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Furthering the Development of Virtual Agents and Communication Robot Devices through the Consideration of the Temporal Home

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Abstract: This paper extends current research on Human–Robot Interaction (HRI) within Human–Computer Interaction (HCI), focusing on how future virtual agents and communication robots can support the temporal structures and routines within the home. We recruited representatives from 15 households with varied compositions, ranging from single inhabitants to full nest families. Drawing upon P.G. Wodehouse's The Inimitable Jeeves as an inspiration, the methodology sought to imitate the relationship between a recruitment agency worker (researcher) and an employer (participant) seeking to hire a personal assistant (e.g., a virtual agent or communication robot device) for their home. A 'household audit' comprising a guided household tour and an architectural survey was conducted to ascertain the nuanced spatiotemporal routines within the home. The study analysed the responses of participants using the Labovian narrative schema, a traditional method in linguistics research. The findings were then examined through the lens of Reddy et al.'s temporal features of work to understand how domestic work unfolds within the home from a temporal perspective. We argue that the temporal concepts discussed by Reddy et al. provided valuable insights into the temporal dynamics of everyday activities and could inform the design of virtual agents and communication robotic devices to fulfil their roles as domesticated 'personal assistants'.

1. Introduction

Human–Computer Interaction (HCI) is currently witnessing the advancement of Human–Robot Interaction (HRI) [1,2]. The effective design of Human–Robotic systems, including virtual agents and communication robots, requires a detailed understanding of how they operate within a specified context. For the purpose of brevity, these technologies will be collectively referred to as conversational agents (CAs), denoting their primary mode of interaction, and their agentive nature.

One domain that has become a significant setting for HCI research in recent years is the home [3], with studies focusing on rhythmical and ritualistic behaviours prevailing as an entry point for design intervention [4–6]. The home is widely recognised as a setting where intimate, social, and mundane interactions intertwine to establish domestic routine behaviours [7–9]. The success of technology introduced into the home depends on the extent to which that technology is integrated into the activities of the home. Rather than just 'doing jobs' in the home, Cas can empower householders and create new, more efficient, and life-enhancing opportunities and routines—in the same way a trusted personal assistant can free up capacity for an individual to lead a more productive and fulfilling life [10].

To design value-adding CAs, understanding behaviours in the home is crucial to acceptance and appropriation [9,11]. Achieving this requires specific methodologies to elicit rich data insights from householders [7]. This would be analogous to the aforementioned

'personal assistant' really understanding what was important within a particular household, what their constraints were, and how to support activities to create a happier and more harmonious home.

An increasingly prevalent and dynamic development in the realm of HRI is the proliferation of "intelligent" CAs such as Amazon's Alexa and Google's Google Assistant. These CAs have gained widespread acceptance in the home environment [12–14]. VAs have garnered significant attention due to their novel user-friendly "just talk" interface [6]. However, the acceptance of CAs as domestic products has traditionally been questioned, with concluding thoughts that these types of agentive devices are inadequate to adapt to the complexities and nuance of home life [15]. Later studies have since reaffirmed this position and have continued to highlight their persistent concerns with the lack of contextual awareness current CAs exhibit when operating within domestic settings. Specifically, these studies have emphasised the limitations of CAs to seamlessly integrate with the diverse behaviours and activities that occur within the home environment [16,17].

Research on the socio-technical implications of living with a CA [14,16,18] has significantly increased our understanding of both user expectations and the technological limitations of these devices. Such research investigations focus on user privacy concerns [19–21], user personification traits [12,18,22,23], and VUI experiences [16,24]. However, research seeking to directly inform the design of future CAs and robots through understanding the temporality of householders' routines has yet to be published, despite its central role in governing human behaviour [25].

To improve the abilities of CAs within the home and enable them to perform more intricate tasks, it is crucial to have a thorough comprehension of how the domestic setting is structured over time. This understanding will aid in creating sophisticated algorithms that can effectively handle and automate various household tasks. The goal of this paper is to build upon the notion of 'temporal trajectories' [26] to understand how acts of domestic work, i.e., everyday household chores, are temporally structured, managed, and unfold within the home. Our study conceptualises the home as a dynamic environment that is ongoingly made and re-made as people, things, and technologies interact together spatially and temporally to create the experience of home [7]. A screening questionnaire was advertised to select a diverse group of fifteen participants based in the UK for a study. The chosen participants represent a mix of socio-demographics, including age, gender, living status, and occupation. The screening criteria enabled the researchers to achieve a mixed variation sample.

To gain a comprehensive understanding of the potential role of CAs with regard to domestic routines, which are not constricted by existing householder expectations of their capabilities, we employed a roleplay methodology [27]. The roleplay method framed the participant employing a personal assistant for the home. The primary objective of this methodology was to employ the technique of roleplay as a creative tool that facilitated the participants to articulate their experiences of home through different modes of comprehension, recollection, and expression [21], as if they were narrating their routine weekday chores to a prospective personal assistant. Drawing upon Reddy et al. [26], we discuss how domestic work at both a collective and individual level is managed through the temporal conditions of the domestic setting. Finally, we consider the theoretical implications of this research and the practical implications for the social development of current CAs.

2. Methodological Framing

2.1. Roleplay

Our study was designed with roleplay at its core to extend the research beyond the participants' current knowledge of what a domestic CA can accomplish but also to orientate the research around the notion of CAs as a personal assistant, employed by the participant to help with acts of domestic work, e.g., time management and recreational activities, such as baking. Thus, from the outset, the study conceptually framed CAs as agentive systems that 'do things directly for the users' [10]. *Roleplay* is an established

research method across multiple subject fields, and although disciplines often adopt slightly different meanings for the term [28], the core of the method is the adoption of an "*as if or make-believe quality*" through the enactment of a fictitious event with participants taking on the roles of fictitious characters [29]. In HCI, roleplay has emerged as a practical method for generating rich empathic responses [29,30] and encouraging participant engagement [31]. Gupat et al. [27] propose the following considerations so that the HCI researcher can become more adept when creating a roleplay experience: (1) inform the participants of their role and expectations prior to undertaking the research activity; (2) encourage the participant to embrace their '*mask and the mirror*', bridging the gap between character and reality; and (3) consider how to ease the participant into the roleplaying experience.

To achieve this, we employed generative research methods analogous to an audit or 'discovery process' that a recruitment agency worker might undertake prior to placing a personal assistant within a household [32]. Participants played the role of a *household employer*, which portrays the role of an individual seeking to hire a personal assistant for their home. The researcher played the role of a *recruitment agency worker*, which created a plausible context for an in-depth discussion with the participants about their domestic routine behaviours. The present research study did not involve the use of a CA, which functions as a 'personal assistant'; instead, the study aimed to gather valuable insights into home management through the metaphor of the home assistant—to then provide insights relevant to the development of CAs.

2.2. Temporal Lens

The relationship between work and time has long been established within the field of computer-supported cooperative work (CSCW) [33,34], with many studies exploring the temporalities of collaborative work, particularly within a medical setting [26,35–37]. According to the philosophic definition, temporality can be described as how the passing of time shapes the being of things [38]. Time for Heidegger [38] can only be experienced from a finite vantage, making time a scarce and valued measure. Temporality can be thought of as the study of the passing of time, with the present day being shaped by historical events and actions.

The individual perception of temporal phenomena, as well as the structuring of personal schedules and prioritisation of tasks, are intricately connected to one's cultural and educational background [39]. Chronemics, which refers to the role of time in communication, is an important aspect of non-verbal communication in different cultures. In this regard, there are two prominent time structures that can be used to classify communication styles, monochronic and polychronic. Monochronic refers to performing one task at a time; this perception of time often reflects personal traits such as being organised and focused. This outlook is common in Western civilisation [39]. It is important to note that our sample, based in the UK, may not solely view time as linear, especially with the current demands of modern-day life which require a polychronic approach (doing many things at once) [40]. However, it is more likely that, based on their cultural backgrounds, they prefer organising tasks independently due to their upbringing and the way time is structured in homes, schools, and workplaces. The treatment of time varies across cultures, manifesting in differences in the tempo at which daily life is lived [41]. As documented by Levin [41], certain regions with warmer climates tend to embrace a slower pace of life, savouring their surroundings without the pressure of time constraints. Conversely, densely populated metropolitan areas often operate at a faster pace, with time being a scarce commodity. Additionally, there appears to be an inverse correlation between a country's level of development and the amount of leisure time its inhabitants have each day. However, it is worth noting that a fundamental understanding and awareness of time is found in all known cultures and among all peoples.

Most notably, Reddy et al. [26] draw on this field and describe the temporal organisation of work in relation to three temporal features—temporal trajectories, temporal rhythms, and temporal horizons. The structured timeline of activities, events, and occurrences makes

up the *temporal trajectory* of work and is focused on an individual. *Temporal rhythms* shift the focus from the individual to the patterns of work that collaborations with others create, and Reddy et al. highlight how people use their knowledge of these re-occurring patterns to understand the temporal structure of work and to anticipate when the information will be needed and when it will be available. *Temporal horizons* represent the 'broad temporal structure to a person's day'. They are person-based, not activity-based, reflecting the individual's understanding of how activities are temporally organised.

With a view to better understanding how CAs and householders could, in the future, share domestic work, we draw on Reddy et al.'s temporal organisation of work to understand how people currently orientate themselves and manage domestic work within the home. The temporality of the home has been previously studied, with calendrical systems being a favoured entry point for both HCI and CSCW researchers [42–45]. Studies in the home have also reviewed domestic technology, with Irani et al. [4] discussing the temporal ordering and management of television viewing. Similarly, Odem et al. [46] implemented 'Olly', a purpose-built domestic music player, to investigate how 'slow technology' could encourage personal reflection. By contrast, Erickson et al. [47] highlight the importance of temporality within the role of a corporate personal assistant, with the expectations of an employed personal assistant being able to anticipate the future actions of their employer as well as to proactively prioritise their employer's schedule based on known patterns of work. For a CAs to develop within the domestic setting, we argue that a more conclusive understanding of a household's temporal trajectories is required to further the agentive qualities of a personal assistant within the home.

2.3. Domestic Work

Historically, research undertaken within the domestic setting, from a HCI standpoint, has been an underrepresented site for investigation, with applied research mainly confined to the workplace, e.g., office, laboratory, and hospital environments [48–51]. However, as information technologies have developed for domestic devices, e.g., personal computers, television, and radio, so has HCI, with research interests being broadened to the home as a site for research investigation concerning interactions and experiences [51].

According to Verkasalo [52], we spend more time in our homes, sleeping, eating, and entertaining, than in any other location, which increased exponentially during the recent national restrictions of COVID-19. Therefore, the home offers considerable insight into human behaviours when undertaking everyday tasks, making it a significant site for comprehending real-life experiences [25] and interaction with information technologies [49], such as a CA device. As outlined by Pink [53] and later Pink and Leder Mackley [54], the everyday rhythm of daily life is formed by the habitual actions that unfold within the home that support everyday tasks. A routine can provide insight into a householder's behaviours, identifying the motives and purpose of their actions. All householders have routines regardless of whether they are consciously or subconsciously acted upon, with the most basic activities (eating, drinking, and sleeping) forming a routine practice [55]. Establishing a routine is not only a productivity tool for structuring the abundance of everyday tasks but has become vital for mental well-being, with the organization of activities providing an individual with clarity [25]. Routines apply to all, with children also gaining benefits from a routine bedtime structure [56].

Routines have become used as a tool to create a structure of a repetitive set of actions, which are undertaken at frequent intervals, as found within the various UK-based cases [7]. These habitual routines, which are created, usually revolve around washing the dishes or securing the home before going to bed. In addition, Shove et al. [57] stress the importance of temporality when understanding the structuring of domestic routines as they outline how morning routines depend on precise and accurate timings, with any deviation from routine behaviour causing temporal distress. The importance of a routine is defined by its repetition and must suit the time constraints of the household, with activities that cause

household issues (e.g., being late for work) unlikely to be maintained without modifications to the activity being made.

The home, therefore, is not a static environment but is dynamic. Routines are not everlasting; instead, they are continuously being made and remade over time as a household's needs change [7,57]. Temporality, i.e., trajectories, rhythms, and horizons, offers a promising approach towards understanding how and why users have undertaken certain behavioural actions in a specific location at regulated times. Implications can provide CA designers and programmers with a greater understanding of human characteristics that encompass domestic routine behaviours. By understanding the nuanced and complex actions that unfold within the home, CA devices can provide value akin to their human counterpart, the personal assistant. Temporality is important within the role of a personal assistant, with the expectations of a personal assistant being able to anticipate the future actions of their employer and proactively prioritise their employer's schedule on known patterns of work [47].

3. Materials and Methods

3.1. Research Sample

To ensure a comprehensive and thorough understanding of human behaviour within the domestic setting, we selected a sample of 15 households as our unit of interest. This approach allowed for a rich and in-depth exploration of a wide range of diverse and common experiences, thereby facilitating the development of overarching themes through the saturation of new information [58,59]. These individuals were recruited through a snowball recruitment process, where individuals known to the lead researcher would disseminate the research call amongst their peers [60]. To organise and manage our research sample, we used Gilly and Enis's [61] updated household life cycle model (see Table 1). All participants within the study were based in the East Midlands, UK.

Table 1. Research sample and living status.

| Code | Age | Occupation | Living Status | Household Composition of the Research Participant (Gilly and Enis, 1982 [61]) | | |
				Participant	Household Member	Status
P01	27	PhD. Student	Renting	1 Adult (M)	1 Adult (F)	Newlywed
P02	32	PhD. Student	Renting	1 Adult (M)	1 Adult (F)	Newlywed
P03	35	PhD. Student	*"Staying with family"*	1 Adult (F)	1 Adult (F)	Bachelor
P04	54	Area Administrator	Renting	1 Adult (M)	1 Adult (F)	Childless couple
P05	27	Beauty Advisor	Renting	1 Adult (F)	2 Children (M & F)	Single parent
P06	30	Project Coordinator	Homeowner	1 Adult (M)	1 Adult (F)	Newlywed
P07	29	Electrical Engineer	Homeowner	1 Adult (M)	1 Adult (F)	Newlywed
P08	32	Pharmacy Category Manager	Homeowner	1 Adult (M)	1 Adult (F) 2 Children (M)	Full Nest I
P09	59	Retired	Homeowner	1 Adult (M)	1 Adult (F)	Childless couple

Table 1. *Cont.*

| Code | Age | Occupation | Living Status | Household Composition of the Research Participant (Gilly and Enis, 1982 [61]) | | |
				Participant	Household Member	Status
P10	50	Private Cleaner	Renting	1 Adult (F)	N/A	Bachelor II
P11	29	Motion Graphics Designer	Homeowner	1 Adult (M)	1 Adult (F)	Newlywed
P12	28	Mechanical Technician	Homeowner	1 Adult (M)	1 Adult (F)	Newlywed
P13	51	Online Seller	Homeowner	1 Adult (M)	1 Adult (F)	Young couple
P14	24	Physiotherapist	Renting	1 Adult (F)	N/A	Bachelor I
P15	29	Tree Surgeon	Homeowner	1 Adult (M)	1 Adult (F)	Young couple

3.2. Operationalising Roleplay

A roleplay script was created to assist the participant in acting out the role of the 'household employer' seeking to recruit a 'personal assistant' (a CA device) into their home. Familiar (but conceptually diverse) domestic role examples, including the 'nanny' and 'butler', were introduced, and the participants were left free to define the type of personal assistant (including hybrid roles) they were recruiting for their home. The researcher took the part of the 'recruitment agency worker', visiting the home and interviewing the participant ('household employer') so a 'personal assistant' that best meets their needs could be placed with them. Following Gupta et al.'s [27] design recommendation, a short script (as presented below) was read aloud by the researcher to contextually immerse the participant before undertaking the research activity:

> *"You, 'the employer' want to hire a personal assistant (PA) for your home. To hire an appropriate PA, the recruitment agency worker needs to understand what your current weekday routine looks like. To achieve this, the recruitment agency worker will undertake a household audit; they will need to be guided around your home while you re-enact your daily household activities. Then, the recruitment agency worker will conclude the household audit by documenting critical dimensions of your home to create architectural floor plans."*

3.3. Household Audit Method

The household audit was designed to examine how the participants in need of a personal assistant currently undertake domestic work as a part of their overarching weekday routine. Designed as a multi-method approach, the household audit consisted of a guided household tour followed by an architectural home survey.

3.3.1. Guided Household Tour Overview

The guided household tour was adapted from Baillie and Benyon's [11] technology tour. Omitting the need to review technology, the guided household tour immersed the researcher (playing the role of the 'recruitment agency worker') within the weekday activities of the participant ('householder employer'). Designed to probe how weekday routines were performed, the guided household tour encouraged the participants to re-enact typical weekday tasks. All guided household tours began in the participants' bedroom, which represented a natural start and endpoint to the tour. Each guided tour typically lasted between twenty-five to thirty-five minutes. The researcher enlisted predefined questions to uncover the main activities undertaken in each room, covering why activities were undertaken, at what time of day the activities took place, how long they typically took, and what the temporal consequences were if activities could not be completed on time.

Research within the sensitive home setting requires the *trust* of householders [62], particularly when extending beyond the more public areas of the home to more private spaces such as the bedroom. A 'Getting to Know You' (GTKY) activity [9] was implemented as an icebreaker exercise. The researcher brought a selection of bottled drinks to the home as a gift, and time was allocated to engaging informally with the participant before undertaking the household audit. The guided tour was recorded with the participant's consent using a digital voice recorder, which sought to limit the potentially distorting effects in behaviour of recording a participant on camera, particularly within the private setting of the home [63]. Again, with the participant's permission, the researcher wrote notes to record the position of objects in the home that were included in the participant's commentary during the enactment of their weekday routine. For example, the location of football boots in a bag by the front door was documented as a temporal reminder for the householder to collect them before leaving home. Gestures and other non-verbal communication that were critical to understanding the meaning being communicated by the participant were also noted. The taking of short notes also assisted in the roleplay as it fitted naturally within the role of the 'recruitment agency worker', attentive to the needs of their potential client, the householder.

3.3.2. Architectural Home Survey Overview

An architectural survey was conducted to create scaled floor plans of the participants' homes, enabling daily routines to be mapped onto the spatial setting within which they performed. Room dimensions were recorded using a laser-enabled measuring device, with low-fidelity schematic illustrations being sketched by the researcher on site. The architectural household survey was somewhat outside the plausible remit of a recruitment agency worker. However, this activity was carried out after the roleplay was completed, and, therefore, did not influence this stage. Depending on the size of the householders' property, the architectural survey took thirty to fifty-five minutes to complete.

4. Analysis

To provide a more nuanced understanding of how temporal trajectories inform householder actions, Labov's [64] schema of personal narratives was used to examine spatiotemporal elements embedded within householders' anecdotal stories. Using this framework, we identified key temporal elements within the domestic activities captured during the tour.

4.1. Narrative Analysis

Information conveyed by the participants when re-enacting their weekday routines produced a wealth of anecdotal stories. As part of the natural storytelling process, household employers described how activities played out over time, often verbalising historical events to make sense of current routine actions. Therefore, the analysis approach was undertaken to explore the temporality of domestic work captured during the household tour.

The study of a narrative is analogous to "the ways humans experience the world" [65]. According to Labov [64] and Labov and Waletzky [66], a narrative is an informal approach summarising past experiences, sustained through a series of clauses, and contains a minimum of one temporal juncture. In other words, the temporal relationship between two independent clauses, whereby the ordering of events would change the semantic interpretation of the original sequence. A narrative, therefore, is temporally structured into a beginning, middle, and end. Labov [64] further structures narratives into the following stages or clauses: abstract, orientation, complicating action, evaluation, results, and coda. For Labov [64], the abstract (what is this about), orientation (who, when, what, where), complicating action (then what happened?), evaluation (so what?), results (what finally happened), and coda (how does it all end?) collectively demonstrate what made the story tellable, but not all may be apparent within a story. The 'complicating action' is, however,

mandatory and details a chain of actions that have taken place. This forms the premise of the narrative. The coda is less common than the other elements, but when present signals the end of the story.

Framed through the roleplay analogy, the narrative analysis data framework (see Table 2) was used to document the participants' (i.e., playing the role of the household employer) routine experiences and represent the 'working thoughts' of the researcher (recruitment agency worker).

Table 2. Narrative analysis framework.

Performed Routine Actions (PRA)	Dialogue Transcript	Observations	Schema of Personal Narratives (Labov, 1972 [64])	
A number which correlates to the exact location of the participant's movements documented on the architectural floor plan(s)	R: P:	*Documented observations by the researcher when undertaking the household audit of the participant*	Abstract	
			1. What—what is the primary goal of the activity? 1a. What—what is the contributing goal of the activity?	
			Orientation	
			Who—who is involved in the activity? When—what time does this activity take place? Where—where does the activity take place?	
			Complicating action	
			1. What—describe the action or events that were performed during the activity.	
			Evaluation	
			1. How—what tools were used to fulfil the goal?	
			Result	
			1. Why—explain the outcome of the activity?	

4.2. Behavioural Mapping

The spatiotemporal dynamics of participants' routine actions were captured by digitising their chronological sequence, as outlined in their dialogue transcripts. The resulting data were then mapped onto the architectural floor plan using a hexagonal shape with a unique identifier for each participant. This approach situated the participants' behaviours within the spatiotemporal context of the home. For example, each individual hexagon represents the participant's performed routine actions, as seen in Figure 1, such as "07", which denotes a single domestic task. However, there are instances, like "03", where multiple locations are involved, yet all pertain to the same domestic task. In this instance, the participant (P04) was multitasking, making coffee for her and her spouse, whilst simultaneously making her lunch whilst the kettle boiled. The three locations illustrated by "03" represent the interactions with the kettle, the pantry, and the fridge, which enabled the participant to achieve their desired domestic tasks in a given context and timeframe.

Each augmented architectural floor plan featured a series of coloured movement trails that visually represented the householder's travel direction. The color-coding of these movement trails served several purposes, indicating transitions between floors and marking the participant's entry or exit from the home. For instance, Figure 1 depicts P04's routine actions and interconnected pathways in red, symbolising the beginning of the participant's day. The colours shift when the participant changes floors or departs or arrives home, with green indicating exits and yellow denoting entrances. Furthermore, the orange pathways and actions signify the participant's preparations for bedtime.
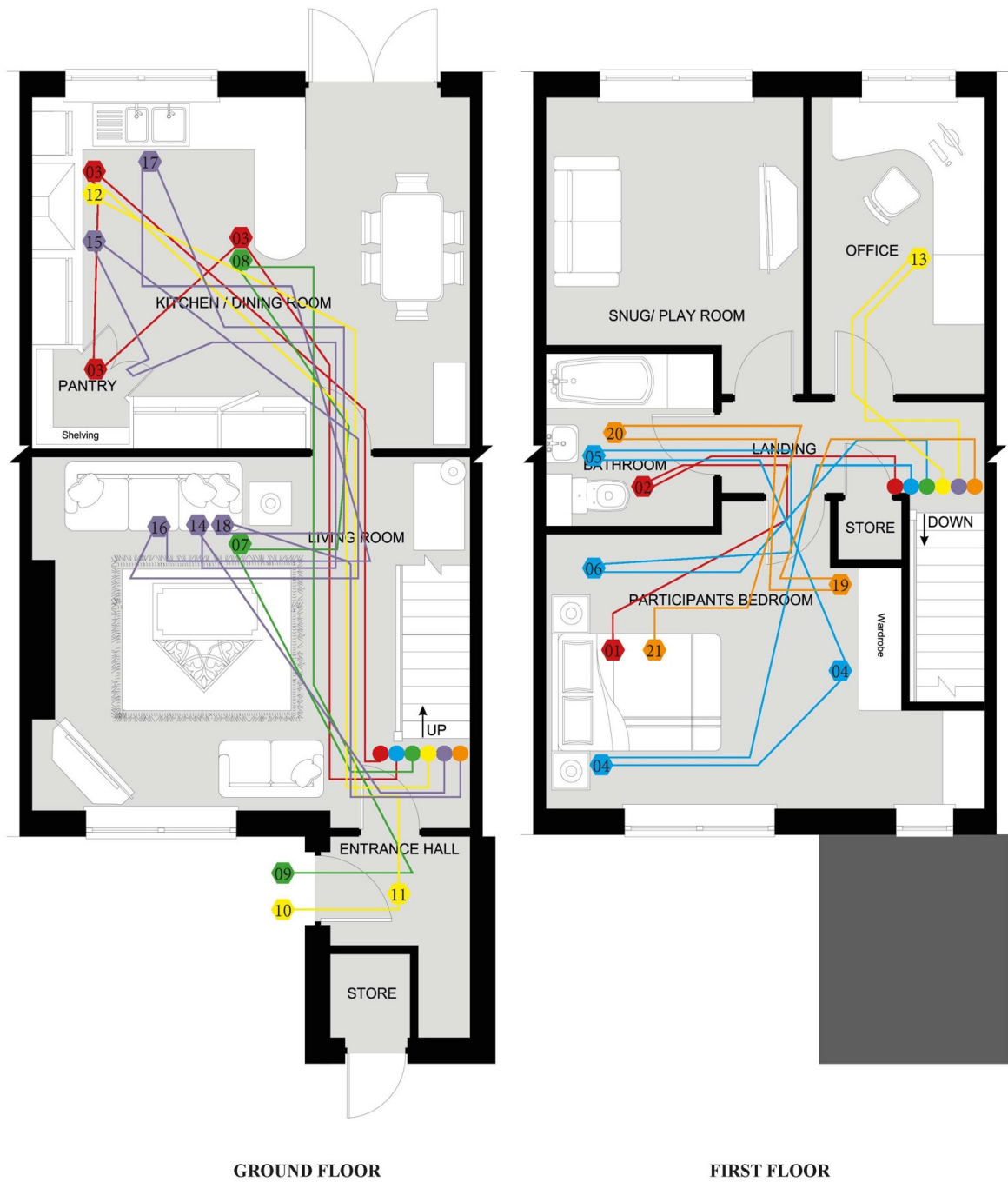
Figure 1. An example of an augmented architectural floor plan.

5. Results and Discussion

Due to the qualitative nature of this research study, we present our findings and discussion together. Using Reddy et al.'s [26] description of how medical work is temporally organised, we provide examples of temporal trajectories in the home. To gain a contextual understanding of the spatiotemporal nature of household behaviours and the future demands of CA devices, we have included selected excerpts from conversations between researchers and participants in dedicated tables that highlight how the home is maintained and managed.

5.1. The 'Handover' from Work to Home

In Reddy et al.'s [26] study, healthcare workers worked 12 h shift patterns, causing an information gap to emerge between day- and night-shift workers. The communication of information at the point of handover was used to bridge this information gap, with healthcare workers starting their shift using interrogative questions to temporally orientate themselves with events that had unfolded over the past 12 h. This study uncovered routine information exchanges between participants that, within the shared temporal rhythms of households, marked an agreed ending of the working day and the start of 'switching off' from work. This activity often had a set place within the trajectory of 'coming home from work' routines, and, depending on the information exchanged, could lead to the reconfiguration of subsequent routines. In our study, the household's daily post-work discussions were commonplace. For example, Table 3 demonstrates how the participant (P06) exchanged information and feelings with his partner when returning home from work, which was a frequent but temporally bounded activity.

Table 3. Post-work discussion between householders.

Orientation	Dialogue Excerpt
Where: Living room When: [18:00]	R: *"So, you get your issues of the day out?"* P06: *"Yeah, we share our moans, so if I am feeling stressed when I come in it's because something has happened at work, I would tell her about it, and then we'd have a chat."* R: *"OK, and this is important to you?"* P06: *"Yeah, it is good to have a chat, we tend to get rid of our moans after work, and then you can sit and chill out."* R: *"So, you do not talk about work after this point?"* P06: *"Well, we try not to, so we can enjoy the evening."*

The approach undertaken by the participant's spouse is comparable to that of the healthcare worker, with interrogative questions used to develop a complete picture of past events, albeit mediated through the informal communication channel of a "*chat*". Another participant P07 stated that once post-work discussions had ensued and a problematic incident had been identified, the householder potentially altered the trajectory of their shared routine to support his spouse's emotional state, with collective work such as cooking being instead undertaken independently as an act of kindness (see Table 4).

We, therefore, saw the sharing of information about each other's days as an essential part of the temporal routines of many couples, which could lead to the adjustment of the personal temporal horizons of individuals (e.g., adjusted expectations about the sharing of the domestic work in response to knowledge about a partner's emotional state). Interestingly, the temporal bounding of this activity was commonly and tacitly agreed upon as part of the trajectory of home life and marked the end of the work shift and the start of a period of leisure. In both examples above, the use of the home space as a place of work was accepted by both parties for an agreed period of time as they collaboratively helped each other to manage the transition from 'being at work' to 'being at home'.

Table 4. How habitual temporal trajectories become adapted.

Orientation	Dialogue Excerpt
Where: Living room When: [19:15]	P07: "So, we would have a chat about our day and any issues we have had at work. Usually, if my wife has had a problem at work, I am the last to know as we do not have our phones on us when on the factory floor." R: "OK, so if your wife has had an issue, how do you respond to that when you walk in?" P07: "Well, depending on what the issues were, but normally we would have a tea and try to talk it out. I sometimes tell her just to watch tv whilst I make dinner just to give her some time to relax."

Information gaps, more like those in the shift-working context of medical work, were apparent when the temporal trajectories of the working days of householders meant that they returned home at markedly different times to each other. How participants collaborated with each other to complete domestic work, in such cases, was often determined by who arrived home first; the absence of the other person would trigger a change in the temporal trajectory for core household routines, considering established temporal rhythms understood by both parties, such as the first one home begins to prepare the evening meal.

In some households, the start and end times for the working day varied from day to day due to the nature of work undertaken by the householder outside of the home. For example, one participant, P12, works within the construction industry and often has three different finishing times within a working week, including finishing on Fridays at midday, marking an early start to the weekend. In such households, the restructuring of daily routines [48] was often reported, as activities were pushed back in time (postponed) or pulled forward depending on the working schedules of the householders in accordance with the shared knowledge of established domestic temporal rhythms, understood by all involved. Sometimes, however, the temporal horizons of couples appeared to be misaligned, with the temporal horizons of an individual impacting negatively on their partner's domestic work.

Reddy et al.'s work [26] described how temporal horizons in the medical setting determined how an individual organised work based on their knowledge of when activities needed to be finished to prepare for upcoming activities, and that this understanding was personal to each individual. This temporal feature was evident in the domestic setting. Table 5 below describes the temporal trajectory of the morning and evening routines for one participant whose temporal horizons included prioritising time with his son in the morning, sometimes at the expense of helping his partner with childcare and cooking in the evening.

We can better understand the participant's behaviour in accepting a 1 h and 15 min difference in returning home through the risk–return trade-off, where the increased risk is equivalent to the reward. In this example, the householder views time as a resource, prioritising time with his son (reward) at the cost of leaving at the latest known time, risking coming home late if traffic results in him arriving late to work. When reviewing the temporal trade-off between the short amount of extra time spent at home with his son to the resulting extended time spent at work, the decision appears irrational. The value placed on different activities is, therefore, critical to how the householder chooses to organise activities and structure his day. The final entry in the table also shows how, on returning home, the participant was able to orientate himself using his knowledge of the established temporal rhythms of the home to slot into the ongoing domestic work of the home. Previous studies of domestic work [48,67,68] have similarly described how homes are formed through reoccurring patterns of domestic work. By foregrounding the temporality of household routines, we shed further light on how the lived experience of the home unfolds in real-time.

Table 5. How householder actions unfold over time.

| Orientation	Dialogue Excerpt
Where: Second bedroom When: [07:30]	R: *"OK, so say it is 07:30 when you leave the bathroom; where do you go now?"* P08: *"Into my son's room; his clothes will all be out the night before school. So, I would then wake him up and get him dressed, that usually takes about 10 to 15 min. Then, once he has used the bathroom, we go downstairs, where I make him his breakfast, and we watch TV."* R: *"Together?"* P08: *"Yeah, as I don't have much time with him during the evening now he's at school, and he has a set bedtime."*
Where: Exiting the home through the back door [kitchen] When: [08:00]	R: *"What time do you leave for work?"* P08: *"Latest is 08:00"* R: *"OK, so what is the consequence in leaving later than 08:00?"* P08: *"I will struggle to get to work at 09:00, and that is the latest I could be if I want to get home at a decent time."* R: *"And is that down to traffic?"* P08: *"Yeah, so the traffic on the M1... If I am late for work, then all of a sudden, everything becomes a rush as soon as I get in [to the office]."*
Where: Re-entering the home through the back door [kitchen] When: [17:15–18:30]	R: *"OK, so thinking of when you come back from work, what time would that be?"* P08: *"Anywhere from 17:15 to 18:30, anytime around there."* R: *"OK, what is the big variance between those two times?"* P08: *"It depends on what time I get into the office, so if I arrive later, then I have to stay later."* R: *"So, you do not have a cut-off point to you leaving work?"* P08: *"No, there is no set time; I just have to get the work done."* R: *"So, finishing time is flexible?"* P08: *"Yeah."*
Where: Kitchen When: [18:30 to 18:45]	P08: *"... I'll help my wife with the cooking if she has already started, as I know by then that the boys have done their homework."*

5.2. Management of Time

Reddy et al. [26] identified how nurses used the established temporal rhythms of their shift patterns to guide how they organised their work. We found equivalent rhythms used to structure domestic work in the home. For instance, we observed how one participant (P15) orientated their domestic work around the ending of a soap opera show, which prompted the householders to begin to prepare their weekday evening meal. Another household (P12) organised domestic work into the advert break of a television programme, using the interval constraint to challenge themselves to complete as much work as possible in the time available (see Table 6).

Table 6. Embedded social cues within temporal routines.

Orientation	Dialogue Excerpt
Where: Living room When: [19:45]	R: *"And then do you leave the pots on the side [living room] or take them out straight away [kitchen]?"* P12: *"We take them out straight away and then put them in the dishwasher and say Coro is on, then in the interval, we would tidy the kitchen up and then come back in to here [living room] to catch the second half."* R: *"Why do you tidy up during the interval and not wait until the end of the show?"* P12: *"I like to see what I can get done in that short space of time ..."*

A spatiotemporal dimension is revealed when reviewing the participant's movement through his home, recreated here using an annotated floor plan (see Figure 2). Through the process of re-enactment, the participant was observed to have undertaken a fast-paced

walk when performing domestic work during the intermission of "*Coro*", with actions from the living room (see PRA 18) to the kitchen (see PRA 19) and back again (see PRA 20), triggering the participant to accelerate the performance of domestic tasks and effectively accelerate and decelerate the pace of time [41,69].
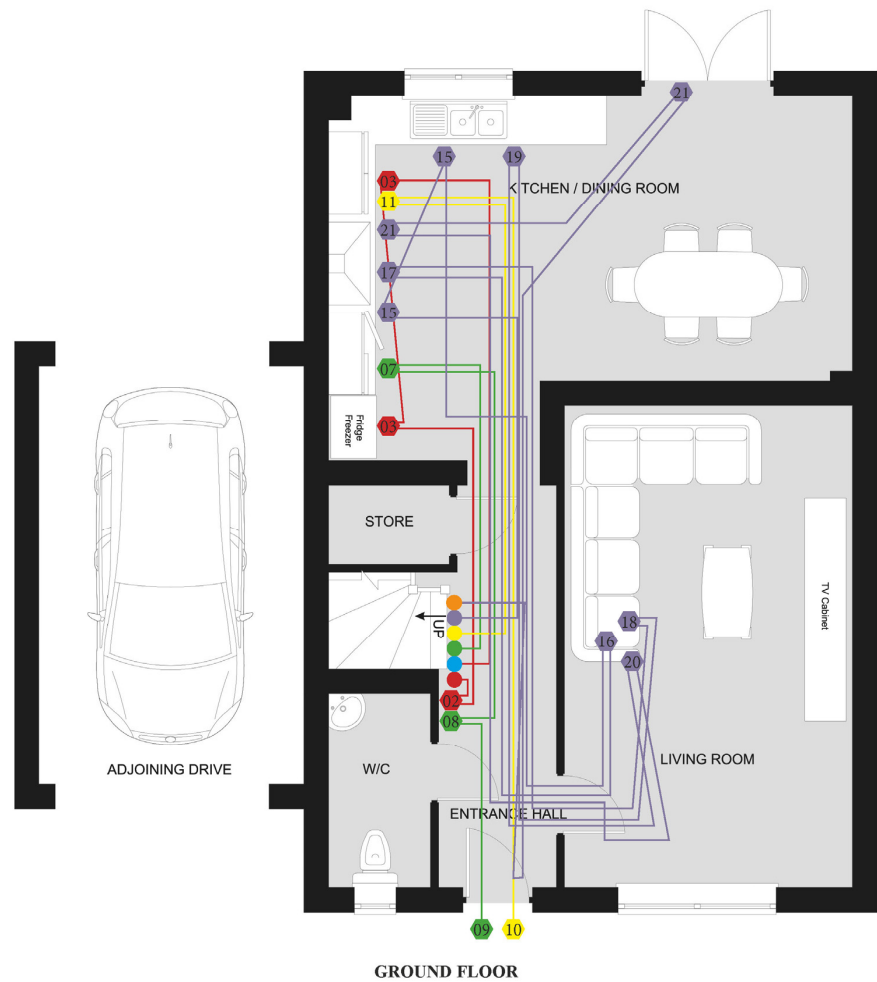
Figure 2. Spatiotemporal conditions of the home.

Our findings contrast with those of Irani et al. [4] who viewed television watching as ad hoc, building on Rattenbury et al.'s [70] notion of 'plastic time'. While we do not dispute that television viewing within the home can be unplanned and unstructured, the regularity of re-occurring weekday television programmes, such as soap operas, provides a temporal structure to the home around which domestic work can be organised, as in the example above, even providing constraints that serve to challenge and motivate householders

to perform mundane tasks to the best of their ability. An interesting consideration is whether households will start to lose some of their informal temporal cues as work becomes more flexible or home-based and as TV shifts from scheduled to on-demand broadcasting. Further evidence of the use of temporal rhythms in the home to coordinate domestic activities can be seen in the following example. Participant P02 used the start of her partner's morning dog walk to indicate that it was time for her to start cooking breakfast (see Table 7).

Table 7. Temporal rhythms supporting timekeeping responsibilities within the home.

Orientation	Dialogue Excerpt
Where: Kitchen When: [08:00]	R: *"OK, so does it take a lot of time out of your morning?"* P02: *"Yeah, so the breakfast is normally like 20 min, and that is when my husband is going out to walk the dog."* R: *"Right, OK."* P02: *"He is gone for like 30 min, so when he comes back, the breakfast is done and ready to eat, and normally lunch is in process."* R: *"So, when your husband leaves home to walk the dog, is that your cue to start breakfast?"* P02: *"Yeah."*

Formal acts of timekeeping were observed in the domestic setting, with 13 participants mediating temporal duties through an alarm-based device (smartphone, analogue clock, or lamp), each being accountable for the programming of their own alarm. The use of an alarm clock to regulate the temporality of the home is, of course, not a new phenomenon [71]; the act of programming an alarm signifies the value of punctuality within the householder's routine. However, a third of householders who set a morning alarm choose to regularly disregard it and snooze the alarm to extend time in bed. Landry et al. [72] found that postponement of a morning alarm was recognised as normative behaviour, with over half of their study sample choosing to disregard their prearranged alarm devices. In our study, participants responded in different ways to the reduced time available due to the unplanned snoozing of an alarm. Their responses highlight how in the domestic setting, as in the medical work setting, individuals must deal with multiple temporal horizons, and how 'flexible' or 'inflexible' these horizons are, to help determine what work gets done when in the home. Participant P02 had a highly flexible structure to their working day and much agency regarding when work was undertaken (see Table 8). They were, therefore, able to prioritise the domestic work of preparing healthy food over arriving at work on time.

By contrast, participant P04 had much less flexibility within her work routine, so would instead reconfigure her domestic routine when staying longer than intended in bed (see Table 9). The disruption of her evening routine through domestic work extended into intended leisure time, which was accepted to still arrive at work on time.

Finally, a third participant (P11) had designed the temporal trajectory of his morning routine in a way that anticipated reducing the time available through snoozing his alarm (see Table 10).

A broad array of factors was observed to have influenced the decision-making process when the participants postponed their morning alarms, with all three outcomes being influenced by time in diverse ways. For example, the cultural traditions and culinary responsibilities led one participant (P02) to postpone their arrival at work on time and instead to prioritise outstanding domestic duties. Descending from Hispanic culture, the householder explained that it was her sole responsibility to prepare and cook the household meals per her cultural norms, as seen in many Spanish-speaking countries today [73]. The decision for the participant to push her work schedule back can be understood by the intertwinement of her domestic responsibilities and cultural expectations, as well as the flexibility of her job role.

The postponement of the participant's (P04) domestic duties recognises the temporal flexibility of his domestic routine. When the temporal trajectory of his morning routine was disrupted by getting up late, acts of domestic work were postponed at the cost of forgoing post-work entertainment privileges. Time, according to Mazmanian et al. [34], is linear and can be broken down into temporal units eligible to be exchanged with other moments with minimal ease. This participant seemed to similarly view time as a chunkable and tradeable commodity with recreational objectives being the first to be sacrificed to complete domestic work routines.

Table 8. Flexibility in a morning routine.

Orientation	Dialogue Excerpt
Where: Participants bedroom When: [07:00–7:45]	R: *"OK, so why is it more difficult to wake up earlier in the UK as opposed to Mexico?"* P02: *"Mainly because of the sky; it is very dark and often raining, and I do not want to get up to that."* R: *"OK, so the alarm goes off at 07:00 and is that just one alarm?"* P02: *"No, two."* R: *"OK, so one of those alarms being at 07:00 and the other?"* P02: *"For 07:45, but that is the very latest I can wake up. But like yesterday it was a rainy day, so I did not get out of bed until 08:20."*
Where: Kitchen/dining room When: [08:00]	R: *"OK, and do you make breakfast every day?"* P02: *"Yeah, whilst I do this, I also make lunch when I am prepping breakfast, which is cooked in the morning."* R: *"So, it can be quite stressful with time pressures?"* P02: *"I rarely arrive at the office at 10:00 as I am still cooking, as I just do not want to get out of bed when it is like this [wet weather]."*

Table 9. Managing acts of domestic work through 'pushing' time.

Orientation	Dialogue Excerpt
Where: Participants bedroom When: [07:00–7:45]	R: *"How many alarms do you have set?"* P04: *"Just the one, but I keep on snoozing it."* R: *"OK, have you ever been late for work because of over-snoozing your alarm?"* P04: *"Not late, but I feel a bit stressed out in the mornings when I have snoozed the alarm."* R: *"Do you ever compromise your morning routine?"* P04: *"I would not do [empty] the dishwasher and other jobs that I do in the morning, I would save them and do it when I get back."* R: *"Does this compromise you at all?"* P04: *"Yeah, it is not something I like to do after work, as that is my time, and I just want to sit down and watch my telly with a coffee."*

Table 10. How a reduction in time is anticipated.

Orientation	Dialogue Excerpt
Where: Participants bedroom When: [06:40]	P11: *"Yeah, I have overslept by snoozing the alarm too many times, and that just creates time problems as I am cramming everything, I need to get done in a shortened time frame. So, I would start to take things for granted, like my bag having the right stuff in it and like my keys being where I expect them to be."*

Participant (P11) appeared more in tune with the temporal rhythms of his own working week, having recognised a pattern of sleeping in, and he had devised a time-saving response of preparing for work the night before. Interestingly, the flexibility of this participant's temporal horizon was curtailed by car-sharing with his wife. His time-saving strategy in the morning, therefore, reflected his responsibilities to her and not just his own desire to arrive at work on time.

5.3. Responsibilities

Reddy et al. [26] describes how responsibility for a patient's trajectory is of vital importance to both physicians and nurses, with both being obligated to investigate the *overall* temporal trajectory (original italics) of a patient's progression before conducting care. Our study has shown, similarly, how responsibilities are key determinants of the temporality of the day, with dependents being other family members and even pets.

Participants often pulled and pushed time to both coordinate their routine activities with the temporal rhythms of their 'dependents' and to ensure that they fulfilled their responsibilities to these other household members. For example, a participant (P09) and his spouse were witnessed to have postponed their dog-walking duties from early evening to late night, as they were being disrupted by their dog during the night. This is an example of a participant modifying their temporal horizon to ensure that mutually satisfactory trajectories play out (see Table 11).

Table 11. Disruption of desired temporal rhythm.

Orientation	Dialogue Excerpt
Where: Exiting the home through the front door [entrance hall] When: [23:00]	R: *"...is there any reason you walk your dog at night-time and not earlier?"* P09: *"It gives him [household dog] a leg stretch before he goes to bed, so he is less likely to get us out of bed then."* R: *"Is that something that is an issue?"* P09: *"Yes, definitely. More for my wife as she is going to work."* R: *"So being disturbed in the night?"* P09: *"Yes, he [household dog] used to wake us up in the night, as he wants to go to the loo, but now that we take him out for a walk before bed, this has really helped him and us get a better night sleep."*

As behavioural patterns unfold within the home and become established as cause–effect pairs, householders can associate meanings with visual and auditory cues and modify the temporal structures within the home. For example, one participant described the pulling of time (from morning to the previous evening) when having recognised potential disruption to his sleeping household when "*rooting*" through his wardrobe during the early hours of the morning (see Table 12).

Table 12. How time is 'pulled' to minimise household disruption.

Orientation	Dialogue Excerpt
Where: Participants bedroom When: [18:15–18:30]	R: *"So, at this point, it is about 18:15 to 18:30?"* P08: *"Yeah, I'd say so."* R: *"When you get changed, do you lay tomorrow's clothes out then?"* P08: *"Yes, I would put my clothes that I can wear again, so like my jeans on the side and my shirt in the wash basket and hook any clean clothes on the corner of this wardrobe"*
Where: Bathroom When: [07:00–07:10]	R: *"Ok, so why do you plan this [work outfit] the night before?"* P08: *"No, because of time and because I do not want to be rooting around in the wardrobe when my children are still asleep."* R: *"Is this about the noise?"* P08: *"Yeah, I don't want my kids to wake up any earlier than they need to…"*

Southerton [74] described similar actions within his comparison study of everyday routine activities in 1937 and the year 2000 within the UK, emphasising that people constantly pushed and pulled time to provide greater flexibility when facilitating the needs of others, including those they were responsible for. However, this shifting of activities was not necessarily cost-free, with a positive impact on short-term trajectories being traded off against a negative impact on longer-term trajectories. We observed one single-parent household, where the parent would read to her children when they could not sleep (see Table 13). Consequently, as they became increasingly engrossed in the story, this resulted in the delay of their bedtime, altering the expected trajectory of the following day.

Overall, when comparing the home with the medical settings described by Reddy et al. [26], many of the same temporal phenomena can be seen to be at play. However, there are some key differences. Rather than the interrogative aspects at play within a medical setting, much of the fact-finding in relation to temporal horizons and trajectories within the home emerges through the awareness of the habitual behaviours of the participants. In addition, the processes of negotiation and adaptation are seen in the home, where the trajectories of individuals are brought into alignment with each other to maximise the functioning of the household. Whereas the key unit of interest in the medical setting is the individual patient, many of the temporal decisions in the home, including trajectories and the temporal horizons, are focused on the household unit rather than the individuals involved. The notions of agency are also clearly different. However, patients have choices over treatment plans, and individuals in a household setting have much greater self-determination over their temporal horizons, trajectories, and the rhythms that occur. The longer-term trajectories at play in a household (compared to the days/weeks within a typical acute clinical setting) are also much more a component of multiple short-term, repeating, and intersecting trajectories. From the point of view of the recruitment of the personal assistant within the role-playing context, although the household generally presents a more complicated temporal structure, it is also more observable and adaptable. The stability of the household and the personal characteristics and habits of the individuals in the household allow the prediction of individual temporal trajectories.

Table 13. Trading off the short-term and longer-term trajectories for dependents.

Orientation	Dialogue Excerpt
Where: Second bedroom When: [19:30]	R: *"OK, and do you have to tuck them in or any ritual like that to comfort them?"* P05: *"Well, my daughter has a reading book from school, and depending on if she is able to get to sleep or not, I would read to her to help her fall asleep."* R: *"Like a bedtime story?"* P05: *"Yeah, but my son often wants to listen in, so he gets into bed with my daughter for the story, and then I carry him out as he is usually falling to asleep by then."* R: *"And do you enjoy reading them a story?"* P05: *"Of course, it is a real joy of mine, but it would be easier sometimes for them to fall to asleep without it as I have other jobs to do, and sometimes, we can get carried away and be reading for an hour or so."* R: *"Making it even later for them."* P05: *"Yes, making it difficult for them to get up the next day."*
Where: Bathroom When: [Circa 07:40]	R: *"How do you make sure they are getting up?"* P05: *"... it is difficult to make sure they are getting out of bed, as they are not the most motivated kids to get ready for school, especially when they have had a later-than-planned bedtime for whatever reason."* R: *"Well, yes, so is your getting ready routine disrupted if they do not do as they are told?"* P05: *"Absolutely, it saves me loads of time and effort if they are getting dressed whilst I am showering as if they are still in bed; then it costs me time, as my priority shifts to them, stopping me from getting ready and this affects what time we get out of the house as well as catching my bus to work."*

6. Implications for Theory

Reddy et al.'s [26] temporal features of work, formed through studying the medical work context, have been shown as a useful lens for understanding domestic work in the home. These temporal features can be used to identify theoretical implications, including priorities for future HCI research. Although the components of horizons, trajectories, and routines are seen clearly in the households, they differ subtly, and these differences help to identify some of the theoretical implications of this work:

- The functioning of the home (and the successes and failures) is dependent on the intersections of multiple temporal trajectories with different timescales and multiple actors. These are either coordinated to generate successful outcomes or are incompatible and result in conflict. The adaptation of these trajectories is key to the success of the household unit, as opposed to the *individuals* within the household. Linked to this is the need to better understand how individual trajectories intersect and move apart, how they influence each other, and how they can be adapted (e.g., change in velocity) to reduce conflict in the home.

- To better understand and manipulate time within the HCI, there is a need for effective means to represent temporal horizons, trajectories, and rhythms, including the actors involved, their agencies, the links to explicit and implicit information cues, and the affordances of the context. Without effective representation, it is difficult to understand the cause–effect relationships within temporal structures, and, therefore, take account of them within the design of technology for the home.

- The push/pull aspects of time within trajectories need to be better understood. It is clear from this study that time was seen as a chunkable [34], and a 'push/pull' strategy was used successfully to alter outcomes arising through trajectories. However, it is not clear how and when decisions are made to employ these strategies and the role that efficacy (short and long-term) plays in its choice and success.
- Temporal tensions [69] were clearly at play within this study and were, to some extent, mitigated by push/pull strategies where these could be employed. However, this was sometimes only partially successful. There is a much greater opportunity to identify how to even out the temporal tensions that were apparent, as well as better understand the role they play in the temporal trajectories that play out in the home.

7. Practical Implications

The practical implications of our work in relation to the successful development of future CAs are as follows:

- CAs need to move towards the 'longstanding trusted butler' model, where they are discreet, learn how a household and the individuals 'tick', and intervene as and when needed. Importantly, their agency will have been agreed upon, and this may differ across different types of activities, different contexts, and for different individuals. To do this, they need to be able to learn the temporal trajectories that play out within homes and the wider world to accommodate and enable household activities for maximum benefit. This goes further than the 'If This Then, That' (ITTT) types of routines seen within current smart homes, since rather than just automating tasks, there is scope to alter the trajectories of the routines to maximize the effectiveness of the household unit, or indeed to enable new routines to emerge.
- Some key technological elements need to be in place, including machine learning and IOT technologies that provide the capability to sense activities and people to identify the context. Ambient technologies (rather than fixed location devices) are also needed to collect and spread intelligence throughout the home. VUI will be key, both in terms of (1) understanding from conversations and contextual data that can be used to identify habitual rhythms and trajectories in the home over time, and (2) enabling easy, personalized, contextually relevant interactions with devices to enable temporally relevant interventions.
- As technology develops, the role of the CAs can change. It will shift from information provided within a temporal structure to a personal assistant that can provide options for courses of action, to one that can provide a recommended course of action, to one that can undertake or initiate optimum courses of action. This increasing shift to autonomy (as seen in vehicles) will require both a breadth of understanding of the influencing factors (including context) and a look back/forward ability to understand past and to project future temporal trajectories. This is akin to the subtleties and nuances picked up by a trusted and long-serving personal assistant. By being embedded into a household over an extended period of time, a personal assistant will have learnt how the multiple temporalities within the household play out and what interventions are effective in enabling better household (and individual) outcomes.
- For new CA device users, recognizing the importance of social and ethical considerations is paramount. Manufacturers must be keenly attuned to the potential pitfalls associated with these devices within a household, guided by UNESCO's 2019 insights on the gender gap in AI technology, as illuminated by West et al. [75]. The practical implication is clear: prioritize ethical design and integrate educational features to prevent harm and promote digital literacy, ensuring that CA interactions are respectful and responsible. This not only safeguards users from negative consequences but also instils a culture of respect in the digital realm, setting a vital precedent for our increasingly AI-driven world.

8. Research Limitations and Future Work

A potential limitation of this research is the influence of the day and time on data collection during research activities [76]. It should be noted that the researcher is limited to observing a singular moment in time when capturing domestic work. Since the visit is a one-time event, it is difficult to verify the accuracy of the claims made and whether any important details were missed during the guided household tour. However, the data collected were specifically framed at understanding habitual habits that could translate to the domestic CA advancements that this process achieved.

To gain a more comprehensive understanding of how householders construct and uphold domestic practices, it is recommended that future research allocate more time to studying the dynamics of households in their natural settings. This may also include weekends or holidays, during which markedly different domestic habits and behaviors occur.

9. Conclusions

The temporal horizons, trajectories, and rhythms of Reddy et al. [26] have been found to be a useful entry point to studying the temporal structures of the home. By comparing our domestic findings with those of the original study, it has been possible to demonstrate how the temporal features identified in a medical context can provide understanding in a different application domain (i.e., the home). Within this study, the domestic weekday routines of our participants have been shown to be made up of multiple, repeating, interpersonal and intersecting trajectories within a setting of repeating temporal rhythms. Understanding and responding to these trajectories presents a challenge for the successful development of future CA devices but also provides a great opportunity to inform future smart home technology through a more nuanced understanding of how the home is temporally made.

A significant proportion of the study participants preferred linear task planning to maximize productivity and efficiency [39,41]. However, many individuals lacked the flexibility to adjust their tasks based on their household composition or work status, while others had the luxury of being able to delay tasks without significant consequences to their daily routine. Our study shows that regardless of the approach, householders prefer breaking their day into smaller, more manageable chunks to better manage their time. These chunks are often bounded by the temporal rules of the home, which vary from home to home.

This presents an excellent opportunity to inform future smart home technology through a more nuanced understanding of how the home is temporally made. To address this challenge confidently, researchers and developers need to pay close attention to the way users interact with CA devices in the home. This requires a deep understanding of the temporal dynamics of both the home environment and the interaction with the CA as it becomes more usefully embedded within the home. Developing CA devices is an iterative process that involves continuous learning and adaptation. Therefore, the design of these devices must be informed by ongoing feedback from users and emerging trends in smart home technology.

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