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Quantified Baby: Parenting and the Use of a Baby Wearable in the Wild

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Baby wearable technologies are becoming increasingly popular, particularly in early infancy. However, little research has been conducted to investigate how baby wearable technologies are adopted and used in parenting. This paper presents a two-week in-depth situated study with six mothers in their homes consisting of contextual entry and exit interviews, video recordings of ‘out-of-box’ experiences, and a diary study. Using interpretative phenomenological analysis, participants’ use and expectations of the baby wearable technology were examined. Use of the device directly impacted upon parents’ knowledge production and anxiety, and influenced the perceived physicality and social factors of parenting. We frame these findings around sociological norms of the vulnerable child and responsible mother, as well as the notion of ‘lived informatics’, where individuals’ interaction with the technology influenced the perception, use and impact of the baby wearable on everyday parenting practices and familial relationships.

CCS Concepts: • **Human centered computing** → **Human computer interaction (HCI)**; *Field Studies*; Empirical studies in HCI; • **Human centered computing** → **Collaborative and social computing**; *Computer supported cooperative work*; *Ethnographic studies*; Empirical studies in collaborative and social computing.

KEYWORDS

Parenting; mothers; baby; baby monitors; wearables; personal informatics; quantified self; situated study; in the wild.

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1 INTRODUCTION

The birth of a child brings about major changes in the lives of parents, and infants’ early behaviours can seem unfathomable [62]. Barclay et al. [4] have described how mothers, in particular, face physical challenges caused by lack of sleep, the constant demands of parenting, and recovery from the birth, as well as

psychological challenges associated with constant learning and uncertainty. Despite preparatory efforts, women in a previous study [4] reported that they felt mentally and physically exhausted when they realised how much they had to give and learn in order to care for an infant. Sethi [56] found that first-time mothers took at least three months of full time caring for their infants to begin to feel confident about understanding them. Women report feeling overwhelmed by this new and life changing endeavour [63]. Postpartum depression and anxiety are also relatively common and “general anxiety” in new mothers is estimated between 4.7% and 33% [35]. New mothers use various resources to support their parenting, with personal trial and error being a significant source of knowledge [4,56] along with advice from books and experts [56]. Technologies have also begun to play an important role in parenting, providing mothers with resources for data sharing, memory-making and social connection, also providing new ways for mothers to understand concepts of care and wellbeing [3].

The remote monitoring of the young infant is commonplace. Various types of baby monitoring products are available as consumer products (see Fig. 1a). Audio monitors allow parents to hear their baby from a mic-equipped base station placed near the baby, with some also offering talkback functionality [9]. Video monitors provide parents with a live stream of footage and audio on a portable screen or their own mobile phones [43]. Other monitoring products use various sensors, such as a thermometer or an under-the-mattress movement sensor [1]. Wearable baby monitors such as the Owlet are now being promoted, which comprise a wireless smart sock that monitors heart rate and oxygen levels during sleep [50] (see Fig. 1b). The availability of these technologies is expanding, with technology giants such as Google engaging in high-tech baby device development [36] and a growing number of products being released [29].



Fig. 1. a) Baby monitors for sale b) Owlet Baby Care [50]

Infant monitors are largely marketed as devices to alleviate parental anxiety at a time of high stress and low perceived personal expertise. However, there are concerns that this provides parents with a “*false sense of security*” for serious instances related to infant health [32]. The sudden death of an otherwise healthy infant under one year of age is known as Sudden Infant Death Syndrome (SIDS). The exact causes of SIDS remain unknown [46]. However, the American Academy of Pediatrics states that home monitoring should not be used to protect against SIDS, and should only be used for “*specific clinical indications for a predetermined period, using only monitors equipped with an event recorder, and parents that monitor use does not prevent sudden, unexpected death in all circumstances*” [6]. Despite this, marketing of wearable baby monitors largely rest upon the notion that they can provide “*peace of mind*” by alerting parents if something is wrong [32].

Despite advances in baby monitoring technologies and technology companies’ increasing interest in “*intimate surveillance*” of infants [36], little is known about how they are actually used by parents and their potential impact on parenting. Therefore, this study takes a situated approach to investigate the use of a baby wearable technology in the wild. Through the study of the Owlet by six mothers in their own homes, we were able to explore how the ‘quantified baby’ might be realized through examining use, non-use, and expectations for this worn monitoring technology *in situ*.

2 RELATED LITERATURE

Technology plays an increasingly important role in motherhood [3]. Beyond baby monitors, websites such as *whattoexpect.com* and *mumsnet.com* have become core resources for information and support, and a plethora of mobile apps exist with the aim of facilitating mothers' desire to learn about, record and track key parenting experiences [48]. Recently, HCI research has begun exploring the role of technology in the context of motherhood and parenting. For example, Gibson and Hanson found that technology helps support parenting confidence by meeting mothers' desire to engage with the outside world and be "*more than just a mother*" [20]. Some products have been designed to solve specific issues of motherhood. For example, *MammiBelli* [26] allows pregnant women to alleviate social isolation through sharing their experience with intimate social groups.

2.1 Learning to Care for the Vulnerable Infant

Barry discusses *phronesis* with regards to parenthood [5], an Aristotelian term meaning practical knowledge gained through experience. Mothers lean on their "*gut feelings*" [38] and base infant assessment on close observation and interaction with their children, with the intention of understanding uncertain reactions and signals [34]. Practical information is critical but there is also a need for experiential and embodied learning, which Johnson describes as "*surreptitious support, where users passively and invisibly receive advice, information and reassurance*" [27]. This echoes discourse around the perception of babies as helpless and innocent, and the infant body as vulnerable, fragile and needing protection [41]. Because of this vulnerability, a societal norm has emerged around the protected world children should be raised in [13] and the infant's body is "*culturally primed for intense and continuous surveillance on the part of its anxious parents*" [38]. This protection persistently remains the responsibility of the mother and contemporary narratives prize "*good*" mothers who invest time, money and energy into raising children [23]. Lupton has discussed how this leads to judgement of maternal behaviours, where social norms dictate that the needs of the infant should be put first by responsible and good mothers [41] who risk being judged by other mothers, medical professionals, family, and friends if they do not comply.

2.2 The Embodied Nature of Parenting

Lauritzen's study of mothers' concerns about health and wellbeing identified basic survival as a worry [34], and Lupton describes the way that mothers of newborn infants constantly checked on their infants to make sure they were still alive [37]. Mothers felt that they were in charge of their infant's health and therefore monitored them closely, even staying physically close to them as they perceived their role as one of ultimate responsibility [34]. Physical closeness, acts of touching, and intimacy between infants and caregivers is a concept named "*skinship*" by Tahhan, and she discusses the "*prolonged physical proximity*" between mothers and children in her study of co-sleeping [60]. Lupton believes "*that the intense physical and emotional bond that mothers experience with their infants may be both pleasurable and problematic*" as the vulnerable nature of the infant combined with the assumption that good mothers are constantly watching over their infant's health means the embodied nature of mothering challenges autonomy and can be a heavy burden [37]. Lupton discusses the changes in how danger is framed, and increasingly how it is used to market baby products. Instead of unlikely but serious health consequences being linked to fate, they are instead linked to risk [42]. Therefore, the danger becomes something that can be mitigated with precautions and health emergencies can be attributed to parents (mothers) who did not prepare or respond accordingly [40,36].

2.3 The Quantified Baby

Johnson discusses the transition to motherhood as an "*embodied project*" which, in the increasingly technocultured world, means increased access to digital health sources and new devices [28]. Dumit et al. go so far as to suggest that infants are "*increasingly rendered cyborg by their immersion in technoculture*" [15].

Gaunt et al. [19] have explored the potential pitfalls of applying Quantified Self approaches to baby products through a theoretical design concept, or design fiction, of a baby monitoring device called 'Baby

Lucent'. The researchers recommend that baby products using data should be designed to avoid "*increasing parental anxiety*", "*inhibiting parental intuition*", and "*increasing the distance between parent and child*." A satirical account of children under surveillance is presented by Marx and Steeves [45]. They discuss this shift towards the connection of baby monitors with responsible parenting: "*Infants are poked, prodded and observed by parents at will – almost nothing is out of bounds for responsible parental inquiry*." In a study of online reviews of baby monitors, Nelson points out that none of the parents justify why they are using the monitors, but rather there is an expectation of use [47]. Nelson discusses the normative status of anxiety, an accepted and un-interrogated aspect of parenting. Through the analysis of these reviews, she finds ironically that "*the solution they put in place to alleviate that anxiety both extends and intensifies [it]*." However, limited research has been conducted on the use of 'quantified baby' products in the wild.

Rooksby et al. [55] introduced the term "*lived informatics*" in their exploratory research on activity trackers, to highlight how people use and reflect on their personal information in multiple ways that are enmeshed with their day-to-day lives and concerns, rather than in an abstract or decontextualised manner, as data scientists do. Wearable tracking devices like the FitBit, Jawbone and Apple Watch are increasingly popular tools for tracking aspects of health, such as heart rate and pulse oximetry [55]. However, use *and non-use* of such health trackers is based on individual user differences and, critically, the context in which they are embedded [51]. Additionally, people use trackers not only for personal tracking, but also for social and collaborative purposes [14,55]. Lupton [40] discusses personal informatics not only as an individual practice but as a *social* practice (cf. [2]). We look to Rooksby et al.'s [55] concept of "*lived informatics*" as a framing for the use of baby wearables, as it does not try to reduce the messiness of everyday life. This is particularly important for examining intimate personal domains [16], such as the care of an infant in the home

Looking to the 'quantified baby', it is of interest to examine how a wearable baby monitor product might be embedded in everyday messy parenting practices. Although there has been research on motherhood in the HCI domain, studies of opinions on baby monitors [47], reviews of baby monitor marketing materials [33], and speculative papers on the possible future of quantifying a baby [19,45], there is minimal research on the *situated* use of baby monitors, particularly novel wearable devices. As such, we endeavoured to investigate the use of one such product 'in the wild' - the Owlet. We used a situated approach to access the experience of using the Owlet in an in-depth study of six mothers and their infants.

3 METHODOLOGY

A pragmatic, situated approach was adopted for this research which sought to gather rich user data while mitigating participant burden [61]. Rogers et al. note that laboratory studies often do not capture the complexities of situations where a technology is used [54]. A flexible situated approach was adopted for this study using a combination of contextual interviews, diaries, and videos of out-of-box experiences. Although Brown et al. [10] propose that methods such as *post-hoc* interviews and diaries are troublesome due to the retrospective nature of data collected, this was done in order to maintain a sense of privacy for the mothers and not overly intrude on parenting. The infants were present at all engagements with the participants, which contributed to richer engagement during the interviews on retrospective and situational aspects of the experience of using Owlet [34].

3.1 The Owlet

This study used the Owlet Baby Care [50], a consumer device available in the United States for around 250 US dollars. The study used the Owlet in an attempt to avoid UK participants' familiarity with the technology and having preconceptions of it. The Owlet is a wireless baby wearable sleep monitor with an embedded pulse oximeter sensor that can detect a baby's breathing, heart rate and oxygen levels. The Owlet comprises a sock for the baby to wear (half-open and with a back strap) with a base station and a companion mobile app. The company advises that the base station is turned on only when the baby is sleeping at night. Also, it is to be put on the nightstand if the baby sleeps in the same room as the parents. The base station is connected to the Owlet via Bluetooth and provides different types of visual and aural alerts: detection of abnormal vital signs results in a red alarm; movement, ambient light and distance from the base station can all trigger blue or yellow

alarms. A blue light is activated when Bluetooth is disconnected (e.g. out of range, body/object blocks the signal); a yellow light is activated when the sock cannot obtain a good reading (e.g. wrong sock size, incorrect placement). If the Owlet can obtain a baby's readings, the mobile app shows the baby's current heart rate and oxygen levels and the 'normal' ranges. Otherwise, the app will show the reason why it is not getting readings. The Owlet offers three different sock sizes in the box and the sock should be changed every day.

3.2 Data Collection

Participants were provided with an Owlet baby wearable to use for two weeks. The research team assessed participants' experiences before, during and after using the baby wearable by capturing their activities and interactions with the Owlet. The data collection consisted of four phases.

The first phase included an entry briefing, contextual entry interview [25] and demographic questionnaire in the participant's home. The purpose of the entry interview was to understand each participant's lifestyle since giving birth, their general technology use, their technology use in the context of parenting and their understanding and expectations of wearable baby monitors. Since the study was exploratory, semi-structured questions [21] were asked to allow opportunities to probe if necessary and let participants talk more freely from their own perspectives. The interviews were audio recorded and transcribed verbatim.

The second phase involved the video recording of the participants' 'out-of-box' experience [18] of the Owlet. Users have certain expectations of a new system when using it for the first time and during and after the 'out-of-box' experience, users explore the product and turn their expectations to perceptions [31]. Each participant was asked to unpack the Owlet box and think aloud as they did so [49], to set up the device and use it for the first time (if possible) as the interaction was video recorded and observed.

Immediately after their 'out-of-box' experience, participants started a combination elicitation [11] and feedback [44] diary study capturing media and making diary entries of use and non-use of the Owlet. A diary study offered a way to record the situation in context of every interaction with the Owlet, and it also ensured that participants recorded their experiences 'in the moment' [11]. Participants were asked to use Microsoft OneNote or a diary application on their phone to record their experiences of using the baby wearable during their two-week experience by capturing photos and taking notes every time they interacted with the device. The primary purpose of this data collection was to allow the researcher and the participant to go through the diary entries together and discuss the experience of interacting with the Owlet.

At the end of the two weeks, the researcher went through the diaries with participants in their own homes. For those who used Microsoft OneNote, they did this using a laptop. Screen captures and audio recordings of the processes were taken. For those who used other methods such as taking notes in a calendar app, these could not be screen captured by the researcher so audio recordings were taken. The researcher would sometimes probe specific events to better understand participants' experiences. Diary analysis lasted no more than one hour for each participant. Contextual exit interviews were conducted immediately after going through the diaries and lasted for approximately 30 minutes. Questions included asking about participants' experiences with the baby wearable, including the use of the mobile app, awareness of the base station, influence of the baby wearable and overall impressions of the baby wearable. These were audio recorded and transcribed verbatim.

3.3 Data Analysis

Interpretative phenomenological analysis (IPA), an idiographic, inductive, and interrogative approach [57], was used to access individuals' perceptions of the Owlet by exploring participants' personal experiences in detail [17]. IPA applies flexible qualitative data collection methods, such as semi-structured interviews and diaries, which allow researchers to find unanticipated themes during analyses [58] from a small sample of participants [53]. Iterative analysis was conducted in five phases: transcribing the audio and video recording to gain a sufficient understanding of participants' experiences [8]; open coding each participant's dataset to understand their baby wearable use in context and to generate initial codes; creating participants' vignettes as a rich description of their diverse experiences; inductive coding [59] to iteratively develop the codes and

categorize them systematically; and reviewing and refining themes, generating definitions of each theme, and producing the report with vivid representative examples.

3.3 Participants

Participants were recruited through social media, adverts on classified websites and snowball sampling. The inclusion criteria required participants to live in London, use an iPhone, have a child under 8 months of age and be over the age of 18. Each participant was financially compensated with a £100 Amazon voucher on completion of the study and all gave informed consent as per institutional ethics clearance. In lieu of full vignettes, details used in the IPA about the six female participants on maternity leave are found in Table 1.

Table 1. Demographics and Description of Participant (pseudonyms used)

Participant	Children	Household
Lisa, 36, MSc Works in communications	Katie, 2.5 months (has reflux)	Two level flat, husband, cot in same room
Kate, 39, MSc Works in digital production	Jenny, 1 month (has reflux) & Christine, 2.5 years	Two level house, husband, co-sleeps alone with Jenny
Lora, 30, PGCE Works in teaching, has fibromyalgia	Roy, 3.5 months (has feeding issues)	Two level home, husband, cot in same room
Sarah, 40, Postgrad Works in compliance	Lily, 4 months	Two level home, husband, two grandparents, uses video monitor, cot in same room
Gloria, 37, MSc Works in occupational therapy, has postpartum anxiety	Kelvin, 3.5 months (had ear surgery)	Two level home, husband, cot in same room
Helen, 38, MBA Works in procurement	James, 6 months and Tom, 3.5 years	Two level home, husband, uses audio monitor, cot in same room & co-sleeps with James & husband

4 FINDINGS

Interactions with the device influenced the act of parenting. In particular, participants described an impact on knowledge production and their perception of the emotional, physical and social aspects of parenting.

4.1 Knowledge Production in the Care of Newborn

Learning and intuition is part of caring for new babies [37]. Even for parents who have other children, a new baby might have different health issues and react in different ways to similar parenting styles [24]. As such, it is a learning process to understand how to care for and engage with a newborn [56]. In this study, the device gave parents an opportunity to interact with information that they would not normally have access to, including pulse oximetry and heart rate data. We found that our participants used this information to experiment with and test hypotheses about their child, to supplement their instinctive understanding of their newborn, and out of curiosity.

4.1.1 Experimenting with the Baby Wearable. Some participants had particular questions about their baby and wanted to use the wearable to find out more information and test hypotheses. In this study, four out of six of the participants used the Owlet to try to find relationships between vitals and baby's behaviours or activities, such as sleep patterns. For instance, Lora confirmed her guess that Roy was a light sleeper through readings on the Owlet:

“His heart rate at the beginning of his sleep was about 120 or 130. When he’s in a deeper sleep, it goes down to about 110 or down to even 100...But his heart rate is always quite high in his sleep and so it kind of confirmed...” (Lora, diary)

Lora had fibromyalgia and was a very light sleeper. She felt that her baby, Roy, had the same difficulty with sleeping as he always woke up after five hours’ sleep “*on the dot*”. She wanted to test this by checking his vitals using the baby wearable:

“I’d like to see if his heart rate changes or his oxygen level changes after 5 hours, to see if there’s any reason. Mine is because I know I’ve got fibromyalgia, I don’t know if he is the same or...” (Lora, ‘out-of-box’ experience).

Sarah wanted to identify her baby Lily’s sleeping pattern through the Owlet so that she could prepare for when Lily woke up to allow her to get more work done and support her own broken sleep. She believed that her baby’s vital signs predicted visible ones, saying “Often visual signs are a little bit after, maybe she’s a bit too tired, so then you’re trying get her sleep but she’s too tired so she won’t go sleep” (entry interview). She mentioned several times during the entry interview that her life had become less efficient since giving birth, and that she was also thinking of using a sleep tracking website to understand Lily’s sleep pattern. Sarah expected that it would allow her to graph her baby’s sleep pattern, enabling her to prepare ahead and feel more efficient.

Lisa read an academic paper on the decrease in a newborn baby’s oxygen flow when they stay in a car seat for too long. As she was house hunting at the time of the study and spending a lot of time in the car driving to different properties, she decided to test her baby Katie’s vitals whilst in the car. She put the sock on Katie and was trying to see her oxygen levels via the app but failed because she forgot she needed to use Wi-Fi and the base station was at home:

“And so I put the sock on and we drove off and then I thought silly me, the base is at home, it’s not going to work.” (Lisa, diary).

4.1.2 Supplementing Knowledge with the Baby Wearable. Beyond testing hypotheses about their newborns by using the Owlet as an experimental tool, participants also wanted to use the device to supplement the information available about their infant. Four of the participants were first time mothers, and so they were very aware they had a lot to learn about parenting and some wanted the Owlet to aid this learning:

“I had no previous experience of babies, I have to learn, and my husband as well, we have to learn everything from scratch.” (Lisa, entry interview).

Participants were particularly keen to access temperature readings, a function not offered by the Owlet. Some participants mentioned they would like to see room temperature and their baby’s temperature on such devices. Although parents often use thermometers in rooms and thermometers to test their children for fever, there is also ongoing monitoring of temperature where parents can feel they need additional help other than touching their child:

“What I would want is temperature because she’s three months old and I still haven’t figured out when she’s too hot when she’s too cold, because her hands are not a good indicator” (Lisa, diary).

There were also new environmental situations that the participants had to navigate in relation to their newborn’s temperature. As this study ran in the summer, parents had to monitor hot days in order to dress their child appropriately. Kate wanted to know from the monitor when the weather was warm, whether putting her baby in a sleeping bag would make her too hot:

“It obviously felt warm but just knowing whether I should, because I like put her inside a sleeping bag thing, and it’s whether maybe I just need to not put her in the sleeping bag?” (Kate, exit interview).

Temperature sensing was mentioned as a source of information that would enhance a parent’s ability to monitor their child, but there were also expectations for additional information sources. Sarah expected the Owlet to be an analysis tool for all day use and provide historical records, so she expressed disappointment at

the 'out-of-box' experience. Other participants reported that they didn't know what data they expected from the device but they hoped to see more vitals. The novelty wore off quickly because of this:

"There was only like the two things, I just didn't feel as though, yeah, like the novelty had worn off if that makes sense" (Kate, diary).

Despite some disappointment with the information the Owlet could provide to enhance parenting knowledge and learning, it did provide some benefit to some participants. The use of the baby wearable changed Lora's thinking about parenting, and despite its issues, she now believes there was room for using technology in parenting. Before the study, she believed that parents had a sixth sense and would "know" if their baby was upset or if she as a parent had done something wrong; however, in the exit interview she acknowledged "But actually you might not".

4.1.3 Fueling Curiosity the Baby Wearable. The information the baby wearable provided was useful for experimentation and there were expectations for the information it provided to supplement the knowledge used in caring for a newborn. However, it was also found that participants sought information from the wearable even when it did not provide a specific function. Information regarding a baby's vital signs was not normally available to participants outside clinical settings - they were curious about this aspect of the tool.

Two participants identified that they had signed up for the study out of sheer curiosity. Before Lisa saw the Owlet, she was interested in some of her baby's data like "how many minutes or hours a day she cries" (entry interview). She explained it as "more just because I'm a geek not because of her health or anything..." (Lisa, entry interview). Kate said she participated in this study because she worked in advertising and was looking at different technologies:

"It would, maybe more be as an interest point of view, rather than for functional" (Kate, entry interview).

All participants used the Owlet during the night when the baby was sleeping and they checked on their phone or tablet to see their babies' vitals. Watching these numbers go up and down as the baby slept did not provide any useful information for the participants when the vitals were normal, but were nonetheless intrinsically interesting. Simply noting the Owlet readings in real time, Kate's husband questioned the purpose of its use. However, Kate was interested in seeing the readings fluctuate when she managed to get the Owlet to work. Lora found herself checking the app "every 5 minutes or so":

"This is quite addictive because I kept checking his vitals even though they were completely normal and they were within range." (Lora, diary).

Although the Owlet does not offer a recording function, participants checked their baby's vitals in the Owlet app at different times of the day, remembered the numbers, and then compared them. Four participants noticed that their baby's heart rate would decrease when the baby was in deep sleep compared to when they had just fallen asleep. Some participants remembered that the baby's heart rate was different during the day and night. When Lisa revisited her diaries, she reflected on her experience of looking at the data:

"We were looking and saying 'oh look now it's 108, oh now it's 105...'. We were actually wondering because the heart rate was changing so we were wondering is it when she goes into the different stages of sleep." (Lisa, diary).

4.1.4 Summary of Knowledge Production. Participants signed up to use the Owlet, a 'high tech baby monitor.' However, beyond monitoring, it was used (and attempted to be used) as a tool to enhance knowledge production of the infants and parenting in general. This ranged from what Rooksby et al. [55] calls diagnostic tracking for fibromyalgia to fetishized tracking as a co-parenting activity. It allowed participants to experiment and engage with information that would not have been available to them otherwise, ultimately influencing how they parented, or how they wanted to parent.

4.2 Anxiety in the Care of Newborn

Emotional aspects of parenting are amplified with a newborn. Caring for a new human presents numerous opportunities for health and wellbeing concerns that the baby obviously cannot communicate. Anxiety and exhaustion can be high in early parenthood, and we observed that these emotions were present across a range of participants' monitoring experiences.

4.2.1 Everyday Worries and Ongoing Monitoring. Although the baby wearable was designed to monitor infants exclusively during sleep, there were expectations that more ongoing monitoring could be achieved with this device. Before they received the device during the out-of-box experience, all participants indicated that they expected the Owlet to be for all-day use and some participants still held this expectation after using the device for two weeks. Sarah said she would like to have a monitor where "you can keep it on them longer and throughout the day," yet perceived her motivations for doing so as different to "the more hypochondriac moms" (exit interview).

Gloria was diagnosed with postpartum anxiety before she signed up for the study (health issues were not considered as exclusion criteria). When asked about her motivation for volunteering in this study, Gloria said "I just thought because I had the anxiety and I wanted to see if it kind of changed how I, or helped me in any way" (Gloria, exit interview). Gloria's baby, Kelvin, had ear surgery one month after birth and was connected to many devices in the hospital at that time. This had allowed her to check her child's vitals and she was therefore interested in using the Owlet for the same purposes to make sure "he is quite well, and everything should be normal" ('out-of-box' experience).

Four out of six participants reported in the exit interviews that they did not need a baby vital monitor because they knew their baby was healthy. As their children did not have major health concerns, their vitals should be within the 'normal' range and therefore they felt as though they did not require access to this information. They thought the device was more suitable for parents that have health concerns for their child:

"I wasn't worried about her health because I know she's a healthy baby and we're not really monitoring for a life-threatening condition." (Lisa, diary).

All participants experienced false alarms, and every participant used words such as "annoying" (Lisa, exit interview) to describe their experience. There was one participant who received an actual alarm signal from the Owlet during the study: Gloria received a red alarm once at in the middle of the night showing her baby's oxygen level was low. However, she physically checked her baby Kelvin and he looked fine, but it still rattled her:

"I don't know if I should leave it off or turn it back on, because I didn't know whether it was going to worry me with another false alarm or whether then turning it off was going to make me more anxious because I'm kind of anxious anyway." (Gloria, diary).

4.2.2 Specific Situations and Situated Anxiety. Ongoing sleep monitoring was considered the primary use for the Owlet by the manufacturer. However, most of our participants suggested it wasn't needed unless there was a specific health concern that they thought would require constant access to their baby's vital signs information. However, there were other situations that bred specific instances of anxiety in the mothers that they wanted to alleviate with the use of the device.

Sleeping practices are a general concern for many parents as there is the underlying risk of SIDS, and during the night parents might be asleep at the time their child needs them. Blair et al. [7] suggests that bed sharing should be avoided when certain circumstances make it more likely that a parent might lie on an infant. Co-sleeping, or sharing a bed with a child, is something that is discouraged in the Owlet pamphlet accompanying the device. The Owlet pamphlet also notes that technical reasons (Bluetooth signal interference) prevent the device from providing readings during co-sleeping. However, one mother wanted to use the Owlet expressly for extra reassurance during co-sleeping:

"I'm interested in products that can help baby safety for when they're co-sleeping, that was a motivation." (Helen, exit interview).

There were also other special circumstances where participants found the Owlet particularly reassuring, such as short-term health concerns. For instance, after vaccinations infants can develop high fevers and there is a low risk of more serious consequences related to the vaccine, so parents can be extra vigilant with

checking their child. Sarah checked her baby Lily's vitals frequently because Lily had an immunization that day and slept a lot:

"I did actually find it particularly useful that evening because she slept a lot, to check that she was ok and that she was still, because she had quite a lot of naps." (Sarah, diary).

Although some participants used the Owlet more frequently when their baby was feeling unwell such as when Sarah's child had immunisations, one participant chose not to put the sock on her baby when her baby had a fever. Instead of the device relieving anxiety in this situation, it was more alarming because she wanted to comfort him and it was disturbing both of them:

"he had a fever and he was waking up a lot, crying, wanting a lot of comfort so I didn't use the Owlet that night...It was more about it [base station] going off frequently during the night and disturbing both him and also me, and also because I was cuddling him a lot that night" (Helen, diary).

Short term illnesses or concern about illness also influenced the use of the device and its perceived usefulness. Gloria found the Owlet useful when her baby Kelvin felt hot one summer evening even though his temperature measured normal. She checked the Owlet app and said the normal readings were an "extra reassurance" to her:

"It was helpful to have the Owlet on again if he wasn't particularly well because then it was another way of getting readings, like his heart rate and stuff, so I guess if someone has like a minor illness it's a good way to keep a check." (Gloria, diary).

This is something that was mentioned about other parenting technologies as well: they would be adopted, bought, and downloaded to deal with certain health situations that arose, as needed. For instance, Roy had some problems with feeding at the time of the study, and Lora used a breastfeeding recording app so that she could show the feeding records to the doctor. However, the cost of the Owlet might prohibit such casual use.

4.2.3 Past Experiences and Anxiety whilst Monitoring. Past experiences influenced the use, adoption and experience of using the Owlet. Past experiences with other children and with health concerns of the infants had a large influence on situated experiences with the baby wearable.

Two participants had previous experiences that might increase their motivation for monitoring their baby. Helen's three and half year old first child, Tom, experienced a health issue that was identified by using another baby monitoring product. The AngelCare monitor breathing sensor system alarmed in the middle of the night when Tom was one month old and alerted Helen and her husband of a breathing problem that led to a hospital admission. However, the sensor mat could not work with her second baby, James, because they co-slept on the same mattress. Therefore, she wanted to try the Owlet as an alternative, although this was discouraged by the Owlet pamphlet:

"It [AngelCare mat] never worked with James, but it worked on my first one. But I would like to see it [vitals information], because I was very nervous about him using the AngelCare." (Helen, entry interview).

As mentioned above, Gloria already experienced a health concern with Kelvin before the time of the study when he had ear surgery. Because of this experience, she was familiar with the normal range of his vitals and thought the allowed range in the Owlet App was too wide; however, she thought it might be useful with regards to her anxiety linked to his previous health issue:

"It's [the Owlet] an extra peace of mind to make sure everything is fine." (Gloria, 'out-of-box' experience).

Two of the participants already had children and this influenced how they parented their second child. For Helen, her first child's health concerns influenced her vigilance in monitoring her second; conversely, Kate was "*much more relaxed*" with Jenny whereas she used to use apps to record "*everything*" about her first child:

"Versus my first, maybe it's just being a new parent, I just felt attached to her through the whole time, whereas feel a bit more relaxed with the second one" (Kate, entry interview).

4.2.4 Summary of Anxiety and Baby Wearables. As in Nelson's work [47], we found that some participants engaged with the baby monitor because of the normative status of anxiety, whether it was ongoing, situational, or based on past experience. Although participants used this device to alleviate anxiety, there were cases where this monitor was inappropriate for that goal and even increased anxiety through frequent alarms.

4.3 Physical Aspects of Parenting

There are physical aspects to parenting that are inherent when caring for a newborn. Proximity and touch are very important in the first months of life, and the baby requires all physical needs from the parent, including feeding and changing on a regular basis. As a newborn can only voice concerns through crying, parents need to be nearby and mindful of these physical needs for sustenance, hygiene, temperature control, and comfort. We found that the device interacted with this aspect of parenting with regards to checking the child and the physical nature of the baby wearable.

4.3.1 Proximity and Physically Checking the Infant. Parents need to be near their children in the early months of life to attend to their physical and emotional needs. This proximity involves hearing and seeing their children, and also being able to touch them. Physically checking a child is an important part of parenting, and this was considered common sense by some participants, such as Kate who thought she didn't need the Owlet:

"I can understand that [people use sensor monitors on unwell babies] but like if you're baby's actually healthy...you know, like common sense, you would actually visually check your baby and your baby would never really be too far from you anyway" (Kate, exit interview).

The structure of the home itself influenced how and when parents felt close enough to their child. Participants' homes were not very large: Lisa and her partner thought that baby monitors were unnecessary because they could hear their baby wherever they were in their apartment: "you keep the door open so that you can hear if the baby has woken up." Although Kate lived in a house, she found the use of the audio monitor with her first child Christine unnecessary "because it was just like an echo" and she could hear her throughout the home, and so didn't use a monitor with her second child Jenny.

The baby wearable had alarms that would go off to alert the user to problems with the pulse oximetry or heart rate readings. This enabled parents to be away from their child and still have access to their 'virtual child'. Gloria described how she checked Kelvin's vitals on her phone when she was exercising in the living room and her baby was sleeping in the bedroom; she simply did not physically check him as often:

"I didn't want him in the same room because he distracted me but then I always run in every 10 minutes and check on him...When I had the Owlet on him I felt much more secure, like I didn't run in and check on him." (Gloria, diary).

The Owlet reduced all participants' frequency of physical checks and increased the frequency of using their phone: "Overnight I would check it [the Owlet app] if I woke up, I might check it to see that she's ok." (Sarah, exit interview). Gloria reported that before using the Owlet, every time she woke up during the night she would physically check Kelvin, sometimes putting her hand on his belly to check he was breathing. However, in the exit interview she reported a change in this practice:

"Checking numbers on the phone is a little bit easier than going and checking the baby and I could do it from the bed rather than having to get out of bed..." (Gloria, exit interview)

4.3.2 Physicality of the Baby Wearable. The physical design of the device was significant. Unlike other baby monitors, the Owlet is worn on the child's foot and although its appearance is similar to clothing, it is quite different to a sock and only worn on one foot.

Participants described different opinions of the Owlet's aesthetic appeal. Some felt the packaging of the device alleviated their concerns about it being too much like a medical device. Lisa said that the Owlet had "nice finishing" during her the out-of-box experience and she thought "it doesn't feel like a medical device at

all.” Conversely, Kate saw a hospital-use wristband on the news and it reminded her of the Owlet and what her first child wore during a hospital visit: “That’s what it’s like in hospitals” (diary, Fig. 2).



Fig. 2. Hospital wristband on TV reminded Kate of Owlet (diary)

Although the Owlet was like a piece of clothing, it was not a normal or necessary item, so it could be forgotten when mothers were dressing their babies for bed. Lisa often forgot to put the Owlet on before Katie went to sleep, and it was not easy for her to put it on afterwards, as Katie wore sleepsuits with covered feet to sleep (see Fig. 3).



Fig. 3. Lisa putting the Owlet on Katie’s foot with her sleepsuit unbuttoned (out-of-box experience)

Lisa once put the sock on the wrong foot while doing this in the dark, which caused a false alarm and this startled Katie and woke up her partner. Similarly, participants’ fatigue meant that they didn’t put it on correctly or just purposely skipped using the device, ultimately leading to abandonment. When Lisa realized she had put it on the wrong foot and the alarm went off, she just turned off the base station:

“It was in the middle of the night, I’m dealing with a full nappy, a baby who is wide awake and wriggly, me who is in a zombie state, half asleep so that was a bit tricky.”
(Lisa, exit interview).

There seemed to be a fundamental design mismatch between the intended use of the device and the natural behaviours of the babies who were supposed to wear it. Five out of six participants reported that their baby kicked the sock off at least once during the two-week study. Roy often was barefoot as he would take socks off and did not like when his feet were covered. He was also a wriggly baby during sleep and the Owlet kept falling off him as he kicked it off. Lora found it difficult to put the sock on and to then keep the sock on him long enough to get a reading.

There were also concerns around perceived comfort. Lora found the sock was too tight for Roy, saying “he came out with marks,” but there were gaps between the sizes of the socks, and the bigger one just didn’t fit Roy’s foot, which caused false alarms. Lisa also found her baby Katie was uncomfortable with the sock and mentioned this in the diary: “That foot (without Owlet on) was completely dry and that one (with Owlet on)

was a bit sweaty.” Another example of possible discomfort was when Kate found her baby’s toes curled when wearing the Owlet while the other foot’s toes were relaxed (see Fig. 4).



Fig. 4. Jenny’s foot with Owlet on and her toes curled (diary)

4.3.3 Summary of Physical Context of the Baby Wearable. Throughout the findings, we saw an interplay between the physical nature of parenting and the physicality of the device. The nature of the functionality created a secondary, virtual baby. The use of this device influenced a very basic physical relationship between mother and child: mothers described a reduction in the frequency of physical checking and a turn towards a reliance and trust in the technology.

4.4 Social Aspects of Parenting

The act of parenting is not conducted in a vacuum. All study participants had partners living and co-parenting with them; contemporary households include parenting arrangements that go beyond the traditional idea of a ‘mother and father’ as parents. Even in our small in-depth study, one household had two grandparents engaged in full time caring for the child. Grandparents, siblings, cousins, friends, childminders, neighbours and so on, can all be engaged in acts of caring for a child, and we found that some of the social aspects of parenting were influenced by the use of this technology.

4.4.1 Co-Parenting with the Baby Wearable. All participants lived with their partners, who also took an interest in the technology (see Fig. 5).



Fig. 5. Lisa’s husband examining the technology (diary)

The technology and the recorded data became topics of conversation in the participants’ relationships. Although none of participants’ partners installed the Owlet app, most of them were interested in the baby’s vitals and sometimes asked about the numbers:

“He did ask about it...”what are the numbers now? Can you get a reading?”” (Gloria, exit interview).

The use of the baby wearable could also become a shared activity. When Lisa went through her diaries, she reflected on her experience of looking at the data with her partner:

“I mean my husband we were playing with it [the Owlet App], we were looking and saying ‘oh look now it’s 108, oh now it’s 105...’” (exit interview).

The women who had signed up to take part in the study quickly took on the role of ‘expert’ users, particularly in comparison to their partners. For example, when Lisa’s husband put the Owlet on their baby for the first time, Lisa presumed her husband could do it without her help: “I told him, “you’ll just figure it out, it’s quite self-evident”” (Lisa, diary). However, it turned out that her husband did not tighten the sock enough, triggering an alarm when the base station lost connection to the sock.

The baby wearable could also be a point of contention between parents. At the beginning of using the Owlet, Lora used a wrong size sock for Roy, which caused false alarms in the middle of the night and annoyed her husband, so she sought out online support and changed the sock size. She argued with her husband when he questioned why they were participating in the study; however, the potential for reducing their anxiety persuaded her to continue:

“I remember the first couple of nights we’d brought the baby home. Both of us took it in turns to just watch him...If I had that, maybe I would’ve slept and not been so worried” (Lora, exit interview).

4.4.2 It Takes a Village... Beyond the two parents of the children involved in this study, there were interactions with people outside the immediate family in relation to the use of the baby wearable, including friends and family. Some participants shared the baby’s data with their family members and friends. Lora talked to her sister on the phone about what she discovered about Roy and her fibromyalgia, sharing her findings about her baby’s light sleep and comparing it to other family members:

“...and she said, ‘oh, that confirms’, her son was the same, our other sister’s son was the same.” (Lora, diary).

In some cases, sharing this data with friends and family was perceived to be a step too far. There was a situation where a participant did not want to share too much detailed health data with their family members. Sarah’s parents had come to London to help her with the baby and also checked the baby’s vitals on Sarah’s iPad. However, Sarah made the choice not to install the app on their phone:

“Then we would have had all the parents asking for it as well and then they would have been constantly looking at it at 3 o’clock in the morning running into our room going “the Owlet, it’s not recording anything”” (Sarah, diary).

Some participants introduced the technology to people around them, including friends, and discussed its relative pros and cons. Lora visited a friend and forgot to take the Owlet off Roy’s foot. Her friend asked about the Owlet, wondering whether Roy had a foot injury. Lora explained the device to her friend and then they started talking about baby monitors in general, including discussing parenting strategies and how “far” they would take them:

“I said, “I don’t think I would [use a sensor monitor]. I think it’s a step too far”...And she was saying, “Yes I agree. I think the sensor is too far”...And then I realized, “oh actually the Owlet is supposed to be like that?”” (Lora, diary).

This influence of friends and family on parenting practices is common, and this was also the case for monitoring technologies. Lisa was sceptical about using the Owlet because she thought it might challenge her common sense and make her paranoid. Lisa’s negative attitude to baby monitors was influenced by watching her friends become obsessed with a video monitor, watching it instead of enjoying dinner together. The baby wearable also influenced some participants to look beyond friends and family. Lora expected to have a community forum where mothers could share their use of the technology and their motivations:

“Because I find parent forums really helpful, in general. And so if they have that on the App as well, I think that would be quite useful” (Lora, exit interview).

4.4.3 Summary of Social Aspects of Parenting. Parenting is inherently social. However, we found that deploying this device for use by a mother and her child also impacted the nature of co-parenting with a partner and a wider social circle involved in caring for the child. Although the focus of this study was on mothers, it

demonstrated that the introduction of high tech baby technology has a greater social impact beyond the one-to-one relationship, and these relationships in turn influenced the use of the device.

5 DISCUSSION

This situated study of the Owlet raises key issues around how use of a baby monitoring product directly impacts on parenting. The use of this baby wearable for two weeks changed how the participants constructed knowledge about how to care for their child, how they physically engaged with their child, how they perceived and experienced anxiety related to parenting, and how they engaged with their social network. Personal impacts of technology have been discussed by Pols and Willems [52], who propose that technologies are incorporated into users' everyday lives and convey meaning to make users think, feel and act in various ways. The Owlet was not a neutral system, incorporated as an adjunct into intimate family life: the baby wearable became influential.

Lupton [39] notes the evident issues of trusting data over embodied knowledge: she found that through their experience with tracking technology, people tended to rely more on the data and thus showed less trust in their own body's perceptions. Our data showed a similarly complex case, fraught with positive and negative implications. Mothers began to trust the phone to provide a new way of checking on their baby, reducing the frequency of their need to use their own lived experience as a source of intuition. Simultaneously, having access to information that they would typically only be privy to in a hospital setting enabled participants to learn about their infants by testing their own hypotheses, providing a source of increased confidence and trust in their own intuitions. It also encouraged simple observation of the vitals moving up and down: this enhanced form of 'curious' parenting allowed a type of knowledge production that was not possible before. The lived experience of gaining knowledge about caring for an infant [41] and the embodied nature of motherhood [37] was thus impacted by this technology. This finding extends related HCI and CSCW research on the impact of website and app technologies related to motherhood to the embodied impact of a physical parenting device and related virtual representation.

As with the study of online reviews of baby monitors [47], a technology that is supposed to relieve anxiety can actually produce a new source of worry. Although past experiences (such as previous health scares) impacted their use of this technology, the technology itself impacted on how participants perceived ongoing and situation specific anxiety. The baby wearable only provided monitoring during sleep; however, the participants discussed the usefulness of 24/7 access to vital signs information. The baby wearable does not work well with co-sleeping, but that is precisely why one participant wanted it. Fears related to the health and safety of the infant were inherent in the motivation of some to sign up for this study, and participants wanted to use the baby wearable to alleviate low levels of constant anxiety as well as specific situations that they worried about. The participants intended to enhance their parenting with this technology, which highlighted tensions between managing anxiety and trusting maternal instinct with the addition of an interactive CSCW system that literally came between the mother and her child.

Technology changes familial relationships. Previous research has proposed that health technologies are not neutral but could impact complex relationships [12,22]. Quantifying children can impact on relationships in the wider family, and there was some indication that the mothers in this study acted as data 'gatekeepers'. Study participants introduced the device to their partner; partners and family members checked the readings together with participants; participants did not provide access to the data to other family members; and numerous failures in quantifying the baby made partners question whether using the device made any sense. This study raises questions about how baby wearables and their associated data streams might influence relationships in unexpected, and perhaps unwanted, ways. This furthers discourse in CSCW on intimate relationships and the impacts of health related technologies [e.g. 30].

We found that participants occasionally elected to check the virtual baby represented through vitals present on their mobile phones instead of their actual baby. Combined with the physical nature of the device as a worn on the child, this brings up notions of the cyborg baby [15]. The technology impacted the physical nature of motherhood, and created a virtual tether to the child [47] that impacted real proximity to the child. The value of this is complex: when does the parents' impulse to check (or not check) their baby go from natural and

healthy to excessive? Some participants reported in the exit interview that they still preferred to use their common sense and visual checks rather than rely on the Owlet readings, indicating some persistent tensions in their relationship with the devices. Some participants evidenced awareness of these tensions in their interviews, and overall, our participants had an informed but casual attitude regarding the potential for the device to impact their parenting style. This casual attitude may have been influenced by the experience of using the device: past novelty and initial insights gained, it wasn't actually that useful in terms of doing more than providing “only [...] two things” (Kate) to look at during the night and participants found the technology’s pragmatic usefulness to be extremely limited (e.g. exercising in a different room). Despite its “nice finishing” (Lisa), the Owlet was a surveillance device that potentially separated women from their babies. Although the participants did not note this as being problematic, we interpret it as such. This device appeared to appeal particularly to more anxious mothers, or those whose infants have medical histories. These mothers both perceive more utility from the device and consequentially are likely to be most vulnerable to amplifying anxiety and the more problematic concerns noted above. Further research is necessary to see how more extended use of baby wearables, in particular in parents prone to anxiety, may affect their parenting confidence and anxiety as well as patterns of physical contact and interaction between mothers and their infants. This is relevant more generally as these appear to be the most likely market for long term use of baby wearables.

Instead of providing design implications, this paper attempts to show some of the ways that parenthood can be influenced by emerging consumer technology marketed to alert if something is ‘wrong’ with a child. Taking care of an infant can be an all-encompassing task, and there has been a trend towards assuming that huge amounts of time, money, and effort should be spent on raising a child [23] in an effort to mitigate perceived risk. This of course means that responsibility is put on parents, and particularly mothers, to care for their vulnerable infants in any way possible and avoid any possible risks to their “protected world” [13]. Some have postulated that this has driven parents towards monitoring their children with the use of technology [45], and this of course means that an increasing number of devices will leverage technological advances and come to market. However, these devices are not a neutral addition to the large number of tools to enhance parenting capabilities; rather they have the potential to disrupt or modify the emotional, physical, social and knowledge production aspects of parenting. There is the risk of changing the embodied act of mothering, perhaps with the digital measurement of vital signs becoming a part of a baby’s identity and the further medicalisation of motherhood.

The Owlet appears to break all of Gaunt et al.’s design suggestions [19]. We found that it did not avoid “increasing parental anxiety” but rather aggravated anxiety while also providing some perception of security. We found at least one salient case where “inhibiting parental intuition” was present with the addition of the data provided by the Owlet. We also found that it allowed the “increasing the distance between parent and child” through a ‘virtual baby’ representation on a mobile phone. We would also add to these design suggestions that aggravating social ties should be avoided in the design of high-tech baby devices, as we found that the baby wearable caused some contention in the social act of parenting. Further research is necessary to see how more extended use of baby wearables might affect these mothers’ relationship to their infants, and importantly, whether potentially negative or maladaptive outcomes begin to appear with the addition of a ‘virtual baby’ to a parenting toolkit.

5.1 Limitations

This was a focused study of women who were interested in using the new baby wearable technology in their parenting practices, and as such, resulted in a small number of participants that were all over 30, able to take maternity leave (all interviews were conducted during week-days), highly educated and interested in technology. Although this was in line with the in-depth qualitative approach taken, it of course limits the generalisability of the findings and biases this study towards people that were interested in acquiring this expensive baby equipment, rather than seeing how the device might influence a wider range of people.

Furthermore, this research did not have exclusion criteria based on medical conditions, and the small sample size included both mothers and children with issues that may have influenced the findings, particularly with regards to anxiety. This study was designed to focus on the experiences of women using a baby wearable based on the extensive sociological literature on mothering, but of course the findings show the wider social aspects of parenting. Future studies could widen the scope of understanding how different people engage in parenting and their use of technologies, not least fathers, partners, child minders, and grandparents. Further studies should also try to engage with various degrees of situated study to understand real world use, beyond what we were able to capture using a pragmatic methodology that relied on some retrospective measures with one device that was given to participants for two weeks.

6 CONCLUSIONS

The aim of this study was to explore the real-world use of baby wearable technology, the Owlet baby wearable. By conducting a flexible situated study with six participants, this work found that each participant had particular experiences of using the baby wearable in her own terms. The use of this device by mothers could be disruptive to their day-to-day parenting routines and lifestyle. The change of mothers' interactions with the baby along with the role the baby wearable plays in the family's conversations influenced the relationships between mothers and their babies as well as mothers with their partners and other family members. These findings highlight the importance of taking a situated approach to investigating the real-world use of technologies that are supposed to enhance aspects of parenting, as they are not neutral tools. Furthermore, this study opens this research area to real world studies of these devices as they are released and more importantly, when they are being designed. This paper is the first to critically engage with how a high-tech monitor might influence parenting. However, the use of technology in intimate settings is a growing trend. The findings of this study are specific to the context and the use of the Owlet, but this paper shows there is much to be learned from the CSCW and HCI communities as we engage further with new technologies embedded in the complexity of people's lived experiences of parenting.

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