote short-duration regular engagement with an intervention. For instance, an eight-week trial of 13 mental health apps (Zhang et al., 2019) led to a significant reduction in depression symptoms, which was partly attributed to regular engagement with the systems.

Digital tools may potentially be effective in preventing older adults' loneliness. Firstly, loneliness impairs fundamental aspects of cognition including previously learned responses to social stimuli, and so

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 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/13607863.2025.2572017>.

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any attempt to reframe these cognitions is likely to require regular and sustained work (Hawkley & Cacioppo, 2010). Secondly, technology is used by many older adults to preserve or maintain connections with others (Liddle et al., 2021), and so a digital loneliness app may be considered more acceptable than, for instance, conversations about loneliness (Harkin et al., 2024), and may feel less threatening or stigmatising than regular in-person social groups (e.g. Stuart, Stevenson, et al., 2022).

Access to existing online social apps and websites is likely to be insufficient to protect older populations from loneliness. Without intervention, older adults developing lonely feelings tend to partake in purely cognitive coping strategies (Kharicha et al., 2018). For instance, older adults may cope by lowering their expectations, distracting themselves from their mood, and withdrawing from social contact as an emotional protection strategy (Morgan et al. 2022). Socio-emotional selectivity theory proposes that older adults commonly focus on fewer, more meaningful connections than younger populations (Moeyersons et al., 2022), such that there is an expectation that older adults will have fewer social groups. However, when individuals are experiencing loneliness, this approach can be counterproductive and can reinforce perceived isolation (Schoenmakers et al., 2015). The cognitive experience of loneliness is a vicious cycle, in which lonely individuals feel less satisfied with subsequent social interactions, and perceive greater threat from others (van Winkle et al. 2017; Hawkley & Cacioppo, 2010). Simply joining a group or engaging in online group communication can ironically result in increased feelings of alienation or mood disorders (Stuart, Katz, et al., 2022; Wakefield et al. 2019). This suggests that an effective intervention to protect against loneliness is one which needs to comprehensively address the effects of the social transitions experienced by adults in addition to the emotional and cognitive aspects of loneliness.

The social identity approach to health (Haslam et al., 2018) provides a theoretical framework which posits that improving connections to individuals' most important social groups (such as family, friendship, and community groups) unlocks valuable psychological (emotional and cognitive) resources. When individuals feel they belong to social groups, they have access to further psychological resources such as support, a sense of shared positive identity, and valued social roles (Jetten et al., 2017). This provides an increased sense of purpose and control, and acts as a 'social cure' or buffer against poor wellbeing (Haslam et al., 2018). A series of interventions which use the social identity approach to health as a guiding framework have been shown to significantly improve quality of life, and wellbeing indicators such as reduced depression and anxiety (Haslam et al., 2019; Steffens et al., 2021). These interventions

(e.g. Cruwys et al., 2022; Ingram et al., 2020) combine social mapping with reflection techniques to encourage users to reflect on the groups they belong to and strategies for sustaining or gaining group memberships. If these techniques can be translated into digital tools, they may provide older adults at risk of loneliness with protective social resources, thus reducing symptoms of loneliness and of mood disorders (e.g. depression, anxiety).

The present study evaluates a multi-disciplinary research programme [anonymised for peer review] which co-designed a technological intervention to protect older adults from loneliness by supporting positive reflection and social identification techniques.

The current study

This study presents a mixed method evaluation of a digital loneliness intervention. This study aims to investigate the efficacy of using this digital loneliness intervention, with the objective of reducing older adults' loneliness, depression, and anxiety. The design of this technology incorporates principles developed from the Social Identity Approach to Health (Haslam et al., 2018) and the iterative design approach of the app has been published elsewhere [anonymised for peer review]. The current study is a mixed method evaluation of the efficacy of the intervention app to reduce older adults' loneliness, depression, and anxiety following four weeks of daily use.

We hypothesise that app users will show improved:

H1 loneliness scores

H2 anxiety scores

H3 depression scores

Further, we hypothesise that these effects will hold when controlling for the effects of age on loneliness (H4), anxiety (H5), and depression (H6).

Finally, we use qualitative post-trial interviews to explore the psychological processes and mechanisms underlying the app's potential effects.

Methods

Intervention design

This study employed a four-week 2×3 between-within trial with participants randomised to an app user group and a waiting list control group. All participants completed a baseline survey, a two-week mid-point survey, and a four-week end-point survey. Participants in the experiment group attended a post-trial interview, transcripts of which were analysed using Braun and Clarke's reflexive thematic analysis (Braun & Clarke, 2006, 2021).

The digital loneliness app: myCircle

The MyCircle app was created using iterative co-design which combined app features to capture social cure processes alongside older adults' feedback on what features work for them. The app contained four key features: My Mood, Daily Record, My History, and My Circle. Figure 1 summarises the actions users completed in the app, and how this linked to proposed intervention mechanisms and outcomes (example screens are provided in the [supplementary materials](#)). Further detail on the app's development can be found in [two references anonymised for peer review].

Intervention mechanism

The app features were designed with a dual aim to a) encourage reflection on the social interactions that impact on daily wellbeing, and b) make social groups salient, and encourage identification with positive social groups. My Mood, Daily Record, and My History Features together are designed to promote reflection on regular activities, mood, and loneliness. This personalised social reflection may make salient the social identities that are important to users and reframe the emotional components of loneliness cognitions. For instance, a user may input a conversation with a neighbour and reflect on the impact their neighbours have on their mood. Furthermore, users were instructed to complete these reflections daily, which may help to break the cycle of negative rumination reported in loneliness (Tong et al., 2021).

The My Circle features presented opportunities to build social identification by mapping out the user's

relationships to their valued groups. Mapping meaningful social groups has been associated with greater life satisfaction and lower depression (Bentley et al., 2020; Jetten et al., 2017). Moreover, this feature used alongside the My Mood and My History feature provides an opportunity to identify group memberships that impact positively on mood. Meta-analyses of social identification building interventions suggests that building positive social identification can improve wellbeing and reduce mood disorders, anxiety and depression (Steffens et al., 2021).

Participants

For the randomised trial of the app, recruitment aimed for a powered sample size of $N > 35$ per group. This was determined by a power calculation using G*Power software (Faul et al., 2007), with a medium effect size for a repeated-measures ANOVA.

384 older adult members of an institutional research panel dedicated to aging research were contacted *via* email in January 2022. Recruitment was supplemented through study advertisements circulated *via* a mailing list for a national society for older adults (U3A) and *via* researchers' social media accounts. Eligibility for the study was to be a smartphone user, 50+ years old,¹ and living in the UK.

One hundred and fourteen participants completed a baseline survey *via* Qualtrics iwith a random assignment function to a waiting list control or app-use condition. 15 participants disengaged from the study ($n=12$ app users, $n=3$ control group). The final sample of older adults ranged in age, with 31% aged 50–64, 45% aged 65–74, and 23% aged 75 or

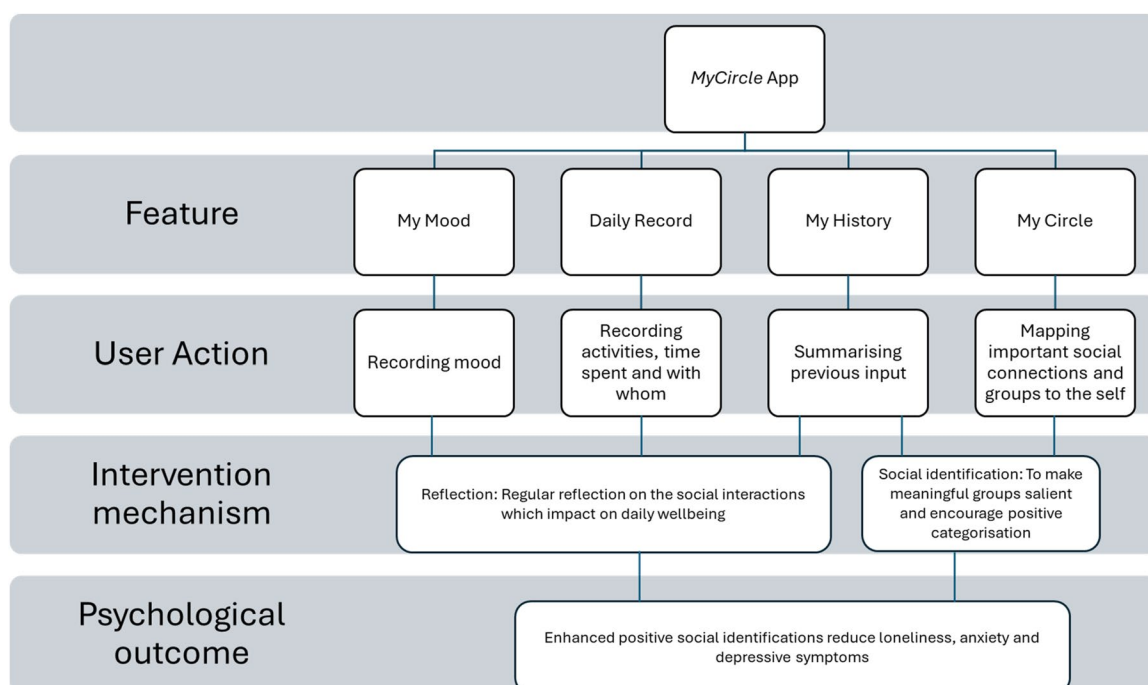


Figure 1. MyCircle App features and their proposed psychological impact.

Table 1. Participant socio-demographic characteristics (N=99).

Variable	Experimental Group (N=44)	Waiting List Group (N=55)	Overall (N=99)
Age Mean (SD)	68.66 (8.24)	68.08 (9.46)	68.34 (8.89)
Relationship (%)			
Never married or never registered a same-sex civil partnership	3 (6.82%)	2 (3.64%)	5 (5.05%)
Married / in a same-sex civil partnership	25 (56.82%)	26 (47.27%)	51 (51.52%)
Divorced / civil partnership has been legally dissolved	9 (20.45%)	14 (25.45%)	23 (23.23%)
Widowed	5 (11.36%)	10 (18.18%)	15 (15.15%)
Other	2 (4.55%)	3 (5.45%)	5 (5.05%)
Education (%)			
GCSEs / CSEs / O levels	4 (9.09%)	6 (10.91%)	10 (10.10%)
NVQ / GNVQ / Foundation diploma	1 (2.27%)	1 (1.82%)	2 (2.02%)
BTEC National / City and Guilds Certificate	1 (2.27%)	4 (7.27%)	5 (5.05%)
A levels / AS levels / VCEs / Higher diploma	7 (15.91%)	10 (18.18%)	17 (17.17%)
Degree (for example, BA, BSc)	9 (20.45%)	17 (30.91%)	26 (26.26%)
Postgraduate degree (for example MA, PhD, PGCE)	15 (34.09%)	10 (18.18%)	25 (25.25%)
Other	7 (15.91%)	7 (12.73%)	14 (14.14%)
Ethnicity (%)			
White - English / Welsh / Scottish / Northern Irish / British	42 (95.45%)	51 (92.73%)	93 (93.94%)
White - Irish	0 (0.00%)	1 (1.82%)	1 (1.01%)
Black / African / Caribbean / Black British	1 (2.27%)	2 (3.64%)	3 (3.03%)
Other	1 (2.27%)	1 (1.82%)	2 (2.02%)

above. All participants in the app trial condition were invited to a Zoom call onboarding session; researchers explained the app to participants, an intervention manual *via* email, and sent weekly participation reminders. Following the four-week trial, all participants in the app-use condition completed an interview. Table 1 presents participants' socio-demographic information.

Materials

Demographic questions

The baseline survey recorded demographic characteristics age, gender, ethnicity and highest education qualification.

Psychological measures

The following measures were collected at baseline, after two weeks, and after four weeks of intervention.

UCLA loneliness scale (Hughes *et al.*, 2004). The 3-item version of the UCLA Loneliness scale (Russell *et al.*, 1980) rates the frequency of loneliness feelings, e.g. 'how often do you feel that you lack companionship?'

Hospital anxiety and depression scale (HADS; zigmond & snait, 1983). The HADS includes 14 items which rate feelings of anxiety and depression in the past week, e.g. 'Worrying thoughts go through my mind'. Bjelland *et al.* (2002) review of 747 studies using HADS found that both subscales reflect optimal sensitivity and specificity for detecting DSM defined depression and anxiety with a threshold score of 8 or higher. HADS is advantageous as it measures the psychological components of these mood disorders but does not include items relating to physical experiences which, in an older adult population, may be attributed to common comorbid conditions.

Procedure

Participants randomised to the app-use condition were asked to record data daily and review their 'My Circle', to record activities with others, and review 'My History' pages. Participants randomised to the wait-list condition were instructed to wait for access to the app following the trial period. All participants completed a wellbeing survey at baseline, two, and four-weeks. After completion of the final survey, the waiting list group were emailed the app manual and installation instructions and the experiment group were invited to a 60-minute semi-structured interview *via* videocall. At each contact, participants who did not respond after two days were sent one email reminder, and after one day further if they did not respond, they were considered to have withdrawn.

The post-trial semi-structured interview contained questions about user experiences of the app and the process of using each feature, and a discussion of their wellbeing, feelings of social support, loneliness, and negative experiences during the trial period.

Ethical considerations

The study was given a favourable opinion from the Nottingham Trent University ethics committee to data collection. All participants gave informed consent and were free to withdraw from the study at any point without requiring an explanation. Participation was incentivised with a £20 shopping voucher at the completion of the 4-week trial. Data were anonymised and pseudonyms are used in interview transcripts.

Quantitative analytical plan

Data was screened for multivariate outliers using robust Mahalanobis' distance (Chalmers & Flora, 2015)

(Alpha = 0.001). Omega was used for reliability analyses, obtained by running a confirmatory factor analysis on the latent measurement model utilised in the study (i.e. loneliness, depression, anxiety measured at three time points). Pearson's product-moment coefficient (r) was used for correlation analyses. To facilitate the interpretation of results, we centered the variables within time points.

Linear Mixed Modeling with maximum likelihood estimation was used to test the hypotheses regarding the interaction of intervention (experimental group, waiting list group) with time (Time 1: baseline, Time 2: 2-week, Time 3: 4-week) on loneliness (H1), anxiety (H2), and depression (H3), and after controlling for age (respectively, for the three outcome variables: H4, H5, and H6). For each outcome variable, random intercept models were compared with models that also included random slopes. The Bayesian Information Criterion (BIC) and likelihood ratio tests (Alpha = 0.001) were used to evaluate model fit and decide on the random effects and type of model to retain. Partial eta squared (η_p^2) was used as a measure of effect size. In the case of significant interactions, contrasts were run to evaluate the effects observed in the experimental group vs. the waiting list group at Time 2 relative to Time 1, and at Time 3 relative to Time 1, respectively.

Post-hoc sensitivity analyses were conducted using the *simr* R package (Green & MacLeod, 2016). One-hundred Monte Carlo simulations were run on the final data set and the final models' parameters, aiming to estimate the power to detect effect sizes 60% below the observed fixed effects' sizes, using the likelihood ratio method (Alpha = 0.05) (Arend & Schäfer, 2019). All analyses were conducted in R (version 4.2.2.) (R Core Team, 2022).

Qualitative analytical plan

Transcripts from 45 interviews were analysed using reflexive thematic analysis (Clarke & Braun, 2021), taking a critical realist approach. This enabled us to identify patterns of meaning across the data. We explored subjectivity as an analytical resource in participant experience of the intervention app (Clarke & Braun, 2021). [Author Initial] led the thematic analysis and began with *data familiarisation* by reading a sub-sample ($n=10$) of interview transcripts and discussing impressions with the lead interviewer. *Preliminary codes* were then generated and applied to the full data set. These codes were inductive, reflecting the explicit content of the data. Similarly coded data were then combined to *generate initial themes*, which were discussed with the research team. The team *reviewed themes* until reaching agreement that the themes captured the data appropriately, were appropriately evidenced by the interview

extracts, and that each theme was sufficiently distinct. The *report* of findings was then completed with illustrative extracts selected for each theme.

Quantitative results

Preliminary data screening and descriptive statistics

No multivariate outliers were detected ($p < 0.001$). Therefore, the data set used in further analyses included data from 99 participants. All the variables showed satisfactory reliability (omega ≥ 0.8) and values of skewness and kurtosis (i.e. between -2 and $+2$) (see Table 2).

Linear mixed modelling

Models were run to test the effect of the interaction of intervention with time on loneliness, anxiety, and depression, respectively. We found that in no case did random slopes improve the fit of the relevant models, based on both the BIC (loneliness: 647.48 vs. 620.39; anxiety: 580.24 vs. 555.16; depression: 702.57 vs. 682.24) and the results from likelihood ratio tests (respectively, $p=0.937$; $p=0.656$; $p=0.154$). Subsequently, we retained random intercept models for further inspection and interpretation.

H1, H2, H3: Intervention and time interaction on loneliness, anxiety, depression

No significant interaction of intervention with time was found on loneliness ($F_{(2, 190)}=1.63$, $\eta_p^2=0.02$, $p=0.198$), nor on anxiety ($F_{(2, 190)}=1.67$, $\eta_p^2=0.02$, $p=0.19$). Regarding depression, a significant interaction of intervention with time was found ($F_{(2, 190)}=3.36$, $\eta_p^2=0.03$, $p < 0.05$), indicating a significant decrease in depression observed in the experimental group vs. the waiting list group at Time 3 relative to Time 1 ($\beta=-0.35$, $SE=0.14$, $p < 0.05$), whereas the interaction at Time 2 relative to Time 1 only approached significance ($\beta=-0.28$, $SE=0.14$, $p=0.051$). Figure 2 illustrates groups' estimated means across time points.

H4, H5, H6: Controlling for Age

Age was significantly associated with loneliness ($F_{(1, 94)}=7.38$, $\eta_p^2=0.07$, $p < 0.01$), anxiety ($F_{(1, 94)}=12.96$, $\eta_p^2=0.12$, $p < 0.01$), and depression ($F_{(1, 94)}=9.21$, $\eta_p^2=0.09$, $p < 0.01$). Table 3 presents the results from all the models, including regression coefficients, random effects, and model fit measures.

Sensitivity analyses

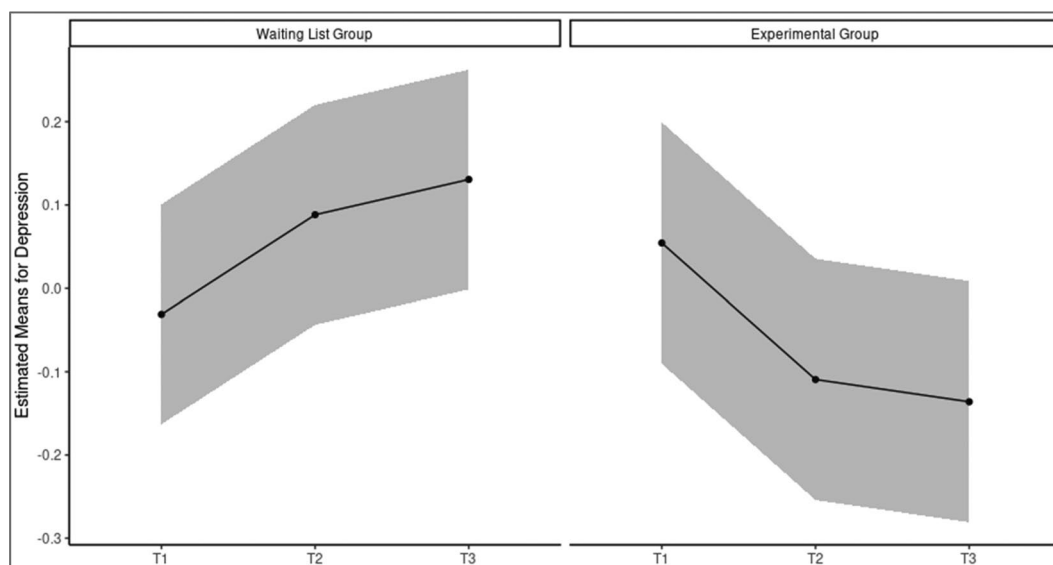
Post-hoc sensitivity power analyses showed $\geq 80\%$ power to detect an effect size 60% lower than the

Table 2. Descriptive statistics, reliability, and inter-correlation matrix (N=99).

Time	Measure	M	SD	Skewness	Kurtosis	Omega (95% CI)	Pearson's <i>r</i> correlations							
							1.	2.	3.	4.	5.	6.	7.	8.
Time 1	1. Loneliness	1.62	0.62	0.64	-0.66	0.86 (0.81, 0.90)								
	2. Anxiety	0.81	0.59	0.83	0.28	0.88 (0.84, 0.91)	0.52***							
	3. Depression	0.52	0.44	1.27	1.47	0.81 (0.75, 0.86)	0.58***	0.78***						
Time 2	4. Loneliness	1.55	0.56	0.71	-0.53	0.84 (0.78, 0.87)	0.83***	0.43***	0.52***					
	5. Anxiety	0.81	0.61	0.90	0.14	0.89 (0.82, 0.91)	0.50***	0.86***	0.65***	0.46***				
	6. Depression	0.54	0.47	1.27	1.07	0.84 (0.78, 0.86)	0.61***	0.65***	0.73***	0.64***	0.72***			
Time 3	7. Loneliness	1.47	0.60	1.06	-0.03	0.90 (0.83, 0.93)	0.80***	0.58***	0.58***	0.83***	0.57***	0.65***		
	8. Anxiety	0.76	0.60	0.86	0.40	0.90 (0.87, 0.92)	0.55***	0.87***	0.65***	0.51***	0.90***	0.68***	0.65***	
	9. Depression	0.51	0.48	1.26	0.81	0.84 (0.69, 0.86)	0.58***	0.62***	0.69***	0.63***	0.64***	0.82***	0.67***	0.68***

Note. *M* and *SD* represent mean and standard deviation, respectively.

***indicates $p < 0.001$.

**Figure 2.** Changes in mean depression scores per condition and at times 1, 2, and 3.

observed effect sizes for loneliness (84.00%, 95% CI = 75.32%, 90.57%), anxiety (90.00%, 95% CI = 82.38%, 95.10%), and depression (91.00%, 83.60, 95.80).

Qualitative findings

Reflexive thematic analysis generated three themes to explain how participants used and experienced the app: (1) Holding up a mirror; (2) Re-appraising loneliness; (3) Acting as analysts.

Theme 1. Holding up a mirror

Our first theme concerns two ways that the app encouraged participants to reflect upon their mood, activities, and social connections. Engagement in reflection was discussed in relation to (1) promoting self-awareness which also raised concerns about (2) reinforcing negative states.

Subtheme 1a: promoting self-awareness

The intervention app promoted taking time out of each day to be self-aware and participants found value in these awareness exercises. App use prompted participants to be mindful of their daily routines, mood, and social connections. Some participants explained that they spent much of their everyday life thinking about others, rather than reflecting upon their fit within their social groups, and how interacting with the groups made them feel. These participants explained that the app encouraged them to be more introspective, appreciating an opportunity to become more attuned to their mood:

Extract 1 (Elizabeth, female, 66 years)

You often ask other people, how are you feeling today? ... We don't ask yourself that and so actually, the strong feedback it would give you on the app was it did make me do that, and it is actually

Table 3. Random intercept models ($N=99$).

Outcome / Predictors	Df	b	SE	95% CI		p
				Lower	Upper	
Loneliness						
(Intercept)	190	0.02	0.13	−0.24	0.28	0.862
Time 2 vs Time 1	190	0.10	0.08	−0.06	0.26	0.211
Time 3 vs Time 1	190	0.04	0.08	−0.12	0.20	0.639
Experimental Group vs Waitlist	94	−0.09	0.20	−0.48	0.30	0.645
Age	94	−0.25	0.09	−0.43	−0.07	0.008
Time 2: Experimental Group	190	−0.21	0.12	−0.44	0.03	0.087
Time 3: Experimental Group	190	−0.05	0.12	−0.28	0.19	0.702
Random Effects: s^2 Residual Variance	0.17					
t_{00} Subject Intercept Variance	0.75					
ICC	0.81					
Marginal R^2 / Conditional R^2	0.08 / 0.83					
Anxiety						
(Intercept)	190	−0.10	0.13	−0.35	0.16	0.456
Time 2	190	0.04	0.07	−0.09	0.18	0.536
Time 3	190	0.08	0.07	−0.05	0.21	0.243
Experimental Group	94	0.21	0.19	−0.17	0.59	0.290
Age	94	−0.33	0.09	−0.51	−0.15	0.001
Time 2: Experimental Group	190	−0.09	0.10	−0.29	0.11	0.387
Time 3: Experimental Group	190	−0.19	0.10	−0.39	0.01	0.069
Random Effects: s^2	0.12					
t_{00} Subject	0.77					
ICC	0.86					
Marginal R^2 / Conditional R^2	0.11 / 0.88					
Depression						
(Intercept)	190	−0.03	0.13	−0.29	0.23	0.816
Time 2	190	0.12	0.10	−0.07	0.31	0.220
Time 3	190	0.16	0.10	−0.03	0.35	0.097
Experimental Group	94	0.09	0.20	−0.30	0.47	0.667
Age	94	−0.27	0.09	−0.45	−0.10	0.003
Time 2: Experimental Group	190	−0.28	0.14	−0.56	0.00	0.051
Time 3: Experimental Group	190	−0.35	0.14	−0.63	−0.07	0.015
Random Effects: s^2	0.24					
t_{00} Subject	0.68					
ICC	0.74					
Marginal R^2 / Conditional R^2	0.09 / 0.76					

something I plan to do going forward, to ask myself how am I feeling.

For some participants, self-reflection provided reassurance that they were content with their daily routines and social connections. For others, this process was linked to a sense of personal resilience, and particularly to challenges that typically present in older adulthood such as medical issues and limited mobility.

Extract 2 (David, male, 71 years)

I think it showed me that I'm a lot more, I am resilient. yeah, so I think it yeah did show me this I'm resilient and it showed me that I wasn't really lonely and other than a bit of a dodgy hip I'm not too bad

This subtheme indicated that the intervention facilitated reflection and increasing self-awareness, which for some participants also instilled a sense of resilience and positive self-worth.

Subtheme 1b: reinforcing negative states

Conversely, participants expressed concerns that the reflective process may reinforce negative emotional states. Specifically, participants felt that regular reporting of low mood or loneliness could worsen these feelings. This was the case for John who highlighted that by using the app they were unable to distract themselves from their mood.

Extract 3 (John, male, 79 years)

I felt depressed recording my loneliness scores... They were amplified by having to give them a score and think about them.

Similarly, participants raised concerns that documenting daily activities within the app could illuminate desirable activities that were no longer achievable for older adults. This could potentially thwart their self-esteem by reminding them that their ought self might not be attainable. This was framed as a particular problem for older adults who were characterised as more likely to be 'stuck at home'.

Extract 4 (Margaret, female, 62 years)

An older person that's stuck at home and hasn't got the ability to get out. They know they want to go out, but they can't get out...it might make you feel worse.

Participants were particularly concerned about the potential for the app to draw attention to a user's limited number of social connections. The app allowed users to rank their connections in concentric circles, and therefore identify their number of close connections, in comparison to peripheral connections. For instance, William realised that he lacked close connections when viewing the My Circle

function. Importantly, participants emphasised that the app would only reflect a user's reality and may simply serve to confirm low mood and loneliness. Therefore, some felt the app may not be appropriate for older adults with fewer social groups and limited ability to expand their social connections.

Extract 5 (William, male, 65 years)

If you're already feeling lonely, it might make you feel more lonely. It might make you realize how few connections we've got and how little support you've got and how unable you are to do anything about it for yourself... that's quite challenging.

These findings suggest that it may not be enough for an app to simply encourage reflection among older adults with low mood, loneliness or limited social resources. Indeed, this reflection may lead to worries and rumination, and ultimately psychological harm. Future app design for older adults should be mindful of sensitivities around activities that are challenging to access due to changes in functional health and ability to make new social connections.

Theme 2. Reappraising loneliness

This second theme concerns how participants framed the app as a device used to re-evaluate feelings of loneliness. Participants explained that, by viewing their map of social connections they gained visual evidence that was at odds with the concept of a 'lonely person', thus helping users to reframe their own position with loneliness. Participants frequently reported that viewing social connections within the app enhanced feelings of gratitude for their relationships, often making comparisons to other older adults who may not be as fortunate. Consistent with this, many participants stated that they did not identify as 'lonely', but there was a shared perception that older adults are often lonely. While these participants did not report being lonely, they still felt they benefitted from seeing a visual representation of their social circle within the app, reporting enhanced confidence and perceived social support. This is illustrated by James' account, in which he defines his self-worth by and compares himself with a stereotype typically associated with older adulthood:

Extract 8 (James, male, 72 years)

The fact that there are people who want to be in contact with me. It's your self-confidence and your self-worth is enhanced by that... There must be many, many people in my age group ... who don't have that sort of support, so it did make me think about what I have and not take it for granted

Notably, the app helped participants to recognise that their perceptions of social contact were not always accurate. For these participants, the app was

particularly useful in highlighting that loneliness is a feeling which is sometimes inconsistent with the reality of their social interactions. By recording social interactions, participants' social relationships were made salient, helping to combat loneliness by drawing attention to the social resources they had available to them.

Extract 9 (Doreen, female, age 72)

...the app required me to address it, it made me realize that one of the things I don't suffer from is loneliness and that's to do with friendship groups... I've always been a great believer always friendship is something we have to work at ... I've always made the effort to continue friendships because it's very easy to become lonely and then start to feel very sorry for yourself, because it loneliness is a horrible thing.

As Doreen describes, the intervention encouraged positive re-appraisal and reduced perceived loneliness through the presentation of concrete reminders of important social groups.

Theme 3. Acting as analysts

Our final theme concerns how participants used the app to analyse their personal data, by taking a 'step back' to consider factors which affected their mood. Participants described using the app to identify trends or correlations between activities and mood when completing their daily log or viewing their history. For some participants, this self-analysis exercise helped them to recognise the value of certain social groups, providing reinforcement that they should continue to engage with these activities. For example, Robert discussed the importance of being a member of a choir, describing a past identity as a trained singer and the role of this social group in sustaining this valued identity:

Extract 10 (Robert, male, 75 years)

The best are the days when I've done the things which I really enjoy. You know, I love singing. I love being part of a choir. ... and that's a huge part of my life. And without it, it made me realise that I need to keep on with that. Because I just sat and thought about it, what do I get out of the choir? Why do I enjoy going there? And, it is just being part of a group

In contrast, other participants stated that analysis of their app data enabled them to recognise loneliness or low mood and the source of this. This was the case for Mary, who noticed that she had not recorded taking part in activities that were important to her identity during the trial, leading to a realisation that she was dissatisfied with her current situation.

Extract 11 (Mary, female, 74 years)

I haven't done any arts and crafts at all in that month. Not my photography, not my stained glass, not knitting, not scrapbooking, nothing. I think that tells more about my mental health than anything else in the app... when I saw that I thought oh, you aren't right, you are pretending.

For some participants, identification of low mood or loneliness through the app spurred them to take action to combat these feelings, by making connections with others or attending group activities. For example, Margaret said the app helped to identify feelings of loneliness and also recognise the importance of her yoga group for her social wellbeing. As a result, she made a conscious effort to attend the group and interact with group members.

Extract 12 (Margaret, female, 62 years)

I've realised really like the actual yoga and also the people there just how lovely they are and how nice it is to see them. So, they have a cup of tea and I'm often quite busy, ... but I did make an effort to sit with them and they're really lovely and that was one of the days when my wellbeing was much better because I'd seen nice people

Other participants felt the app prompted them to evaluate some of their social relationships and groups when using the My Circle function. By doing this, participants were able to identify which social groups or relationships were not positively contributing to their wellbeing. For Catherine, the app helped her to recognise that, while she had logged her engagement with an autism support group, she struggled to identify with the group and this prompted her to re-consider membership of this group.

Extract 13 (Catherine, female, 65 years)

I started thinking about what's this what's this doing in my social network it's not...really relevant to me... looking at the circles and seeing it there thinking well I've been along, have attended it, but I don't think I was really fitting in I don't think I really connected with anybody, is it really worth going at the moment.

While some participants felt the app was useful in facilitating self-analysis and prompting behaviour change, not everyone may be able to identify solutions and take action.

Future digital loneliness interventions may better serve *via* collaborations with local community and support agencies which can help to identify solutions.

Discussion

We evaluated the effect of our *MyCircle* digital app on the loneliness, depression and anxiety levels of older adult participants. We also elicited experiences of engaging with the intervention. Over four-weeks,

participants in the app-use condition used the app to record their social groups, daily social activities, and mood. Quantitative analyses revealed a significant reduction in depression (though not in loneliness or anxiety) between times 1 and 3 for the app-use participants, compared to the waitlist participants. This study provides an important contribution to this field which has called for greater evidence of the efficacy of digital technology for older adult loneliness, as we combined a longitudinal experiment with in-depth rich qualitative data to understand older adult experience of the app use. Findings suggest that the app is potentially useful as a preventative measure for low mood in older adults, though it is not yet possible to draw conclusions about the relative benefits vs risk of its use.

In-depth interviews with app users indicated a range of reported benefits. Daily use of the app was reported to provide a valuable opportunity for reflection on their lived experiences of social connectedness. Emotion regulation is important for psychological wellbeing in older adulthood (Sykora et al., 2021). Interviews revealed that the app facilitated reappraisal of participants' social situations, enabling greater positive evaluations. In turn, the information and opportunity for reflection may allow participants to critically analyse their behaviours and determine which activities were beneficial for improving mood. Our study therefore provides some evidence towards enhanced reflection and self-analysis as a mechanism for improving appraisals of social connectedness, proactive social engagement, and resilience to the common challenges of social network shrinkage in older adulthood (Moeyersons et al., 2022).

During the trial, depression scores lowered for participants using the app in comparison with those in the control group. This may be attributable to the app allowing users to directly monitor fluctuations in the valence of mood, which is known to reduce depression (e.g. Faurholt-Jepsen et al., 2016). However, it is important to note that there was no measurable impact of the app on loneliness and anxiety, and symptoms of mood disorders did not increase for the control group. This suggests that the present sample were not at immediate risk of loneliness or mood disorders. Further, though the present study used a short form loneliness scale to limit participant fatigue, more sensitive measures capturing different clinical properties of loneliness may provide greater insight into the impact of the app. Regarding anxiety, the extant literature suggests that anxiety and loneliness have a bidirectional relationship (Yang et al., 2023). It may be that the intervention, which relies on reflection based techniques, does not sufficiently address anxiety. For a greater effect on anxiety, it may be prudent for future loneliness intervention technology to address

facets of anxiety that may maintain loneliness cognitions and vice versa.

An important limitation is that the sample was non-representative in terms of demographic or clinical profiles and may not fully reflect the broader population in terms of diversity, baseline symptom severity, or help-seeking behaviours. This may limit the generalisability of the findings, particularly for clinical populations or individuals with more severe depressive symptoms. On one hand, this was suitable to the study aims, as the present study explored the app's functioning as a protective intervention for older adults vulnerable to loneliness. On the other, it is not yet possible to extrapolate these findings to clinically depressed, anxious, or lonely populations and further work is advised before app interventions can be recommended for clinical populations. Based on our qualitative findings, however, we advise that future apps involving social reflection incorporate safeguards from rumination such as providing access to appropriate clinical support.

The study sample are relatively young and highly educated older adults; over 50% of our population were educated at degree level or above, whereas only 23% of people aged 65 years and over are educated to this level (Office for National Statistics, 2023). Similarly, a study eligibility criterion was for participants to be smartphone users, whereas 36% of adults over 75 years are not internet users. Our sampling approach was helpful to identify an engaged group of older adults for this small-scale trial to understand participant experiences, but wider app testing would be required to understand how the app might impact a broader population of older adults.

The relatively small scale and short duration of the investigation mean that the more subtle effects of the intervention on loneliness or anxiety may have been missed and its longer-term effects are undetermined. After all, qualitative findings showed that the *MyCircle* app allowed users to see ways that loneliness could be modifiable, which has previously led to improved loneliness outcomes (Morgan et al. 2022). However, we suspect that for longer-term effects to take hold a more interactive app that incorporates community building (e.g. Ingram et al., 2020) is required to enable improvements to social connections. Further app innovations may involve capitalising on digital technology capabilities to understand the pathways through which the app is protective against low mood, loneliness, and anxiety, for instance, by incorporating app usage data or biomarkers of stress, or by utilising an active control condition using alternative digital resources.

The study makes several contributions to the literature. Firstly, our work provides evidence that digital technology can be used by older adults to harness the positive effects of group connections (Cruwys

et al., 2022). Our app was designed on Social Identity principles to highlight shared identities in participants' networks (Haslam et al., 2018; Stuart, Katz, et al., 2022) and several participants reported that it did indeed enable reflection on the positive social and psychological benefits of specific group activities. This suggests that group-based wellbeing interventions can be delivered by technology which allows distanced engagement and potentially allows group-based interventions to reach individuals with a wider range of mobilities.

Secondly, the efficacy of the intervention suggests one way of overcoming a paradox in the loneliness enhancement literature - that those most in need of social connectedness are often least pre-disposed to group engagement (Stuart, Stevenson, et al. 2022). By providing an alternate means of asynchronously and autonomously harnessing the benefits of group dynamics, individuals who have limited interest or ability to participate in new group interaction can still benefit from social identity processes.

Third, we note that the app enabled some participants to identify and prune those group activities which had negative effects on mood. While research has previously acknowledged the potentially negative impacts of exclusionary or unhealthy groups on wellbeing (Wakefield et al., 2019), this aspect of group life has yet to be incorporated into loneliness interventions. We suggest that a social identity-based intervention such as *MyCircle*, which serves to inform and empower individuals to take control of their social connections (Relke et al., 2022), could support a strategy of removing those unhealthy or exclusionary groups which negatively impact upon wellbeing alongside strategies of enhancing salutogenic groups.

Conclusion

We opened by drawing attention the scope and scale of the challenge of reducing loneliness among older adults for whom social vulnerability is often high and access to in-person support limited. Digital connectivity provides one means through which group dynamics can potentially be harnessed to inform and empower older individuals to self-manage the quality and quantity of their social connections. The current study establishes that even a very minimal level of technological support can increase the benefits of existing connections while having a positive effect on wellbeing and lays the basis for future social identity-based digital interventions of older adults.

Note

1. AgeUK define older adulthood as individuals ages 50 years and older (AgeUK, 2022).

Acknowledgements

We would like to thank Ronnie Jieru Yan for her contributions to this project.

Ethics approval statement

This study was reviewed by the Nottingham Trent University Ethics Committee (STEVENSON 2022/373) and received a favourable opinion. It adheres to the APA Code of Conduct and British Psychology Association ethical guidelines.

Authors' contributions

LH, AS, CS, DK, DG, and BP conceived and planned the study. AS and RJY facilitated participant recruitment, onboarding, and data collection. CT led the qualitative analysis. EF and MSA-P led the quantitative analyses. LH and CS jointly led in writing the manuscript. All authors provided critical feedback, checked and revised the manuscript.

Disclosure statement

The authors declare that they have no conflict of interest.

Funding

This research was supported by a grant from the UK Engineering and Physical Sciences Research Council (EP/V027263/1).

Data availability statement

The anonymised survey and app datasets are available on Figshare (Stuart, Avelie; Price, Blaine; Harkin, Lydia (2023). Circles App Evaluation Trial Data. figshare. Dataset. <https://doi.org/10.6084/m9.figshare.21444144.v3>), the app software code has been made available on GitHub (https://github.com/OU-STEM-SIES/SERVICE_server, https://github.com/OU-STEM-SIES/SERVICE_mobile). The analytic code files that support the findings of this study are openly available on the Open Science Framework at https://osf.io/9cxft/?view_only=49627a7f6995473187db164b89bb75a8. Transcripts from interviews are stored privately and not been made public, but reasonable requests for access will be considered.

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