Designing Pervasive Display Systems for Residential Care Settings

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Abstract—As our population ages, care homes play an essential role in providing long-term support for older adults, prompting many to explore technology-based interventions to help meet these growing care needs. While much of the technology in this sector has focused on health monitoring and operational efficiency, there is increasing interest in technologies that support residents' emotional, cognitive, and social wellbeing. The ubiquity of pervasive displays makes them promising candidates for a wide range of applications in care environments. However, despite widespread use in other sectors, digital signage systems have seen relatively little exploration in residential care settings. Drawing on insights gained from a long-term collaboration with a local care home and two decades of experience in managing the world's largest research digital signage deployment, this paper identifies key design considerations for signage systems in residential care settings.

The world's population is ageing and the share of individuals aged 60 and over is projected to increase from 12.66% in 2020 to 21.43% by 2050 [1]. As our population ages, the demand for high-quality, cost-effective care environments and the corresponding pressure on the sector has grown. In response, the UK care home sector has seen a shift from smaller, traditional care homes toward larger, purpose-built facilities that benefit from economies of scale. In parallel, emerging technological interventions (e.g. wearable devices for health monitoring and medication reminders, motion detectors for fall detection, and pain assessment apps) are being adopted with the aim of supporting new efficiencies in the way day-to-day care is provisioned [2].

While many of the existing technological interventions in care settings have so far focused on health monitoring and operational efficiency, there is increasing interest in technologies that support a person-centred approach to care, supporting residents' mental, emotional, and social wellbeing [3]. The growing ubiquity of pervasive displays makes them promising candidates for use in care settings. While often associated with advertising and generic information delivery, research has shown that pervasive signage can also support interventions such as spontaneous social interactions [4], reminiscence [5], and sensory stimulation in dementia care [6]. However, despite widespread adoption in other sectors, the use of digital signage in residential care settings remains relatively unexplored. Building on over a decade of experience deploying displays in care settings, this paper describes the key considerations for future pervasive display systems designed to support the growing percentage of the world's population that lives in residential care settings.

RELATED WORK

Digital signage systems have become a ubiquitous element of contemporary public spaces, seamlessly integrating into the fabric of everyday life. This ranges from urban media facades and LED billboards to arena displays, retail kiosks, and transportation hub installations. Although advertising remains one of the most prevalent applications, digital displays are also increasingly used as communication media in domains such as education, public affairs, art, and healthcare, serving informational and interactive functions [7]

HCI research has long emphasised the potential of digital signage beyond the presentation of generic information, exploring pervasive displays as tools not only for communication, but also for applications such as persuasion [8] and the promotion of well-being. However, most real-world deployments fall short of the interaction-rich, context-sensitive, socially-aware systems envisioned in academic research [9]. For example, digital billboards are often implemented as static replacements for analogue posters, failing to take advantage of contextual or participatory design features. In domestic settings, research has explored how

displays can blend into everyday routines to enhance entertainment [10]. In addition, prior work has examined design principles for home-based displays [11], privacy considerations in shared living spaces [12], and how digital displays can support family connection through always-on audio-video links [13]. Commercially available digital photo frames have also been studied as cost-effective tools to improve the well-being of older adults and maintain ties with remote family members [14].

In healthcare, pervasive displays face a different set of design challenges. Touch-based interaction is often avoided due to hygiene concerns, prompting the exploration of non-contact modalities such as gaze, foot input, and gesture-based control. Hospital environments also introduce situational nuances. For example, displays are commonly placed in waiting areas, where they serve both as standard signage tools and calming distractions for patients and visitors, helping to reduce stress and enhance the perceived quality of care by improving the waiting experience [15]. In patient rooms, displays have been proposed to support access to electronic medical records and improve transparency for patients who often feel underinformed [16]. Meanwhile, systems like AwareMedia demonstrate how staff-facing displays can facilitate coordination and awareness in clinical settings through real-time updates, communication tools, and contextual information sharing [17].

However, despite extensive research on digital signage and pervasive displays in public, educational, healthcare, and home contexts, few projects have focused on how such technologies could support the specific needs of care home environments (with [6], [4], and [5] being notable exceptions).

To the best of our knowledge, no other work has attempted to offer design guidelines for a digital signage system specifically designed for residential care settings. Even the aforementioned papers have typically reported on single applications of digital signage in care homes, rather than focusing on concrete design requirements for a comprehensive signage system intended for care environments.

METHODOLOGY

To understand the requirements of a digital signage system designed for care home environments, we need to understand how care homes differ from other, conventional digital signage deployment locations.

We, first and foremost, draw on insights gained through over ten years of close collaboration with a local family-owned care home with a capacity for up to 25 residents. This collaboration has resulted in two long-term deployments that use pervasive digital signage to support reminiscence and sensory stimulation in dementia care [6], [5]. Both deployments offered valuable insights into the practical challenges and opportunities of introducing digital technologies into care home settings, expanding our understanding of the domain.

While we acknowledge that findings based on a single site may have limited generalisability, the richness of insights made possible by this longstanding relationship provided a valuable, detailed understanding that would have been difficult to obtain otherwise. To strengthen the broader relevance of our observations, we also extended our work through collaboration with a second care home, allowing us to identify patterns and needs beyond a single deployment.

Our care home experience is supplemented by 20 years worth of experience in running a large-scale, bespoke digital signage system. Established at Lancaster University in 2005, *e-Campus* is the world's largest digital signage research testbed, comprising over 125 public displays distributed across the campus, including departmental buildings, lecture theatres, and communal areas [18]. Managing this long-term, real-world deployment has provided us with deep, practical knowledge of digital signage technologies and usage patterns.

DESIGN CONSIDERATIONS FOR PERVASIVE DISPLAYS IN CARE SETTINGS

Digital signage systems are complex entities consisting of many interdependent components that enable the delivery and presentation of content to users. To help structure our analysis of the design considerations for care settings, we use the architectural framework presented in [18] that identifies four distinct segments of digital signage software, each addressing a specific set of concerns: content creation; scheduling and management; display and interaction; and, mobile support (see figure 1). We supplement this consideration of software issues with an initial analysis of hardware and networking considerations.

Hardware and Network Infrastructure

At the hardware level, digital signage systems include a *Display Device* (e.g., LCD panels, large-scale video walls, e-paper displays) and a *Media Player* that runs the software necessary to retrieve and present content. Media players can range from lightweight single-board
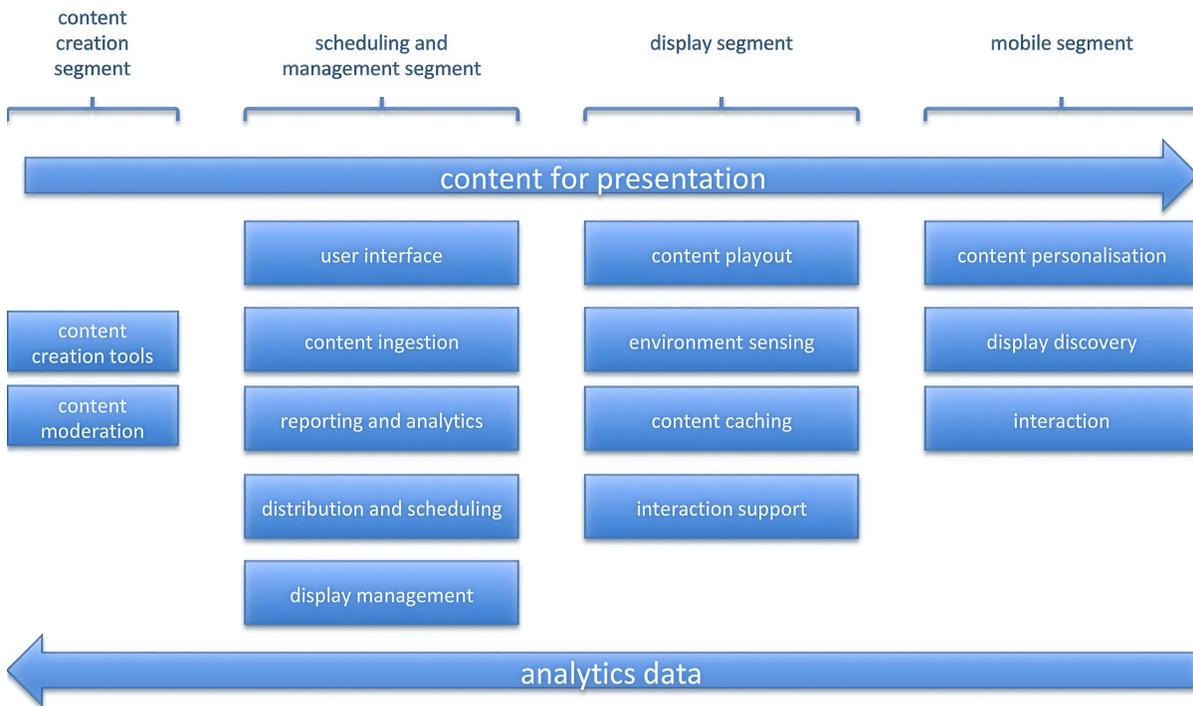
FIGURE 1. Digital signage architecture framework as presented in [18]

computers (such as Raspberry Pis) to robust industrial-grade computers. Some display systems now incorporate the media player directly into the screen through System-on-Chip (SoC) technology, reducing hardware complexity. In larger deployments, *Server Hardware* (e.g. designated desktop computers or cloud services) may be employed to host content centrally and manage multiple displays across a network. These hardware elements are connected via a *network layer*, typically using Ethernet or Wi-Fi, to enable real-time content updates and remote management [19], [20], [18].

Observations Hardware requirements for digital signage in public environments greatly differ from those of domestic and care home settings. Public signage typically uses large-scale LCD or LED screens positioned to maximise visibility, often mounted at raised heights or in prominent, open areas. These installations tend to prioritise robustness, with durability and exposure resistance taking precedence over aesthetic considerations. Additionally, setup and maintenance in public spaces can be logistically complex, often requiring working at height and special access permissions. As such, cost of individual hardware elements is often small in comparison to installation costs, particularly in commercial or civic infrastructure projects.

In contrast, installations in domestic and care home environments must take place in very different, smaller-scale surroundings. Screens are often expected to blend in rather than stand out; not all displays need to be visible to everyone at all times, and their placement prioritises discretion, comfort, and aesthetic harmony. Safety and unobtrusiveness are critical, especially in shared residential spaces. Care home environments also frequently already have large displays in the form of televisions that are used extensively by residents. Deployments are usually cost-sensitive and often constrained by limited technological infrastructure and support. Therefore, consistent internet connectivity, for example, cannot always be guaranteed. However, setting up displays in care homes may require nothing more than a stepladder, making deployments considerably easier.

Implications Digital signage deployments in care homes need to prioritise low-cost hardware solutions that align with the constraints of these environments. Small-scale, unobtrusive devices such as consumer-grade TVs, tablets, or wall-mounted displays are well-suited for care settings and can often be repurposed from existing equipment. Repurposing existing hardware also has the additional benefit of being less

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obtrusive, as the infrastructure will already be familiar to residents. When combined with affordable external media players (e.g., Raspberry Pi or Intel NUC), these setups can meet performance requirements while remaining cost-effective. Although commercial System-on-Chip (SoC) displays offer streamlined installation, their cost-benefit balance can vary, particularly when they are bundled with proprietary software subscriptions that may not align with care home budgets.

Connectivity presents an additional challenge. Although wired Ethernet connections are typically preferred for their stability, care homes, especially those in converted domestic properties, may lack a structured cabling infrastructure. Ethernet ports may not be available in all rooms, and temporary cabling introduces safety risks, particularly for residents with limited mobility. As such, networking solutions need to strike a balance between reliability, affordability, and the unique spatial and safety considerations of care home environments. In practice, this means relying primarily on Wi-Fi, possibly extended through mesh networks, to avoid invasive installations or hazardous cabling in rooms not originally designed for digital infrastructure.

While security is of critical importance in public signage systems to avoid unauthorised access to show content that may be harmful or cause reputational damage, this is much less of an issue in a typical residential care setting. Standard techniques used to secure the facility's network infrastructure are likely to be sufficient for the digital signage system.

Content Creation Segment

Content is a central component of any digital signage system and can be created for a wide range of purposes including entertainment, marketing, and information dissemination. It typically include the use of both static and dynamic media formats such as text, images, video, animations, data feeds (e.g., news tickers), and audio. Signage content is increasingly tailored to specific audiences based on context or user characteristics [18], [19].

Content creation is commonly done using standard commercial or open-source tools, such as Adobe Creative Suite[1] or Canva[2], which provide flexible design capabilities. However, many signage systems also include built-in content creation tools designed to streamline the process for non-professional users,

enabling quick and easy production of layouts and media assets directly within the system interface.

Observation   Content shown on pervasive displays in public places often represents brands or businesses and therefore must follow rigorous brand guidelines. As a result, content in digital signage systems is usually created by professionals, such as internal marketing or communication departments, or external specialists, who are experienced in producing high-quality multimedia content. In contrast, content in domestic settings is often more personal, emotionally resonant, and informal, hence not requiring the same design considerations. Moreover, users typically lack design training or the access to professional tools to create content.

Content for care homes represent a unique blend of the two environments. On the one hand, there may be official content, such as announcements, that represents the care home itself. Although this content might be expected to follow certain design standards or branding conventions, it is typically created by care home staff who do not have formal training in graphic design and may lack familiarity with advanced digital tools. Moreover, creating content for a digital signage system is just one of many responsibilities of care staff, so the process must be quick and effortless to fit within their already demanding daily routines. On the other hand, care homes may also display personal content, such as photos, messages, or updates from residents' family members; material that is often emotionally expressive and does not follow institutional branding.

Implication   Since neither care staff nor family members are likely to be familiar with professional digital signage tools, the content management system needs to support the creation of visually appropriate content assets with minimal effort. While many signage platforms nowadays include tools to simplify content creation for non-expert users, they can still present a steep learning curve. Confusion around the system capabilities and limited technical knowledge can lead to underutilisation of its features [19], highlighting the importance of a user experience that accommodates not just diverse levels of digital literacy but also the varying levels of time users might be willing to commit to the task.

Furthermore, to avoid placing additional strain on carers' and family members' daily routines, content contribution should be made as straightforward as possible. Supporting tools that reduce technical friction, such as mobile-based uploads directly from a user's photo library, can help ensure that content upload re-

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[1] https://www.adobe.com/home
[2] https://www.canva.com/en_gb/

mains both accessible and sustainable across different user groups. In many cases speed and ease of use is more important than the quality of the resulting presentation (mirroring the benefits and usage models of traditional paper notice boards for example).

Scheduling and Management Segment

This segment is responsible for content ingestion, scheduling, and remote display management (e.g., analytics, monitoring, and diagnostics). Scheduling, in particular, is an essential and complex task, as knowing when certain content items should best be presented depends on the preferences of the display owner, the preferences of the viewer(s) present in front of the display, the available content, and the context in which the display is situated. To address these potentially conflicting requirements, different approaches, ranging from round-robin and playlist-based to dynamic, context-aware, and interactive scheduling, have been developed. [18], [20].

Observation Ingestion of content in care home settings must cater to a diverse set of contributors (care home staff and residents' family members). However, this more diverse range of contributors introduces additional complexities around access rights and privacy. While staff are expected to have control over content scheduling decisions to decide when and where content items should be displayed, family members should be able to provide content assets, but only for the resident to which they are related.

Content scheduling itself is not a straightforward process. Firstly, the duration content items are shown for is pivotal to the success of any signage system. While advertising-based systems typically optimise duration to maximise content exposure and impact, optimising duration may be even more important in care home settings where signage supports interventions such as reminiscence and sensory stimulation. For example, reminiscence materials may benefit from prolonged display times to allow residents to process and engage with the material meaningfully. However, the ideal duration can vary not only by content type but also by individual, as residents have varying cognitive abilities and attention spans. Furthermore, informational content aimed at staff or family members may benefit from shorter timings that align with their brief interactions during visits or routine tasks.

Secondly, scheduling decisions are further shaped by the spatial and privacy dynamics unique to care homes. Although privacy is rarely a primary concern in traditional signage deployments where content is typically generic and not directed at specific individuals, digital signage in care homes often displays highly individualised content, private to the viewer. When talking about the levels of privacy that are expected in any given space we often differentiate between Public (e.g. hospital foyers or reception areas), Semi-Public (e.g. shared dining rooms or main corridors), Semi-Private (e.g. small lounges or private gardens) and Private (e.g. individual bedrooms) areas. Usually, all of these spatial categories can be found within care homes due to the way they blend domestic and institutional settings. However, one might even argue that care homes introduce a fifth, unique privacy category: "care". In care homes, even traditionally private spaces, such as residents' bedrooms, can not be considered entirely private as they are accessed by multiple staff and visitors throughout the day. As such, privacy expectations vary significantly across different areas of just a single home (with required levels of privacy possibly changing from room to room).

Finally in the context of this segment, we note that care settings have analytics requirements that vary significantly to those typically seem in digital signage. Analytics are a core component of traditional digital signage systems, closely tied to content scheduling strategies and value models. Tracked metrics such as dwell time and viewer demographics are used to optimise when and how frequently specific content is shown, enhancing audience engagement and supporting revenue generation through targeted advertising. Advertising-based models often depend on such data-driven strategies, leasing screen space to third parties or partnering with advertisers that subsidise system costs in exchange for access to target audiences [19], [18].

In contrast, digital signage in care homes is not driven by monetisation and is unlikely to rely on advertising-based business models. Instead, its value proposition lies in supporting residents' well-being, enhancing communication and operational efficiency for staff, and providing relevant information to visitors. As such, deployment decisions are guided by care goals rather than financial return. Scheduling in these environments typically aligns with daily routines, such as mealtimes, visiting hours, or residents' activity schedules.

Implication As family members should not have access to assets associated with other residents, the content management system will need to differentiate between individuals who provide assets and screen managers who are in charge of deciding where content should be shown. This requires a means of separating

assets into groups to which access rights can be assigned so that privacy can be ensured.

Additionally, because uploaded assets may contain personal data (e.g. photographs or personal messages), the content management system must also support compliance with data-protection requirements. This includes securing access, recording who contributed each asset, capturing the contributor's consent for its use, and maintaining basic retention information.

Moreover, although a baseline of trust can be presumed, with family members and care staff expected to upload appropriate material, content moderation remains essential. Content does not need to be intentionally inappropriate to cause harm; even well-meaning material may be unsuitable for a particular resident or context. A practical approach is to assign moderation responsibility to screen managers, since they already decide which assets are scheduled on which displays. This requires screen managers to have access to all content groups and the authority to remove material that is inappropriate or potentially unsafe. Where multiple screen managers exist and providing all of them with full access is undesirable, appointing a dedicated content moderator may be more appropriate.

To accommodate the diversity of content types and user needs observed in our care homes, the system will need to support flexible content display durations. Where feasible, these durations ought to be tailored to individual viewer profiles, reflecting differences in cognitive ability and attention span. In addition, the signage system should offer simple and accessible controls that allow users or facilitators to manually adjust pacing. For example, "continue" or "skip" options during reminiscence sessions could enable more personalised and responsive interactions for each resident.

Digital signage solutions designed for care homes have to be sensitive to the privacy contexts of its deployment spaces. This context awareness, in turn, has to feature into content scheduling decisions so that, for instance, displays in public or semi-public areas focus on general information or communal updates, whereas those in semi-private or private areas support more intimate or emotionally resonant use cases. Beyond spatial context, the physical characteristics of the display device itself (such as screen size and visibility) also ought to factor into these decisions. For example, in a resident's bedroom, a large wall-mounted TV might display semi-private content, appropriate for both the resident and those who frequently enter the space. In contrast, a smaller, more discreet device (e.g. a tablet) could be reserved for highly personal content, as it draws less attention and offers more visual privacy.

In order to ensure content relevance and system usability by non-technical staff, the use of rule-based or even manual scheduling may be preferable to complex analytics-driven scheduling strategies. That said, lightweight analytics can still offer meaningful insights, as they can help determine which content items best engage residents (e.g. using eye tracking or care logs to track the time spent viewing reminiscence materials), or to determine whether important notices have reached their intended audience. In this context, engagement metrics could feed back into scheduling decisions to enhance the personal relevance and effectiveness of the content shown.

Finally, we note that the bandwidth limitations often inherent in the technological infrastructures of care homes also impact the design of the system. Videos, for example, will take longer to download onto the player system than they would in a high bandwidth deployment environment. As such, the system needs to manage large files conservatively and, for example, support staggered file downloads. Furthermore, due to the likelihood of intermittent network connectivity, media players will probably need to locally cache content so that playback can continue uninterrupted even during temporary network outages.

Display and Mobile Segments

Player software is installed on devices that render content on connected displays. This can be a simple web browser displaying a local or remote file or a more complex application capable of handling multiple media types and rendering interactive, web-based experiences. As digital signage has evolved, so too has the emphasis on interactivity. Although not a separate architectural component, interaction is increasingly viewed as a characteristic that permeates hardware, software, and content design. Interactive signage can use a range of modalities, including touch, gesture, gaze, speech, RFID, and Bluetooth. The mobile support segment covers software that viewers run on mobile devices (typically smart phones) to facilitate interaction with digital signage displays. Examples include QR-code readers for clipping content from displays and software used for Bluetooth-beacon-based proximity detection and display personalisation as viewers walk past displays [18], [20].

Observation Digital signage is often perceived as a passive medium, primarily used to broadcast information or advertisements without requiring any user input. However, in recent years, signage systems have increasingly adopted interactive features. For example,

systems in public spaces now often incorporate sensors or cameras to detect demographic characteristics of passers-by and dynamically tailor content based on this data. On the other hand, information or self-service kiosks use active interaction modalities such as touch input or mobile integration via QR codes to enable users to navigate content, make selections, or complete transactions directly on the system. However, while some signage systems in public environments incorporate accessibility features, they are rarely designed to support the full spectrum of physical, cognitive, and contextual needs found in more specialised settings.

In care homes, interaction with digital signage systems must account for the distinct characteristics and capabilities of the three primary audience groups: residents, family members, and care home staff.

Care home residents are typically older adults who often face a range of age-related health issues, including impaired vision, reduced motor control, cognitive decline (such as dementia), and severe mobility problems. These factors can significantly restrict their ability to engage with interactive signage, particularly if it requires precise input, sustained attention, or physical proximity to the screen.

In contrast, family members, often adult children in their 50s or 60s, tend to have varying levels of digital proficiency. They might typically engage with digital signage inside a care home only briefly during visits. This limited and situational exposure means they are unlikely to develop sustained familiarity with a system's interface or features.

Care home staff form the third key user group, comprising both management and frontline carers. Management staff are generally more technologically proficient, while carers, who are primarily responsible for day-to-day hands-on support, may have limited experience with complex digital systems. Moreover, findings from [5] suggest that carers can be hesitant or slow to adopt new technologies, particularly when already managing high workloads. However, carers' daily exposure to the signage system allows for gradual familiarity with the system's capabilities, provided the system offers tangible support in their routines.

Implication To accommodate the diverse cognitive and physical abilities observed in our care homes, interaction with the signage system must be intuitive, accessible, and require minimal training. Techniques commonly used in public signage systems, such as touchscreen navigation, QR code scanning, or mobile integration, may not translate effectively across all user groups. While such methods might support staff

workflows or management use, they are likely to be inaccessible to many residents, particularly those with cognitive impairments or limited motor control.

As such, rather than relying on a one-size-fits-all interaction model, systems need to support a range of interaction modalities tailored to each group's needs. For residents, passive or low-effort interactions, such as automated content changes based on scheduled routines, proximity-based triggers, or ambient sensors, may be more appropriate than direct touch interaction. For staff and visiting family members, optional active interactions could enhance engagement, provided these features are simple to use, require minimal onboarding, and do not disrupt existing care routines.

CONCLUSIONS

Digital signage systems designed for residential care home environments need to address a distinct set of challenges rarely found in purely public or domestic settings. These include infrastructure limitations, nuanced privacy requirements, a target audience with diverse requirements, ranging from residents with cognitive or physical impairments to care staff and visiting family members with varying levels of digital literacy and time constraints. As such, rather than adopting strategies from corporate or retail signage that focus on mass communication, systems in residential care need to be tailored to the highly specific needs of these environments.

Based on long-term collaborations with local care homes and close to two decades worth of experience running a large-scale, bespoke digital signage system, we have outlined practical design considerations for the distinct elements of signage systems: hardware and network infrastructure; content creation; scheduling and management; and display and mobile. Table 1 summarises the resulting design considerations.

Our work with one class of care homes suggests that designing pervasive signage for residential care homes requires more than technological adaptation; it requires rethinking the default assumptions around who the system is for, how it will be used, and what the emotional and spatial contexts are in which it operates. Further research is needed to determine the extent to which these findings generalise to other types of care facilities.

TABLE 1. Summary of Design Considerations for a Pervasive Digital Signage System for Care Environments

Category	Design Recommendation
Hardware and Network Infrastructure	Select existing and new hardware that is sympathetic to the care setting, recognising the distinction between residential and organisational settings. Adopt a wireless-first network strategy due to the challenges of installing network infrastructure in residential properties
Content Creation Segment	Content creation tools for standard signage content need to support non-expert occasional users to accommodate care homes with limited technical staff. Support should be provided for simple workflows that enable families and carers to upload content for display, potentially following appropriate editing.
Schedudling and Management Segment	Support fine-grained content selection/scheduling and access control to enable display of content to be tailored to individual residents (rather than the mass communication typical in signage systems). Provide scheduling support for viewers that spend significant time watching the display, enabling the signage system to provide functionality akin to personalised media streaming. Support scheduling to both semi-public and private spaces to enable support for content display in individual residents' rooms. Explore the opportunity to create scheduling systems that respond to individual care needs.
Display and Mobile Segments	Interaction techniques should accommodate the diverse range of users' cognitive and physical abilities, recognising that these abilities may change significantly over short periods of time.

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