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Evaluating User Engagement with a Reminiscence App Using Cross Comparative Analysis of User Event Logs and Qualitative Data

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3 Title:

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6 Evaluating User Engagement with a Reminiscence App Using Cross Comparative Analysis
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8 of User Event Logs and Qualitative Data
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14 Running Head:

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17 App evaluation using cross-comparative analysis
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20 Introduction

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23 Reminiscence refers to a range of interventions that prompt memories significant for an
24 individual. Because reminiscence draws primarily on longer term memory, it is widely used
25 as a therapeutic approach for people in the early stages of dementia.^{1,2,3} Reminiscence has
26 become increasingly recognised as a psychosocial intervention which may be as effective as
27 and even preferable to pharmacological interventions, especially to avoid unnecessary
28 medication side-effects.^{4,5,6,7}
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40 The use of digital systems to facilitate reminiscing has been shown to be beneficial for people
41 living with dementia.⁸ Technology that facilitates reminiscence increases opportunities for
42 people living with dementia to participate in conversations and to enhance their social
43 interactions.^{9,10} Many existing software systems, apps and social networking websites
44 provide opportunities to gather and share multimedia resources.¹¹ However, there is little
45 research into the usability of these systems for reminiscing amongst people with deteriorating
46 cognitive function.
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3 Lorenz et al. (2017)¹¹ conducted a review to explore technology-based services for people
4 living with dementia and their carers and identified the role of technology in supporting
5 therapeutic interventions and home-based reminiscence to reduce caregiver burden.¹² While
6 Lorenz et al. (2017)¹¹ acknowledged the significant role technology can play in supporting
7 connection, communication and independent living, they also highlighted the challenges
8 posed by the ever-changing cognitive status of users. This was supported by other studies
9 recommending that technologies for people living with dementia and their caregivers need to
10 be accessible at the right time, adaptable to changing needs, easy to use and inexpensive to
11 buy.^{13,14} Advances in digital technology have enabled opportunities for supportive
12 interventions, such as reminiscence to be conducted in the home.¹⁴ However, technology-
13 facilitated reminiscence has its challenges, since it relies on the caregiver's willingness to
14 participate and source memorabilia.¹⁵

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17 Many authors have described the learning potential of people living with dementia,^{16, 17, 18}
18 whereas, Riley et al. (2009)¹⁹ refer to the inability of people living with dementia to learn
19 new skills. It is noteworthy that in their review on involving people living with dementia in
20 the development of digital applications, Span et al. (2013)²⁰ concluded that cognitive
21 impairment is no reason to exclude people living with dementia from research. Recent
22 research into technology-facilitated reminiscence has shown that it can facilitate opportunities
23 for people living with dementia to retain an empowered role in conversations and
24 relationships.¹ However, as there is a lack of research that evaluates the actual usage and
25 adoption of these technologies amongst people living with dementia and carers, this study
26 contributes to a deeper understanding of this process.

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3 This research was part of a wider feasibility study designed to investigate the outcomes of a
4 home-based individual specific reminiscence intervention through the use of a co-created
5 iPad app known as InspireD for people living with dementia and their family carers,
6 implemented with a paired sample of 30 people living with mild to moderate dementia and
7 their family carers. That study is detailed in previously reported work by the authors²⁰. The
8 intervention consisted of reminiscence training, information technology based (IT) training
9 and a 12-week period of independent use of the InspireD app to support individual specific
10 reminiscence in the home.
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23 The aim of the study reported here was to evaluate the user experience of a reminiscence app
24 by people living with dementia and their family carers by cross-comparing the event log data
25 that is automatically generated from the app usage, with the qualitative lived experience of
26 using the technology.
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33 The objectives were to use machine learning to identify behavioral clusters which typify the
34 different user engagements with the InspireD app; to cross-compare the event log data
35 generated by app usage with quantitative data on previous participant experience; and to
36 contextualize behavioral cluster patterns with the process themes generated from the
37 qualitative interview analysis. The rationale for using machine learning to identify and typify
38 user engagements was to assess if such unsupervised machine learning techniques could
39 uncover realistic patterns that would be of use to the study.
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53 Method
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3 This study was conducted in a large health and social care trust in the UK, with recruitment
4 facilitated by Trust staff and the UK Alzheimer's Society. Event log data were collected
5 from all participating dyads (n=30) throughout the 12-week period of InspireD app home
6 usage; however, data files for two dyads were corrupted and not used. Individual interviews
7 were conducted with a volunteer sample of participants at the end of the study (interviews: 16
8 people living with dementia and 16 family carers). Ethical approval for this study was
9 granted from Ulster University's Research Ethics Committee, the regional ORECNI and the
10 NHS Trust's Research and Development office.
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25 Data Collection

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28 Event logging is when each user interaction with an app is automatically logged and stored in
29 a database. This study adopted the health interaction log data analysis (HILDA) pipeline,²²
30 which involved data cleaning and preparation as well as the use of exploratory data analysis
31 and K-means clustering to uncover behavioural patterns of usage by users of the InspireD
32 reminiscence app.
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43 A qualitative approach is an appropriate methodological choice when an understanding of
44 how an individual experienced a phenomenon is necessary.²³ In the context of this study,
45 semi-structured interviews with participants facilitated the presentation of key trends whereby
46 qualitative findings were compared to the 'ground truth' of the multiple strands of electronic
47 data conducted within the wider study.²⁴
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3 Event logging involves storing three variables, namely: 1) the unique user ID to denote who
4 made the interaction, 2) the date and time stamp to denote when the interaction occurred and
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8 3) the event name that describes the interaction. Individual interviews facilitated a more in-
9
10 depth exploration of participants' perspectives about key aspects of the study. The researcher
11
12 used an interview schedule, which included questions on the reminiscence training, IT
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14 support, use of the app and reminiscence activity. The interviews lasted no longer than 45
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17 minutes.
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23 Quantitative data analysis 24 25 26 27 28

29 R studio and the R programming language were used for statistical programming. Hypothesis
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31 testing included t-tests, Wilcoxon and Chi-square tests where appropriate ($p < 0.05$ was
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33 considered statistically significant). Different users started the 12-week trial at different
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35 times, therefore data preparation involved transforming the dates of each interaction/event
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37 into common trial days (from 1 to 84) to allow for comparable usage patterns between all
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39 users over the 84 days. This also facilitated exploratory data analysis and the visualisation of
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41 each user journey using dot plots.
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48 K-means clustering is an unsupervised machine learning technique that was used to uncover
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50 the number of archetypal users that existed. Given a series of variables that describe a user,
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52 K-means clustering computes clusters of users who have similar characteristics. In this study,
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54 we chose five variables to characterise each user. This included: 1) the number of interactions
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56 the person living with dementia had with the app, 2) the number of interactions the carer had
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58 with the app, 3) the number of unique day interactions the person living with dementia had
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3 with the app, 4) the mean day interval between each unique day interaction, and 5) the
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5 standard deviation of the intervals between each unique day interaction. When combined
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7 these variables are sufficient to characterise, 1) the relationship between the person living
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9 with dementia and the carer's interactions with the app, and 2) the frequency of these
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11 interactions and the consistency or variability of this frequency. After determining clusters,
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13 principal component analysis was used to visualise the clusters on a 2-dimensional plot (clues
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15 plot).
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23 Interview questions pertaining to participants' usage patterns provided the team with an
24
25 invaluable presentation of comparable data from the 'ground truth' of the event logging data
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27 with participants' previous experience in relation to the intervention. The use of Miles and
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29 Huberman's (2014)²⁵ checklist matrix (see Table 1) was employed as it not only enabled the
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31 exploration of all participants' responses to one key variable, but it enabled the display of an
32
33 individual participants' responses to a range of variables.
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40 Qualitative Thematic Analysis 41 42 43 44 45

46 The qualitative stage of analysis was conducted using Braun and Clarke's (2006)²⁶ six-
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48 phased method of analysis, as this provided the flexibility and responsiveness necessary for a
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50 rich and dynamic approach to analysis. Braun and Clarke (2006, p.87)²⁶ six-phased method
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52 of analysis is comprised of the following steps: familiarizing yourself with your data;
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54 generating initial codes; searching for themes; reviewing themes; defining and naming
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56 themes; and producing the report.
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6 Lincoln and Guba's (1985)²⁷ four criteria of credibility, dependability, transferability and
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8 confirmability was used to maximise the credibility of the qualitative data with research team
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10 members discussing and agreeing the final themes and sub-themes.
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16 Results

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23 Figure 1 shows basic exploratory data analysis of event logs. A total of 71% of the
24 interactions from people living with dementia are within the reminiscing screens in the app,
25 which is more than carer interactions ($p < 0.001$). Figure 1 (A) shows that people living with
26 dementia preferred to interact with photos and reminisce with personalised media.
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28 Reminiscing peaked on Thursdays and Fridays but dipped at the weekends. There are peaks
29 of reminiscing at 11am, 3pm and 8pm.
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40 [Figure 1 about here]
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46 There is a correlation between the number of days the people living with dementia and carer
47 interacted with the app ($r = 0.577$, $p < 0.001$). However, people living with dementia had many
48 more interactions than carers. People living with dementia interacted with the app on 13.73%
49 of the days, which is akin to one reminiscence session per week. The median interval
50 between each exclusive day using the app was 7.10 days; hence, if a person living with
51 dementia used the app on a given day they are not likely to use this again until one week
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3 later. Figure 2 (a & b) shows the interaction events over a time-line (where the x-axis denotes
4 days). A horizontal jitter was applied to each dot to show the density of interactions per day.
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17 [Figure 2b about here]
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23 Figure 2 (a & b) shows that each dyad has a unique experience eliciting various usage
24 patterns, where some indicate short bursts of activity. Table 1 illustrates the participants'
25 previous IT and reminiscence training and usage patterns generated from qualitative
26 interviews.
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36 [Table 1 about here]
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42 K-means clustering uncovered four clusters or user archetypes. The description of the
43 centroid characteristics of each cluster is provided in Table 2.
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50 [Table 2 about here]
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3 Figure 3 shows a two-dimensional visualisation of the four clusters but does not fully
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5 represent the uniqueness of the clusters, given the inability to visualise data points in high-
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7 dimensional space.
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13 [Figure 3 about here]
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20 Figure 4 provides box-plots that show how each individual feature compares across each
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22 cluster. Whilst this shows the extent to which each individual feature discriminates between
23
24 the clusters, one must bear in mind that it is the combination of all features that provide the
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26 discrimination in K-means.
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32 [Figure 4 about here]
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38 Interview Findings 39 40 41 42 43

44 The four themes that emerged through analysis were: Cluster 1- *“I’m starting to get really*
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46 *good”*; Cluster 2- *“Able to keep me right”*; Cluster 3- *“It was a very difficult mountain to*
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48 *climb”*; and Cluster 4- *“If I wanted to use it...she was here”*. These are described in
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50 sequence below.
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57 Cluster 1: *“I’m starting to get really good”*
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3 One person living with dementia repeatedly engaged with the system (3.6% or 1 user per 28
4 users), as they had 7.2 times more interactions than their carer. Whilst the person living with
5 dementia enthusiastically used the app, the carer showed a normal amount of usage, hence the
6 person living with dementia was independently dedicated. The independent people living
7 with dementia and carer used the app for over half the days in a month (55% of days) and,
8 with little variability, used the app every two days.
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21 *“I forgot quite a bit but X (carer) has a good memory and she was able to keep me right. Just*
22 *the basic things now. I’m starting to get really good. I’m faster as well. “(Hugh¹)*
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29 Cluster 2: “Able to keep me right”
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35 The majority of people living with dementia (43%) fall into this cluster, hence making them
36 the most typical usage profile. These people living with dementia has only 1.7 times more
37 interactions with the app than their carer. This indicates that these people living with
38 dementia have some dependence on the carer for app usage. This dyad uses the app 15% of
39 days in a month. This dyad used the app unpredictably, but on average interacts with it every
40 6.61 days (approximately once per week).
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52 *“Aye, it was grand. I would be very, very slow in picking a thing up, but I’m getting on to it*
53 *now. The wife knows a bit about it so she can help me.” (Peter)*
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60 ¹ All names changed to protect identities

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6 For the carers, the process of reminiscence training also offered them the time to share
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8 memories which were defining to their relationship and history.
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14 *“Oh, it’s lovely to have them and nice to look back...I would have photographs and every*
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16 *year or so you might look through them, but apart from that, no, you never would have*
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18 *bothered.” (Sally)*
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25 It was evident that in the dyads who struggled to use the app or admitted infrequent usage, the
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27 carer acknowledged they had not adapted well to this type of technology or had felt this type
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29 of medium was not appropriate for their loved one.
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35 *“I would put the whole thing down to me. I’m not accepting of it. I wasn’t maybe doing as*
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37 *much as I should have been doing.” (Ann)*
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43 Cluster 3: “It was a very difficult mountain to climb”
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49 This reflects 25% of people living with dementia as they had 25% fewer interactions with the
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51 app than the carer. These dyads use the app 9% of the days in a month and can typically go
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53 for 20 days without using it, making them the least consistent users. However, whilst the
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55 people living with dementia had fewer interactions than their carer, they did enjoy using the
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57 app.
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6 *“Well, there’s nothing to actually stop me from using it. That’s number one. And I like using*
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8 *it.” (Denis)*
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14 The carer had fewer interactions than other carers in all other clusters and felt that, regardless
15 of the training received, they found they had a limited interest engaging with it.
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23 *“Well definitely for some people who are not au fait with computers ...it was a very difficult*
24 *mountain to climb...I am neither a TV fan or a radio fan or any...I have no interest in any of*
25 *them things at all...not at all.” (Nuala)*
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33 By using the photographs or memorabilia the dyad already owned, the process enabled the
34 shared memories they captured to become the focal point of the reminiscence training.
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41 *“it brought me back a good bit, like, you understand life, you know. I was a go, go guy... I*
42 *wouldn’t have had time for anything like that in my life, but when I seen this, this, sort of,*
43 *made me sit up and take notice”. (Denis)*
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52 Cluster 4: “If I wanted to use it...she was here”
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58 This reflects 29% of people living with dementia - the second largest usage categorisation.
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60 These people living with dementia had 36% fewer interactions with the app than their carers.

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3 The carers are very enthusiastic and have more interactions than other carers in all other
4 clusters. Similar to the typical users in cluster 2, these dyads interact with the app 16% of the
5 days in a month and on average use the app every 6.97 days.
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14 *“He would never, he was always kind of afraid to switch it on himself... He would always*
15 *say, ‘no I’ll wait on X, oh no I can’t’... He was afraid, he had this apprehension of ... maybe,*
16 *oh I’d mess things ... He thinks he’s going to lose the photographs.” (Helen)*
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23 Discussion

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31 The aim of this paper was to evaluate dyad engagement of the InspireD app through a novel
32 cross-comparative analysis of clusters identified from machine learning using k-means
33 clustering, derived from the event logging data generated from app usage, together with the
34 qualitative experience of the process. Event log data for 28 dyads were presented, outlining
35 the behavioural usage of each participant. From this, four clusters of behavioural usage were
36 identified based on five usage characteristics. This data was analysed with interview data for
37 16 dyads.
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48 In previous research studies, authors have identified the potential for people with dementia to
49 learn new skills and thereby maintain their quality of life at home. Three of the four clusters
50 derived from the machine learning of the event log data are in concordance with this
51 literature. These three clusters demonstrate that it is the case that people with dementia
52 together with their carers report a sense of gain and self-confidence.
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3 Four themes pertaining to the four clusters of different behavioural usage patterns were
4 identified. The first thematic categorisation was Cluster 1: *'I'm starting to get really good'*,
5 which described the enthusiastic usage of one dyad, particularly the usage patterns of the
6 person living with dementia. Electronic data revealed that the person living with dementia
7 was using the InspireD app 7.2 times more than their carers which would indicate
8 independent and self-reliant usage.
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21 The second thematic categorisation was Cluster 2: *"Able to keep me right"*, which described
22 the majority of usage patterns for people living with dementia. Event logging data revealed
23 that the people living with dementia engaged with the InspireD app 1.7 times more than their
24 carer, thus showing a level of dependence in their usage. Twelve of the interviewed carers
25 indicated they had some basic previous IT experience. It could therefore be argued that
26 previous carer IT experience was a determinant of InspireD usage. Despite this, all
27 participants found the IT training to be helpful and a significant support within their own
28 usage. This is evident in Figure 2, where electronic usage among Cluster 2 dyads is greatest
29 following the last IT training session and then begins to reduce throughout the duration of
30 home use.
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49 The research team observed that some dyads who were less enthusiastic about the
50 intervention occasionally referred to their difficulty in adapting to a caregiving role. This was
51 confirmed by the event logging data, which thematically categorised three dyads in Cluster 3-
52 also reflected in the theme: *'It was a very difficult mountain to climb'*. It is interesting to note
53 none of the Cluster 3 dyads had any previous reminiscence experience, and only two carers
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3 had previous IT experience. However, further analysis revealed Cluster 3 people living with
4 dementia found the process of reminiscence training “*made me sit up and take notice*”. This
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6 would indicate that for Cluster 3 people living with dementia engagement was not maintained
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8 throughout the intervention.
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17 The event log data indicated some carer disengagement; however, this is not fully captured in
18 the qualitative data. Of the 16 carers interviewed, only three revealed they felt they played a
19 role in poor technology adoption, as ‘*I am not accepting of it*’ (Ann, Cluster 2). When
20
21 comparing the qualitative and electronic data, only one carer was categorised in Cluster 3
22 while the other two carers (Cluster 2) and (Cluster 4) did, in fact, demonstrate considerable
23 support. This could suggest that the carers were either unduly self-critical or did not view
24 their lack of engagement to be a contributing factor for poor usage. This finding resonates
25 with O’Connor et al.’s (2016)²⁸ proposition, that negatively held carer views on technology
26 was not only a significant limitation on the development of technological programmes for
27 people living with dementia but reduced the potential to enhance their relationship through a
28 shared activity.
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46 The cross-comparative analysis suggested that those living with dementia felt nervous of the
47 technology and relied on their carer who was ‘*able to keep me right*’ in Cluster 2 and ‘*If I*
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wanted to use it she was there’ in Cluster 4, providing various levels of IT support throughout
the duration of home use. As previously proposed¹⁵, with appropriate carer support those
living with dementia were able to develop a level of independent use as demonstrated in
Cluster 1 (1 dyad) and Cluster 2 (6 dyads). The 6 dyads in Cluster 4 did require more carer

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3 engagement than the other clusters, but this could be indicative of where they are in their own
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5 dementia journey.
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9 The main limitation of this work in comparing qualitative interview data with thematic
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11 clusters derived from the event log usage of a reminiscing app is that the machine learning
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13 algorithms operate on quite a small data set, derived from the small dyad size of the primary
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15 study. Another limitation is the loss of data from one dyad, which represents the problems of
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17 utilising real world data for research purposes.
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25 Conclusions

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28 The novel cross-comparative analysis of clusters derived from machine learning of event log
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30 data, and qualitative interview data provides significant insights of actual app usage
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32 contextualised by the key elements which facilitated involvement in the intervention and
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34 supported engagement for those living with dementia. Carer engagement in the process was
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36 vital to support participants living with dementia. However, the cross-comparison of data
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38 revealed that the nature of the relationship was a significant factor for dyads less engaged
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40 with app usage (Cluster 3).
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49 The paper clearly shows the value in future work of combining objective clusters derived
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51 from machine learning of event log data, and qualitative data to understand user engagement.
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53 Both methods are complementary. This work indicates the value of adding qualitative data to
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55 enrich the description of clusters elicited by unsupervised machine learning. User event log
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57 analysis can inform us of 'what patterns exist', and qualitative interview data can inform us of
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3 'why certain patterns exist'. Together, augmenting qualitative data with usage data provides
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5 key insights into the benefits of using mixed-methods for evaluating human-computer
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7 interaction technologies and offers new insights for future research in this area.
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11 Digital phenotyping is an emerging term given to the capturing and use of user log data from
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13 health and wellbeing technologies used in apps.^{29,30,31} Significant ethical questions arise as
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15 machine learning of digital phenotype usage data become more commonplace. In particular,
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17 for vulnerable app users such as people with dementia, to what degree can self-management
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19 of their care be supported by, for example, personalized care provided by machine learning of
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21 digital phenotype usage data?
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7 Figure 1. A) shows the number of interactions with different types of media for reminiscing,
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9 B) shows the number of interactions per personal and general media, C) shows the number of
10 interactions per hour of the day and D) shows the number of interactions per day.
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17 Figure 2. a) - Usage patterns of Dyad's interacting with the InspireD app -Dyads 1-16 (G=
18 reminiscing using generic media, P= reminiscing using personal media, Admin= Carer
19 interactions)
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28 Figure 2. b) - Usage patterns of Dyad's interacting with the InspireD app -Dyads 17-30 (G=
29 reminiscing using generic media, P= reminiscing using personal media, Admin= Carer
30 interactions)
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38 Figure 3. Behavioural usage clusters depicted in two-dimensions using principal component
39 analysis.
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47 Figure 4. Each box-plot shows the distribution of each variable in each cluster. This shows
48 the extent to which each individual feature discriminates between the clusters.
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Total Number of Dyads	Completed reminiscence activity before?	Previous IT experience?	Preferred functionality	Event logging data	Function most commonly used
Total 16 Dyads (n=30),	14 PLWD-No 0 PLWD-Yes 13 Carers-No 3 Carers- Yes	12 PLWD-No 2 PLWD- Yes 4 Carers-No 12Carers- Yes	3 Dyads enjoyed music/photos 14Dyads enjoyed photos/music	1 Dyad enjoyed music/photos 15 enjoyed photos/music	2 Dyads am/early afternoon 15 Dyads late afternoon/ PM

Table 1. Participant training and usage profiles (PLWD = People living with dementia)

Cluster	Description	Cluster size (#dyads)	Number of PLWD interactions	Number of carer interactions	Number of PLWD unique day interactions	Mean day interval between interactions	Standard deviation of interval between interactions
1	A PLWD who demonstrates independent and consistent use of the app	1 (4%)	572.00	79.00	46.00	2.00	2.28
2	A PLWD who is reliant on his/her carers for support with the app and exhibits unpredictable usage patterns	12 (43%)	134.83	78.42	12.58	6.61	8.05
3	A PLWD who is highly reliant on his/her carers for engagement with the app. This user has little interaction with extremely unpredictable and inconsistent usage patterns	7 (25%)	38.28	51.14	5.71	19.66	14.71
4	Infrequent user	8 (29%)	127.00	200.25	13.50	6.97	8.99

Table 2. A description of the four clusters using statistics from the centroids of each cluster, hence describing an average dyad in that cluster (PLWD = People living with dementia)

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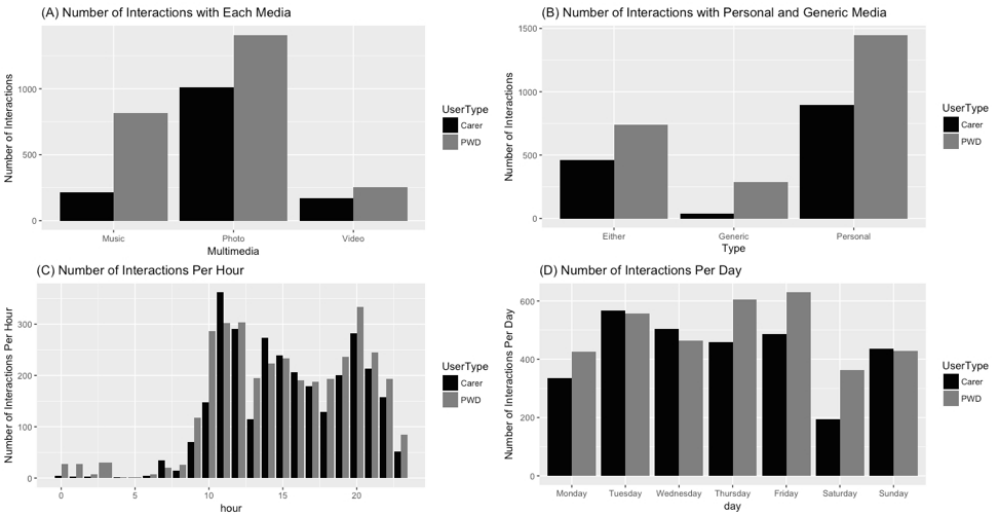


Figure 1. A) shows the number of interactions with different types of media for reminiscing, B) shows the number of interactions per personal and general media, C) shows the number of interactions per hour of the day and D) shows the number of interactions per day.

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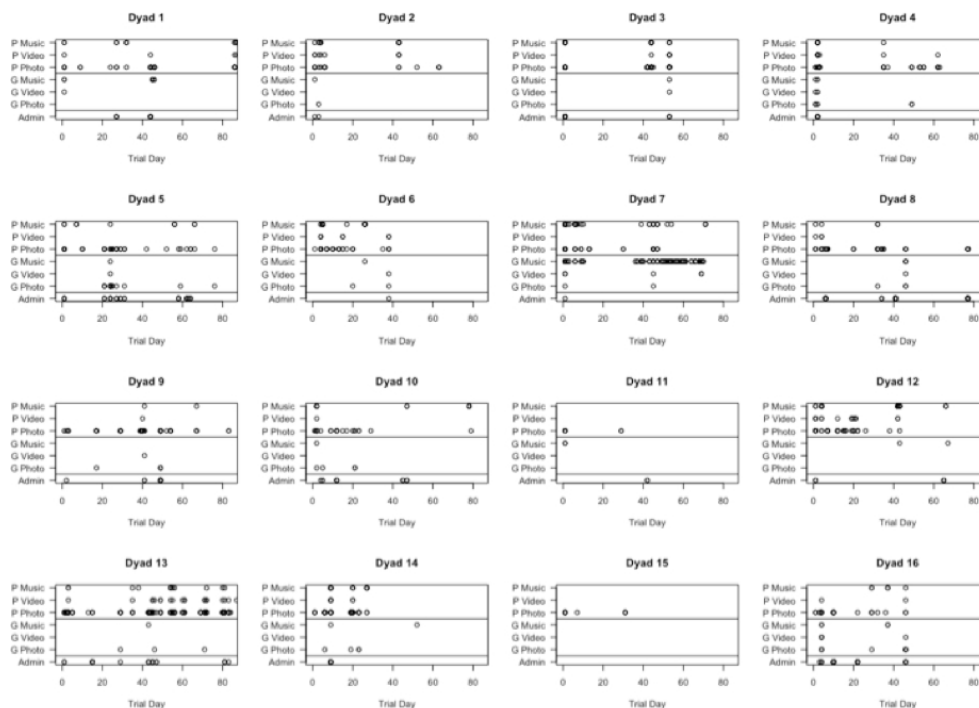


Figure 2. a) - Usage patterns of Dyad's interacting with the InspiredD app -Dyads 1-16 (G= reminiscing using generic media, P= reminiscing using personal media, Admin= Carer interactions)

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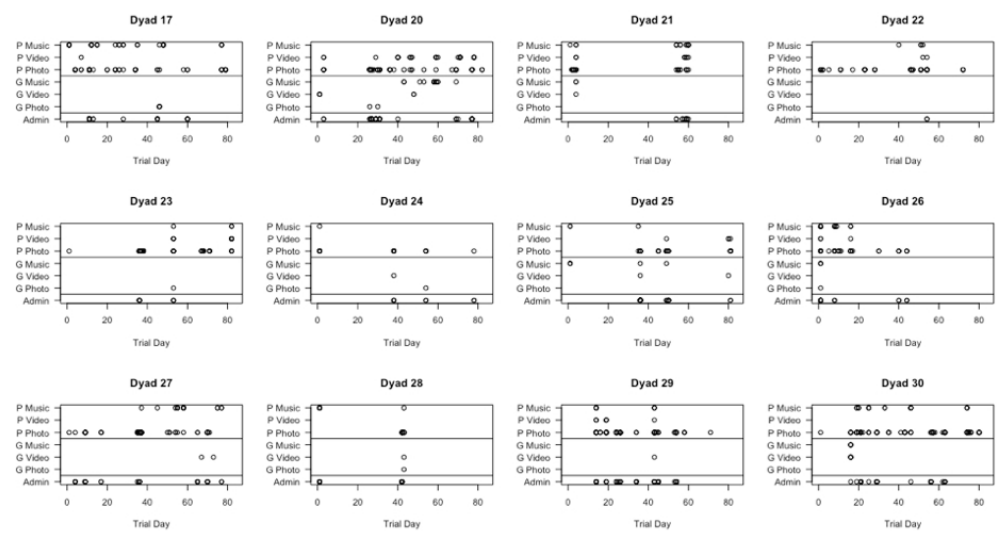


Figure 2. b) - Usage patterns of Dyad's interacting with the InspiredD app -Dyads 17-30 (G= reminiscing using generic media, P= reminiscing using personal media, Admin= Carer interactions)

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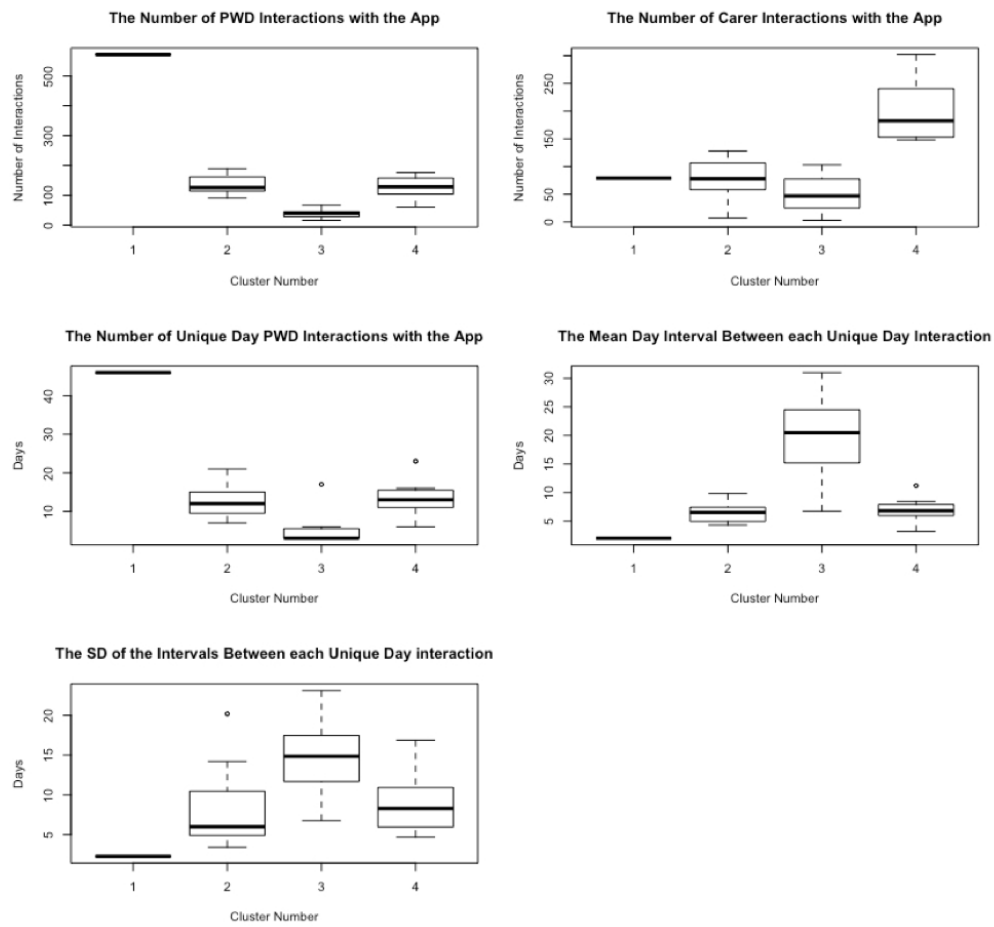


Figure 4. Each box-plot shows the distribution of each variable in each cluster. This shows the extent to which each individual feature discriminates between the clusters.

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