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Research Article

Smart Technologies: The Use of the Internet of Things for Children's Health and Well-Being

Kajal Mistry[1, *] and Georgios Dafoulas[2]

[1]Research Scholar, Department of Computer Science, Faculty of Science & Technology, Middlesex University London, The Burroughs, NW4 4BT London, United Kingdom

[2]Professor, Department of Information Systems & Business Computing Computer Science, Faculty of Science & Technology, Middlesex University London, The Burroughs, NW4 4BT London, United Kingdom

[*]Corresponding Author: Kajal Mistry. Email: K.Mistry@mdx.ac.uk

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Abstract: The use of Internet of Things (IoT) wearable sensors in healthcare, particularly for monitoring children's mobility, is on the rise. Applications range from addressing obesity and mobility constraints to ensuring safety in densely populated areas. However, adopting these technologies raises concerns, including device safety, potential skin risks, data privacy, and the impact on family routines. Issues such as familiarity with digital technologies and the implications of tracking vital signs and location data are central to adoption challenges. This paper provides an up-to-date analysis of emerging concerns and innovations in child health monitoring using IoT technologies. By examining safety, privacy, and usability considerations, it aims to enhance understanding of practical challenges and propose solutions for adopting wearable health technologies to support children's well-being

Keywords: Internet of Things (IoT), Smart Wearables, Children's Independent Mobility (CIM), Emotion Detection, Health and Well- Being

1.Introduction

The integration of IoT wearable technologies in healthcare presents a transformative opportunity for monitoring children's mobility and well-being. The rising prevalence of childhood obesity highlights the need for real-time, non-invasive monitoring to support early detection and preventive healthcare [1]. Additionally, the decline in Children's Independent Mobility (CIM) due to parental safety concerns and societal constraints has worsened physical inactivity and health issues [2][3]. This study explores how IoT wearables can enhance children's health and mobility while addressing parental concerns. It aims to provide parents, educators, and healthcare providers with actionable data to improve care quality and safety. Despite the known benefits of IoT sensors, challenges remain in data privacy, usability, and family integration. This paper makes several key contributions:

1. **Framework Development:**Proposes a technology-assisted model integrating IoT devices for health monitoring, location tracking, and well-being assessment.
2. **Empirical Insights:** Presents findings from a pilot study with surveys and observations, highlighting parental and child perspectives on IoT adoption.
3. **Review of Current Practices:** Analyzes state-of-the-art IoT applications in children's healthcare, identifying adoption and scalability challenges.

This research uniquely addresses parental concerns while promoting CIM through ethical IoT applications. It emphasizes the need for accurate health tracking, location monitoring, and emotional assessment for a holistic approach to child health. Using a mixed-methods approach, including surveys and observational studies, the pilot study monitored 10 children (aged 3–10) with Fitbit Charge HR devices, alongside parental surveys during COVID-19. Aligned with the Fourth Industrial Revolution (IR 4.0), this study leverages IoT to advance sustainable, ethical, and effective child health monitoring systems across diverse socioeconomic contexts

2. Background

The integration of Smart Technologies and the Internet of Things (IoT) is transforming children's health and well-being by enhancing Child Independent Mobility (CIM)—allowing children to navigate their environment without constant supervision. CIM fosters responsibility, confidence, and social skills. Wearable devices and IoT-enabled systems support physical activity, emotional growth, and independent travel through applications such as fitness trackers, remote monitoring, and smart home integration. IoT Wearables (e.g., smartwatches) track vital signs like heart rate and activity levels, while remote monitoring enables real-time data sharing with parents and healthcare providers. Smart home technologies, such as air quality sensors, enhance safety. However, CIM is influenced by factors like age, gender, parental attitudes, and societal norms [4][5]. Boys and older children often have more freedom, while traffic dangers and societal fears limit CIM, reducing physical activity and social development. Urban infrastructure (bike lanes, safe crossings) plays a key role in CIM, while air pollution and unsafe environments deter independent mobility. Wearable trackers and real-time location monitoring help alleviate parental concerns [6].

However, privacy remains a challenge, as children's data is classified as ”special data” by the UK Information Commissioner's Office (ICO), requiring parental consent for children under 13 [7][8].Devices like Fitbit Charge HR, Kids Nav Venture, and XPLORA GO are well-suited for CIM, offering health tracking, location monitoring, and activity assessment. However, features like GPS microphones, and cameras must be secured to prevent unauthorized access. Our proposed CIMHAST framework integrates biometric data, surveys, activity tracking, and environmental observations, prioritizing safety, privacy, and well- being. It offers a structured approach to developing personalized health interventions for children

3. Related Works

The integration of IoT technologies into children's lives enhances health, well- being, and independence but also raises concerns regarding physical health, social behavior, and autonomy. This review evaluates research across key domains—Child Well-being (Fitness/Obesity), Technology Use, and Independent Mobility—to identify benefits, challenges, and gaps in IoT adoption. Ching Lam et al. (2020) reviewed IoT technologies for childhood obesity, emphasizing potential benefits but overlooking behavioral, social, and environmental factors essential for long- term adoption [9-11]. Ethical concerns, such as data privacy and security, were inadequately addressed, and the study lacked systemic integration. Messena and Everri explored IoT's impact on children's well-being but failed to account for cultural, socioeconomic, and geographical diversity. Their study also neglected parental roles, peer interactions, and risks like cyberbullying and surveillance [12-13]. Alkhalifah, Alqahtani, and Orji (2020) examined mobile apps for co-monitoring children but did not integrate caregivers, educators, or ethical data collection. Practical scalability across diverse healthcare systems was also overlooked [14-15]. Uddin Ahmed et al. (2017) proposed a solar- powered wearable for children with autism, including GPS tracking and health monitoring, but failed to address concerns about over-surveillance, autonomy, and advanced emotional detection [16]. Riazi et al. highlighted the benefits of Children's Independent Mobility (CIM)—fostering responsibility, confidence, and social skills—but did not adequately address socioeconomic disparities or surveillance risks [17-18]. Collectively, these studies show IoT's potential in improving child health and mobility [19] but reveal critical gaps in privacy, systemic integration, and long-term impact analysis. Future research should adopt holistic, ethical approaches that consider cultural, socioeconomic, and environmental factors to ensure sustainable and equitable IoT applications for children

4. Proposed Framework - CIMHAST

The Children's Independent Mobility and Health Assisted Smart Technologies (CIMHAST) framework shown in fig 1 provides a practical solution for promoting children's independent mobility while monitoring their health and well-being. Developed from study findings, it offers a comprehensive approach for parents, guardians, and health professionals, including dietitians, to support physical activity and disease prevention. CIMHAST consists of four key stages derived from the literature review, observations, and data collection:

- Data Collection – Three intervals of data gathered for the study.
- Key Performance Indicators (KPIs) – Identified through literature analysis.
- Suggestions – Derived from previous findings.
- Proposed Solution – A structured IoT-based approach to enhance child mobility and health

This research consisted of three stages for data methods which are:

- Stage 1 – Survey: Perceptions of from participant's habits of technology including children
- Stage 2 – Consent form: An agreement from parents which allow their child to participate in the data collection and Observation: Data collection from Fitbit
- Stage 3– Survey: Parent and child experience of Fitbit used Stage 1 – Data collection included four types:
- **Surveys:** Gathered insights on technology use, health monitoring awareness, and biometrics from adults and children.
- **Device Input:** Tracked activity, heart rate, GPS location, and vitals like pulse and temperature.
- **Children's Information:** Collected BMI, age, gender, and other personal data relevant to mobility and health.
- **Observation:** Assessed wearable accuracy, emotional response tracking, and practical usability.

Key Performance Indicators (KPIs) identified in the literature review include health, well-being, and safety factors influencing children's mobility. Environmental concerns such as pollution and neighborhood safety directly impact CIM, requiring IoT-driven interventions.

Stage 3 – Suggestions: The filtered KPIs align with IoT features to provide effective solutions.

- Pulse detection can monitor pollution effects and assist in obesity prevention.
- Heart rate monitoring supports physical activity analysis and health trend predictions.
- GPS tracking enhances security and facilitates location-based activity monitoring.
- Activity tracking promotes fitness while addressing parental concerns.

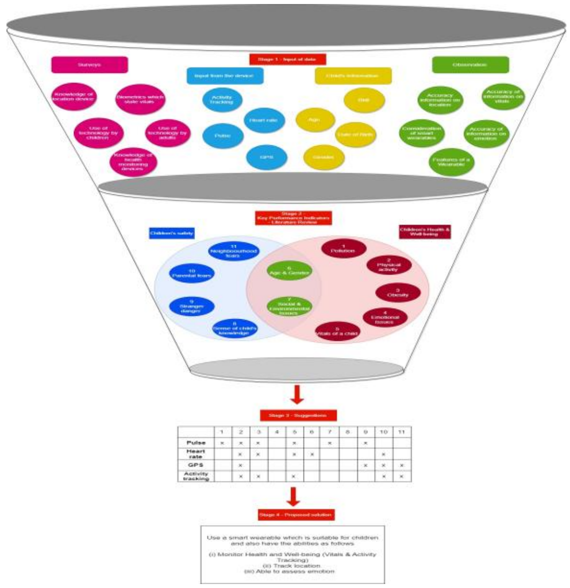

Figure 1: Proposed Framework - CIMHAST

The final phase integrates the findings into a proposed IoT-based solution for child health and mobility. This framework is adaptable, allowing additional features based on technological advancements.

Non-functional requirements include:

- User-friendly interface with accessibility features.
- Real-time data collection and continuous monitoring.
- High security to ensure privacy compliance.
- Ethical considerations for children's data and research participation.
- Scalability to integrate various wearable technologies.
- Reliability for consistent and precise data tracking.

Stage 3 – Suggestions This phase refines KPIs into practical IoT solutions.

The matrix table links KPIs with device features and functions. **Pulse Detection:** Smart wrist technology can monitor pulse changes due to pollution and physical activity. It assists in detecting obstacles in blood flow, addressing obesity concerns, and alleviating parental fears regarding their child's health. **Heart Rate Monitoring:** Wearable sensors efficiently track heart rate, supporting fitness improvement and early detection of potential health conditions based on gender and age differences. **GPS Tracking:** Enables monitoring of children's locations, addressing safety concerns, and mitigating parental fears while supporting CIM. **Activity Tracking:** Encourages movement, combats obesity, and reassures parents by displaying a child's activity levels and locations. Filtered results from these phases inform the proposed IoT-based solution, combining literature review insights with real-world applications to enhance child health and mobility.

The framework can evolve with new device features and functions. Beyond functional requirements, non-functional aspects include:

- Child-friendly and parent-accessible interface.
- Real-time data collection and monitoring.
- Robust security and compliance with data protection laws.

- Ethical considerations for children's data use.
- Scalability to integrate multiple wearable technologies.
  Reliable data tracking for continuous monitoring.

This structured framework ensures security, usability, and effectiveness, contributing to children's well-being through smart wearables while offering valuable insights for parents and health professionals.

5.Methodology

The framework consists of three phases, each contributing to a comprehensive investigation:

- Phase 1: A survey examined children's and parents' technology use, focusing on familial dynamics, concerns, and experiences.
- Phase 2: Observations were conducted using the proposed device to assess IoT's potential for tracking location, health, and vital signs. This phase involved (i) 10 children aged 3–10, (ii) activities spanning 1–3 hours, and (iii) guided tasks. Fitbit Charge HR was chosen for its child-friendly design and ability to capture relevant data. Parental consent was secured, and instructions were provided before data collection over four months.
- Phase 3: A survey gathered parent and child feedback on device functionality, usability, and overall experience.

Parental perspectives on smart wearables were also evaluated, exploring purchase intent and key motivators such as vital signs monitoring, location tracking, and communication enhancement. Due to COVID-19 restrictions in early 2021, the study adapted to a smaller participant pool while considering logistical and sanitation challenges. Additionally, insights on pandemic-related technology usage were examined.

Ten children participated in this study, aligning with developmental stages where parental mobility restrictions are common. Each child completed activities tailored to their age within a 1–3 hour period, with data collected via Fitbit Charge HR. Activities were conducted in flexible order, allowing personal adaptation. Literature-guided tasks ensured engagement, aiding data collection on emotion, heart rate, and well-being. Fig 2 explains the data collection process.

The activities included:

- **Building the tallest tower:** Encourages creativity and competition, tracking emotional response through heart rate variations.
- **Treasure Hunt:** Encourages movement and exploration while tracking steps, calories burned, and location.
- **Coloring/Dot-to-dot:** Measures resting heart rate, leveraging relaxation effects.
- **Jigsaw Puzzle:** Assesses cognitive engagement, detecting emotional states tied to problem-solving.
- **Card Matching Game:** Evaluates memory and cognitive function, identifying focus-related biometrics.
- **Balancing on Tape:** Tests balance and motor skills, tracking stability- related indicators.

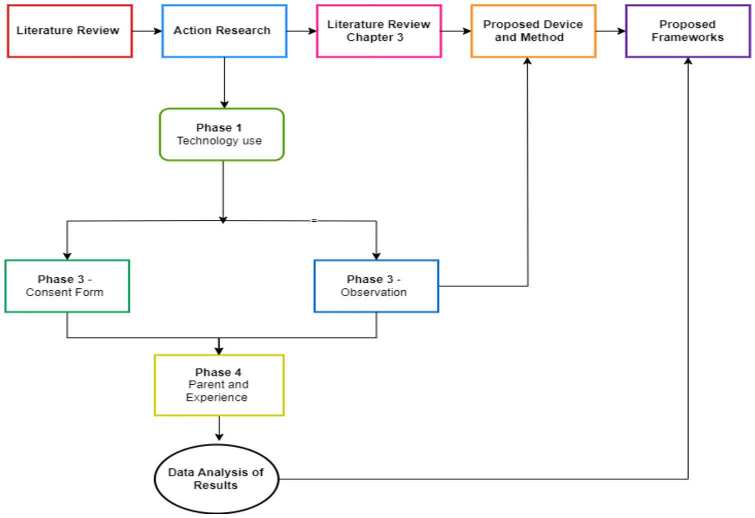

Figure 2: Data Collection Process

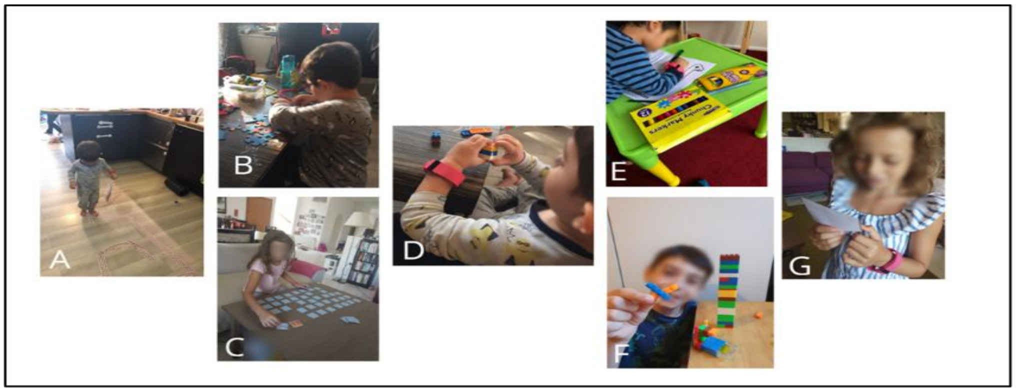

Figure 3: Participants Engaged in Activities

Participant images shown in fig 3 were used with parental consent, ensuring anonymity. The following activities were visually documented:

- Image A: Tape balancing
- Image B: Jigsaw puzzle
- Image C: Matching cards game
- Image D: Tower building
- Image E: Coloring book
- Image F: Lego construction
- Image G: Treasure hunt

5.1 Chosen Device

The chosen smart wrist wearable for this research was the Fitbit Charge HR, selected to (i) track location, (ii) monitor health and well-being, and (iii) track activities. This device effectively records activities such as walking, running, and cycling while monitoring vital signs like heart rate. Its durable screen withstands wear and tear, displaying key data that can be fully analyzed on a connected device, such as a laptop. Additionally, its lightweight design ensures a comfortable user experience. Initially, two devices were considered—one with Bluetooth connectivity and one with cellular connectivity. However, the cellular device failed to establish a connection. The features used in this research included: PurePulse Heart Rate Monitoring: Embedded for continuous and automatic tracking, providing real-time readings and resting heart rate measurements. This was especially useful for monitoring children during various activities. Wireless Syncing: Enabled seamless data transfer between the Fitbit tracker and connected devices like computers or smartphones. SmartTrack Feature: Automatically recognized and recorded workouts, capturing key statistics such as activity duration, calories burned, and heart rate zones. This feature conveniently tracked steps and movement throughout different activities.

6.Results

Understanding how children interact with smart devices is essential for comprehensively studying their digital habits. Investigating behavioral patterns reveals how often and for how long children engage with technology. Exploring educational impact provides insights into device usage for learning, including educational apps and online activities. Examining social interactions highlights whether devices facilitate or hinder communication among children. Lastly, considering health and well-being factors, such as screen time, sleep patterns, and overall physical and mental health, helps assess the broader impact of technology on children's development. Addressing these aspects offers a nuanced understanding of how smart technologies shape various dimensions of children's lives.

6.1 Survey Results

The first survey allows exploration of the focuses within the family and their view, concerns, practices, and their experience of their own and concerning children within the house. Understanding how children interact with smart devices is essential for comprehensively studying their digital habits. Investigating behavioural patterns reveals how often and for how long children engage with technology. Exploring educational impact provides insights into device usage for learning, including educational apps and online activities. Examining social interactions highlights whether devices facilitate or hinder communication among children. Lastly, considering health and well-being factors, such as screen time, sleep patterns, and overall physical and mental health, helps assess the broader impact of technology on children's development. Addressing these aspects offers a nuanced understanding of how smart technologies shape various dimensions of children's lives.

As seen in Figure 4, the bar chart titled ”Devices used per age group” illustrates the number of devices children use at different stages of development. The devices analyzed include smartphones, computers, TVs, tablets, and smart wearables. One of the most striking observations is the high reliance on smartphones across all age groups, with particularly strong usage among 0–1, 2–3, and 6–7- year-olds.

However, there is a noticeable decline in smartphone use in the 8+ age group, suggesting that as children grow older, their engagement with other digital devices increases. Computer usage, on the other hand, is minimal among younger children but sees a sharp rise in the 8+ category. This could indicate a shift towards educational purposes, school-related tasks, or gaming activities that require a more advanced interface. Meanwhile, television use is relatively high in early childhood, peaking around the 2–3 and 4–5-year-old groups, before gradually decreasing in older children. This decline might be attributed to the growing preference for interactive or on-demand content over traditional TV viewing.

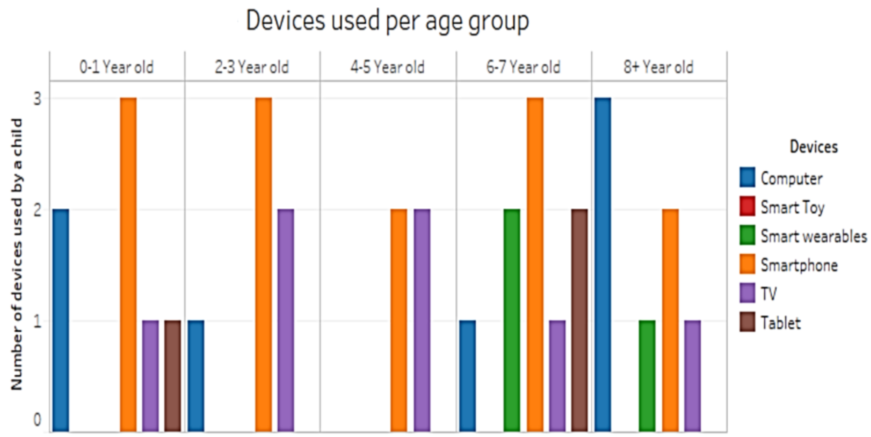

Figure 4: Device used per age group.

Tablet usage remains fairly consistent across most age groups, suggesting that it serves as a versatile device for both entertainment and learning. Smart wearables, however, are absent from the younger age groups and only appear in the 6–7 and 8+ categories. This pattern implies that these devices are primarily adopted by older children, possibly due to increasing interest in fitness tracking, digital accessories, or parental investment in monitoring technology. Overall, the data highlights a clear evolution in device preference as children grow, moving from smartphones and TV in early childhood to computers and smart wearables in later years. This trend reflects changes in technological exposure, learning needs, and digital engagement across different developmental stages.

As seen in Figure 5, the chart categorizes children by age group and device usage. The given options were Computers, Smart Wearables, Smartphones, TV, and Tablets. The analysis highlights distinct device preferences across different age groups. Infants (0-1 years) predominantly use smartphones. In the 4-5 age range, smartphones and tablets are the most common, while 6-7-year- olds use multiple devices, with smartphones leading, followed by computers, smart wearables, tablets, and TV. The study examined device usage across five categories: Communication, Learning, Health Monitoring, Playing Games, and Watching Videos. The most popular activity across all age groups is watching videos, particularly on platforms such as YouTube, Netflix, and Disney+. Playing games ranks second, followed by learning and communication. Notably, health monitoring is the least common use of smart devices among children. These insights are valuable for designing age-appropriate content and interventions that align with children's needs and preferences.

Figure 6, This visual representation consists of two bubble charts that illustrate the average time children spend on devices per day and the increase in device usage during lockdown. In the first chart on the left, the largest bubble represents children who use devices for 2–3 hours per day, with a frequency of 6. This suggests that the majority of children fall within this range of screen time. A smaller proportion of children use devices for 0–1 hours per day (with a count of 2), indicating a relatively low engagement with screens in this group. There is also a segment of children who spend 4–5 hours per day on devices, though this group is smaller, suggesting that extended screen time is less common but still present. The second chart on the right highlights the increase in screen time during lockdown. The largest bubble shows that 7 children experienced an increase of 0–1 additional hours per day, suggesting that, for most, the change was moderate.

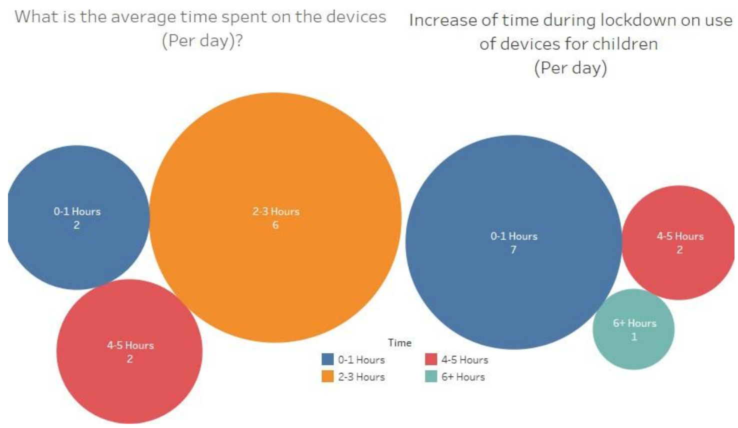

Figure 5: Bubble chart of hours spent: Pre-COVID and Post-COVID Times

However, there is also a significant group who saw an increase of 4–5 hours per day, reflecting a substantial rise in screen time, likely due to online learning, entertainment, or reduced outdoor activities. Additionally, a smaller group reported an increase of 6+ hours per day, indicating extreme shifts in digital engagement during lockdown. Overall, these charts suggest that while 2–3 hours of daily device usage was the norm before lockdown, the pandemic led to a noticeable increase in screen time, with some children experiencing drastic changes. This highlights the impact of lockdown measures on children's digital habits, potentially reshaping their long-term media consumption and device reliance.

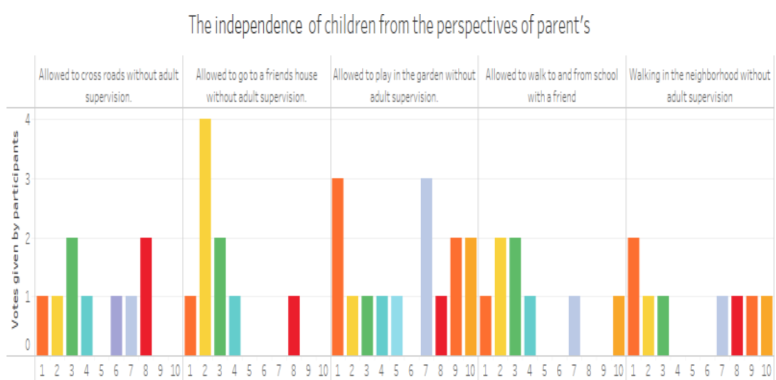

Figure 6: Purpose of use of Devices

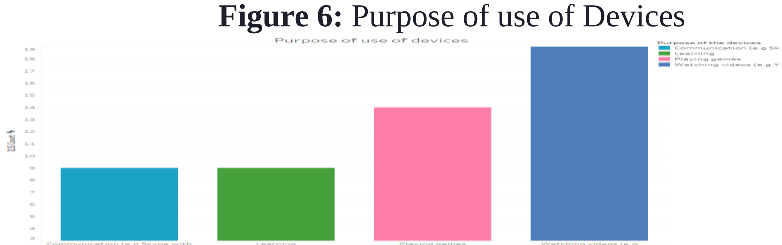

Figure 7: Level of Independence- Parent's Perspective

Figure 7, presents data on parental opinions regarding different aspects of a child's independence. The categories measured include whether children are allowed to cross roads, visit a friend's house, play in the garden, walk to and from school with a friend, and walk in the neighborhood without adult supervision. The bars represent the number of votes given by participants for each level of independence. In the ”Allowed to cross roads without adult supervision” category, the responses are relatively mixed, with some parents permitting it while others remain cautious. This suggests that road safety remains a concern for many. ”Allowed to go to a friend’s house without adult supervision” shows a strong variation, with one category receiving a notably high number of votes, indicating that many parents have a defined age or level of maturity at which they allow this independence. For ”Allowed to play in the garden without adult supervision,” there is a clear peak in one of the bars, showing that a significant number of parents feel comfortable letting their children play outdoors in a controlled environment.

However, the ”Allowed to walk to and from school with a friend” category displays a more even distribution of responses, suggesting that parental comfort levels vary depending on location, perceived safety, or a child’s maturity. Finally, ”Walking in the neighborhood without adult supervision” follows a pattern similar to crossing roads, where responses are scattered across different levels. This implies that neighborhood safety and child responsibility are key deciding factors for parents. Overall, the data reflects how different aspects of a child’s independence are perceived differently by parents, with some freedoms being granted more readily than others

Figure 8, illustrates the number of participants whose children own a smart wearable device. The results show a clear disparity between ownership and non- ownership. Out of the total participants, only 3 reported that their child owns a smart wearable, while the remaining 12 stated that their child does not. This suggests that smart wearables for children are not yet widely adopted among the surveyed group. The reasons could range from cost, necessity, parental concerns over screen time, privacy issues, or lack of awareness about these devices. While smart wearables can provide benefits such as fitness tracking, location monitoring, and communication features, the data indicates that they are not yet a common accessory for children. If adoption rates increase in the future, it may be interesting to explore whether parents begin to perceive them as essential for safety or learning. Additionally, trends in wearable technology advancements and affordability may influence their uptake among younger users.

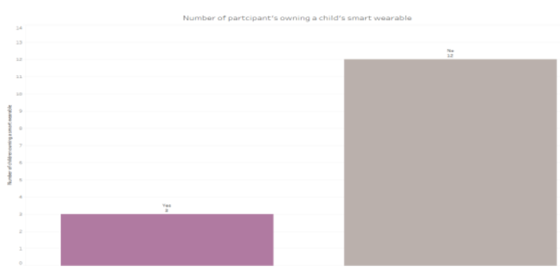

Figure 8: Ownership of a Child’s Smart Wearable

The analysis depicted in Figure 9, bubble chart highlights the key areas of conflict between parents and children regarding technology use. The most significant point of contention is the amount of screen time, with 11 parents reporting this as an issue. This suggests that parents are highly concerned about excessive device use, possibly due to its potential impact on health, social interaction, and academic performance. The second most common conflict relates to homework, with 6 parents indicating disputes over balancing schoolwork and device use. This could suggest that digital distractions interfere with children's ability to focus on educational responsibilities. Additionally, 4 parents reported concerns about bedtime/sleep, likely indicating that screen use before bed is affecting sleep quality. Another 4 parents mentioned disagreements over the activities done on the device, suggesting that the type of content children engage with is also a concern, possibly in terms of educational value, safety, or appropriateness. Overall, the data reflects a broader challenge for parents in managing their child's technology use. It highlights the importance of establishing digital boundaries, promoting healthy screen habits, and ensuring that device usage aligns with educational and well-being goals.

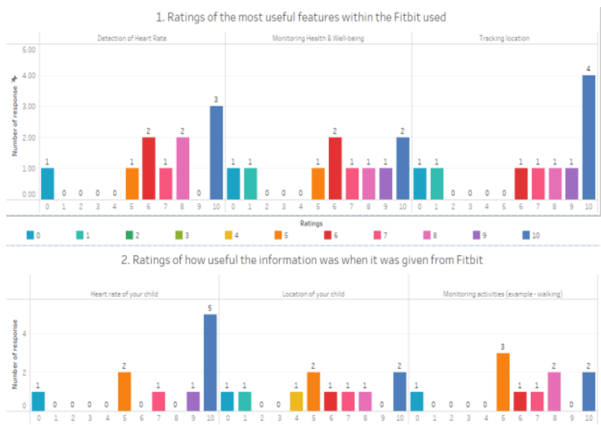

Figure 9: Conflicts between technology and their parent

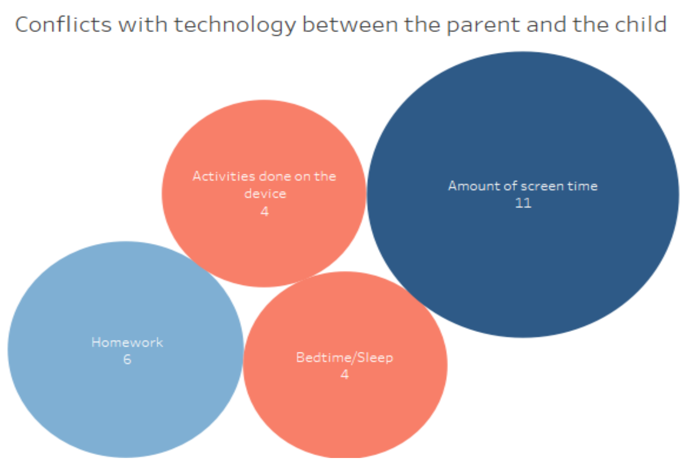

Figure 10: The Usefulness of the Fitbit Device

Figure 10 presents ratings on the usefulness of Fitbit features and the information it provides. Among the most useful Fitbit features, the detection of heart rate was highly rated, with three participants giving it a perfect score of 10, while others provided moderate ratings between 5 and 8. Monitoring health and well- being received mixed feedback, with some participants rating it highly (10 by two people) and others giving lower scores ranging from 5 to 8. Tracking location emerged as the most highly rated feature, with four participants awarding it a 10, indicating its strong perceived importance. Regarding the usefulness of the information provided by Fitbit, heart rate monitoring stood out as particularly valuable, with five participants rating it 10, signifying that parents found this information highly beneficial. Location tracking was also well-received, earning a 10 from two participants, although the ratings were more dispersed across different values. Meanwhile, monitoring activities such as walking received a broader range of responses, with three participants rating it a 5, indicating that while useful, it was not considered as critical as other features. Overall, the results suggest that parents prioritize features that enhance safety and well- being, particularly those that track vital health metrics and a child's whereabouts. Heart rate monitoring and location tracking were the most valued aspects, while activity tracking was seen as useful but not as essential.

Figure 11, illustrates the most important features parents consider when choosing a device for their child. Battery life was the highest priority, with five participants selecting it as the most important feature. Ease of use followed, receiving three votes, suggesting that parents value a user-friendly interface for their child's device. Tracking location was chosen by two participants, indicating that while location tracking is important, other factors such as battery life and usability take precedence in decision-making. This suggests that parents prioritize long-lasting functionality and ease of interaction over location tracking when selecting a suitable device for their child.

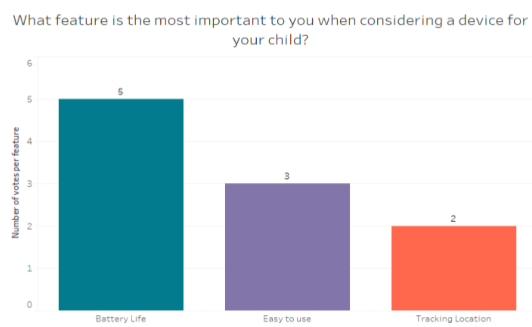

Figure 11: Future Purchase of a Smart Wearable

Figure 12, encapsulates the response to the likelihood of parents purchasing a Fitbit or a similar device for their child in the future. The results reveal that 7 out of 10 parents express an interest in acquiring the same or a similar device. Importantly, the data from previous charts indicate that parents primarily intend to use such a device for monitoring their child's health and well-being, as well as tracking the child's location. This information is crucial for the research as it provides insights into the potential adoption and acceptance of smart wearable devices for children among parents. The fact that a significant majority express willingness to purchase such devices suggests a positive inclination toward integrating technology for monitoring and ensuring the well-being of their children. Understanding these parental preferences and intentions can guide the development and marketing of future smart wearable devices, tailoring them to meet the specific needs and expectations of parents. Additionally, this data highlights the perceived value parents associate with such devices in terms of monitoring their child's health and location, reinforcing the potential impact and relevance of smart wearables in the context of children's well-being.

6.2 Information collected from Participants via Fitbit

Parents/guardians had full access to the connected Fitbit account. They could sync data wirelessly via a mobile app or use a USB dongle with a computer. The Fitbit app enabled activity tracking, workout insights, progress sharing, and health monitoring. For this study, data was synced through the app and downloaded for analysis. Figures 12 and 15 illustrate how parents accessed the data. Participants followed specified activities while wearing the Fitbit Charge HR, which met requirements for location tracking, health monitoring, and activity tracking

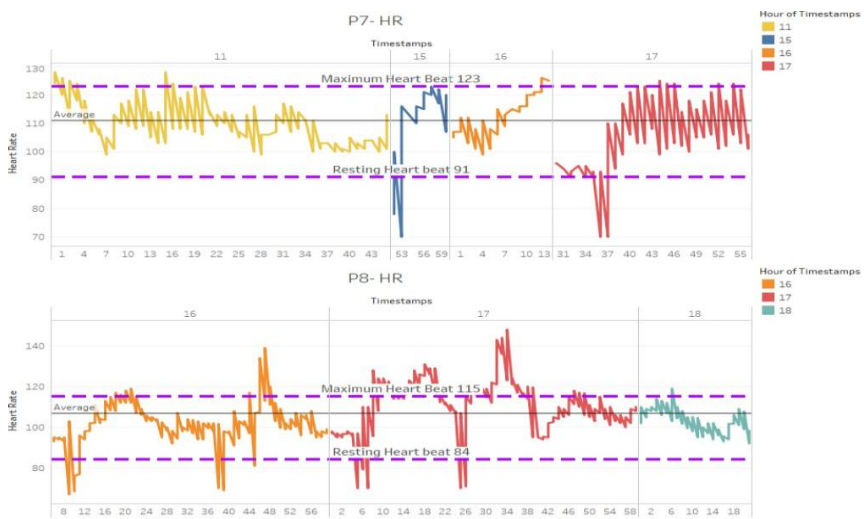

Figure 12: Sample Heart Rate data from the Fitbit Device

Figure 13 represents sample data collected from two participants, created using Tableau. The data is divided based on the times and dates when parents indicated their child/children took part in some or all of the activities. As advised, participants were instructed to wear the device for at least 10 minutes before the experiment started to obtain a resting or average heartbeat, and the experiment duration could range from 1-3 hours. Each participant's data includes three key factors determining irregular heartbeat:

- Heart Rate during the activities
- Resting heart rate (according to the NHS)
- Maximum heart rate for a child (according to the NHS and WHO)

Each colour in the visualisation represents a different hour, depending on when the participants conducted the activities, as mentioned above. The device's screen displays and analyses data it collects, offering a comfortable user experience. Prominent features include PurePulse heart rate tracking for real-time monitoring during activities. Heart rate data underwent analysis using the Kubios software, facilitating emotion calculation through electrocardiogram and RR interval data. Additionally, the framework incorporates the meanings of RR intervals (the time between successive R peaks in the electrocardiogram) and Heart Rate Variability (HRV), crucial metrics derived from smart wrist technologies.

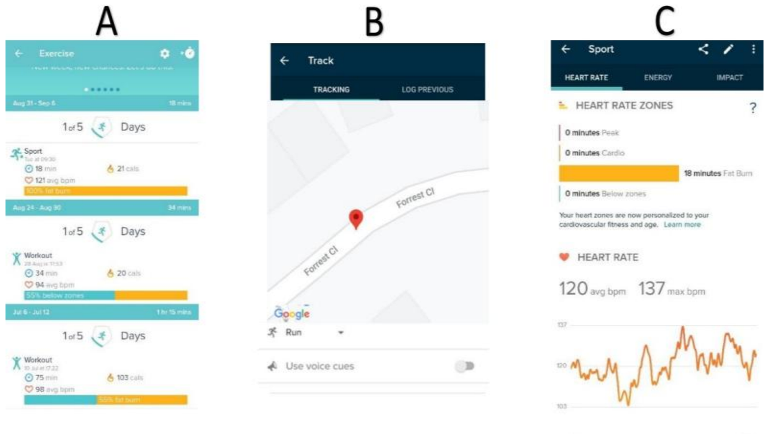

Figure 13: The Usefulness of the Fitbit Device

Subsequently, this data-set was cross-referenced with a sheet provided to parents, documenting their perceptions of the emotions their child experienced during the observation period. This supplementary information included corresponding activity details, as well as start and end times. By incorporating this contextual data, the collected information was effectively segmented into distinct emotions and associated activities. Consequently, the precise emotional states experienced by the children were linked to specific activities, enabling a comprehensive exploration of the interplay between emotions and activities.This investigation involved children who reported similar emotional states, allowing for a comparative analysis across diverse conducted activities. The contrast between identical emotions within varying activity contexts enriched the insights drawn from the study.

To ensure data anonymity, participants were assigned random numbers to protect their identities. The key focus of this study lies in Table 2, which consolidates the results and presents aggregated data for each emotion. These results are derived from the participants' Root Mean Square of Successive Differences (RMSSD) values, serving as indicators of the emotions perceived by each participant.

The subsequent step involves crucial cross-referencing: these detected emotions are compared with the input provided by parents in the data sheet for validation. This meticulous validation process ensures a robust connection between the identified emotions based on physiological measurements and the emotions reported by parents, enhancing the credibility and reliability of the emotional data collected.

Tables 1 and 4 display the parents' input regarding their child's emotions and the duration of activities. These tables provide valuable insights into the emotions experienced by the children during different activities, as perceived and reported by their parents. From the aforementioned tables, emotion detection was successful for 8 out of 10 participants. Emotions could not be determined for rows with missing data. Table 2 reveals variations in children's abilities to perform various tasks and the levels of enjoyment they experienced during these activities. In Table 3, parents reported their child's emotions based on their judgement of displayed emotions, whether through actions or facial expressions. This data was used to establish correlations between the emotions obtained from RMSSD values and the actual perceived emotions. To calculate the RMSSD values, the longest time spent per activity for each participant was input into the software. This process allowed for the comparison of emotions and values across all participants for each activity.

The results of the study hold significance on various fronts, offering valuable insights into children's emotional responses and contributing to the study's overall depth and relevance. These results provide a quantitative dimension to emotional analysis, assigning numerical values to emotions such as Anger, Enjoyment, Sadness, and Surprise. This approach enhances the objectivity and measurability of assessing emotional states. The specific range values associated with each emotion serve as a crucial baseline for comparison and evaluation

These ranges become reference points for gauging variations in emotional responses, providing a valuable foundation for future extensions or repetitions of the study.

Additionally, the detailed results, particularly the range values for emotions like Surprise (0.72-0.77) and Enjoyment (0.31-0.34), offer actionable data for the development and refinement of the technology-assisted framework. The validation process, involving cross-referencing with parental inputs, strengthens the reliability of the framework in accurately capturing and interpreting children's emotions. This robust validation is instrumental in ensuring that the technology's outputs align with human reports, contributing to the credibility of the emotional data collected. Beyond the technological implications, these results hold relevance for assessing children's well-being in the context of their interactions with technology.

Understanding the emotional responses of children provides crucial insights that can inform strategies to enhance positive emotional experiences and mitigate negative ones. This holistic approach contributes not only to the development of technology but also to broader discussions on the impact of digital interactions on children's emotional health. In conclusion, delving into the intricacies of children's interactions with smart devices provides a multifaceted understanding of their digital behaviours. The exploration of behavioural patterns unveils not only the frequency and duration of engagement but also the evolving dynamics of their technological interactions. A closer examination of the educational impact elucidates the role of devices in shaping learning experiences, encompassing the utilisation of educational apps and engagement in online activities. Furthermore, the scrutiny of social interactions highlights the devices' influence on communication dynamics among children, acting as both facilitators and potential barriers.

Table 1: Emotion with calculated RMSSD values

Emotion	RMSSD Calculated Val
Anger	**0.2-0.3**
Enjoyment	**0.31-0.34**
Sadness	**0.2**
Surprise	**0.72-0.77**
Fear	
Disgust	–

Moreover, the detailed results, particularly the range values for emotions like Surprise (0.72-0.77) and Enjoyment (0.31-0.34), offer actionable data for the development and refinement of the technology-assisted framework. Lastly, the consideration of health and well-being factors offers a holistic perspective, encompassing screen time, sleep patterns, and overall physical and

mental health, enabling a comprehensive evaluation of the broader impact of device habits on children's development. By addressing these dimensions, researchers gain nuanced insights into how smart technologies intricately shape various facets of children's lives in the digital age

Table 2: Overall Result

Participant No.	Activity	Emotion	Duration	RMSSD [ms]
1	Treasure Hunt	Enjoyment	1:57	**0.3**
2	Building Tallest tower or similar	Anger	0:48	**0.3**
3	Jigsaw puzzle	Sadness	1:51	**0.2**
4	Colouring / activity book	Sadness	0.59	**0.2**
5	Colouring / activity book	Surprise	0:58	**0.72**
6	–	–	–	–
7	–	–	–	–
8	Matching card game	Enjoyment	2:33	**0.4**
9	Building Tallest tower or similar	Enjoyment	1:43	**0.2**
10	Treasure Hunt	Surprise	4:47	**0.77**

Table 3: Overall Time taken per Participant/Activity

Participant no	Total Duration	Building Tallest Tower	Treasure Hunt	Colouring Book	Jigsaw Puzzle	Card Game
1	2hrs and 23 mins	33 mins	20 mins	40 mins	15 mins	19 mins
2	1hr and 39 mins	23 mins	28 mins	25 mins	15 mins	13 mins
3	59 mins	17 mins	17 mins	13 mins	15 mins	15 mins
4	38 mins	7 mins	6 mins	9 mins	8 mins	6 mins
5	2hrs and 12 mins	2 7mins	14 mins	18 mins	13 mins	16 minx
6	–	–	–	–	–	–
7	–	–	–	–	–	–
8	2hrs and 15 mins	20 mins	20 mins	25 mins	30 mins	35 mins
9	3 hrs and 3 mins	30 mins	25 mins	35 mins	35 mins	43 mins
10	3 hrs	40 mins	15 mins	30 mins	25 mins	22 mins

Table 4: Emotion Sheet Results

Participant no	Building Tallest Tower	Treasure Hunt	Colouring Book	Jigsaw Puzzle	Card Game	Tape Game
1	Enjoyment	Enjoyment	–	Enjoyment	–	Enjoyment
2	Anger	Surprise	Surprise	Enjoyment	Enjoyment	Enjoyment
3	Enjoyment	Enjoyment	Enjoyment	Sadness	Enjoyment	Sadness
4	Enjoyment	Enjoyment	Sadness	Enjoyment	–	Enjoyment
5	Enjoyment	Enjoyment	Surprise	Surprise	Surprise	Enjoyment
6	–	–	–	–	–	–
7	–	–	–	–	–	–
8	Enjoyment	Enjoyment	Surprise	Sadness	Surprise	Enjoyment
9	Anger	Enjoyment	Surprise	Enjoyment	Enjoyment	Surprise

10	Anger	Surprise	Enjoyment	Enjoyment	Enjoyment	Surprise

7.Conclusion

We have explored selected methods for child tracking, health monitoring, and activity assessment, aiming to investigate technology's impact on parental perspectives regarding children's well-being. As we discussed in the previous sections, significant properties, including heart rate and activity tracking, shed light on technology's influence on Children's Independent Mobility (CIM) and health professionals.

The exploration of IoT and wearable technology delves into various aspects of child health, well-being, and independent mobility. This research study involved the investigation of findings from three sources, including published research works, case studies, and online content, leading to the uncovering of certain challenges faced by health professionals and parents. Phase 1 findings revealed obstacles such as financial constraints and past experiences hindering smart wearables adoption for children. In contrast, Phase 2 emphasised on positive experiences, especially regarding heart rate accuracy and location tracking. As explained, the proposed heartrate-based approach successfully extracted emotions for 8 out of 10 participants, necessitating parental observation during specific activities. The Children's Independent Mobility and Health Assisted Smart Technologies (CIMHAST) framework suggests an alternative method for child health monitoring, emphasising technology's potential to enhance CIM and health while addressing parental concerns.

This proposed framework compared to existing methods such as the Traditional Health Monitoring (Many traditional methods of children's health monitoring rely on periodic check-ups and manual recording of data, such as physical activity logs or heart rate measurements.) and Wearable Devices (Current Solutions): Existing wearable technologies often focus on basic metrics like physical activity and heart rate. However, many devices lack a comprehensive approach that combines health monitoring with real-time location tracking and emotional assessment, particularly in children's health contexts. Our proposed framework provides:

- Comprehensive Monitoring: The proposed framework integrates multiple functionalities—health monitoring (vitals and activity tracking), location tracking (via GPS), and emotional state assessment—into a single wearable device. This holistic approach is a significant advantage over current solutions, as it provides a more complete picture of a child's health and well-being.
- Child-Centric Design: The framework is specifically tailored to children's needs, considering factors such as comfort, safety, and usability. Unlike many existing devices, which may not be optimized for children's smaller body sizes or their emotional and developmental needs, this framework ensures the technology is suitable for long-term use in a child's daily routine.
- Real-Time Data for Parents and Healthcare Providers: By offering real-time data and continuous monitoring, the framework empowers parents, educators, and healthcare providers to make informed decisions promptly, potentially leading to early intervention and better preventive care.
- Focus on Safety and Emotional Health**:** The inclusion of emotional state monitoring sets this framework apart from existing solutions. It addresses an often-overlooked aspect of child health, which can be critical for understanding overall well-being

8. Future Works

This research included one experiment which was layered into four phases with one main framework. The list below indicates some suggestions on how other researchers and professionals can take this work further:

- Working with more participants ranging from different age groups.
- Allowing a comparison within a time frame on how Fitbit motivates children to become fit Extracting micro expressions with advanced use of heart rate sensor.
- The idea of looking into the pandemic and how health and fitness has changed within children How professionals could use IoT for children in the future in terms of health and well-being,
- Expand the phases and data collected for the framework: Different smart wrist technology with more advanced features and functions and children from different demographics/health issues

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References

[1] S. Bennetts, "What Influences Parents' Fear about Children's Independent Mobility? Evidence from a State-Wide Survey of Australian Parents," *American journal of health promotion*, vol.32, no.3, pp. 667-676, 2018.
[2] K. Leung and B. Loo, "Association of children's mobility and wellbeing: A case study in Hong Kong," *Travel Behavior and Society*, vol.9, no.1, pp. 95-104, 2017.
[3] I. Marzi and K. Reimers, "Children's Independent Mobility: Current Knowledge, Future Directions, and Public Health Implications," *International Journal of Environmental Research and Public Health*, vol.11, pp. 99-112, 2018.
[4] A. Karale, "The Challenges of IoT Addressing Security, Ethics, Privacy, and Laws," *Internet of Things*, pp.5-12, 2021.
[5] Z. Alpaprone and M. Pacilli, "On Children's Independent Mobility: The Interplay of Demographic, Environmental and Psychosocial Factors," *Children's Geographies*, vol.10, no.1, pp. 109-122, 2012.
[6] C. Lam, M. Milne-Ives, R. Harrington, A. Jani, M. Velthoven, T. Harding and E. Meinert, "Internet of things–Enabled technologies as an intervention for childhood obesity: A systematic review," *PLOS Digital Health*, pp.1-21, 2022.
[7] S. Foster, K. Vilanieva, L. Wood and J. Christian, "The impact of parents' fear of strangers and perceptions of informal social control on children's independent mobility," *Health and Place*, vol.26, no.1, pp. 60-68, 2020, 2004.
[8] Available at: https://ico.org.uk/for-organisations/guide-to-data-protection/key- data-protection-themes/children/ [Accessed Monday, July 2020].
[9] Fitbit, 2018. Fitbit Privacy Policy for Children's Accounts. [Online] Available at: https://www.fitbit.com/us/legal/kids-privacy-policy [Accessed Wednesday, June 2020].
[10] M. Messena and M. Everri, "Unpacking the relation between children's use of digital technologies and children's well-being: A scoping review," *Clinical child psychology and psychiatry*, pp.161-198, 2023.
[11] S. Guo, M. Wang, H. Akezhuali, X. Zhou and J. Lu, "The effects of parent-child separation on the digital literacy of children and adolescents: A bidirectional perspective study," Cellpress, pp.1-15, 2024.

[12] F. Allhoff and A. Henschke, "The Internet of Things: Foundational ethical issues," *Internet of Things*, pp.55-66, 2018.
[13] G. Aikhalifah, F. Alqahtani and R. Orji, "Towards Mobile Applications for Co-Monitoring Children's Health Condition," *IEEE 8th International Conference on Serious Games and Applications for Health (SeGAH)*, pp. 1-8, 2020.
[14] I. Uddin Ahmed, N. Hassan and H. Rashid, "Solar powered smart wearable health monitoring and tracking device based on GPS and GSM technology for children with autism," *IEEE Publisher*, pp.1-6, 2017.
[15] M. Hillman, "One False Move. In: A Study of Children's Independent Mobility," *A Study of Children's Independent Mobility*, pp. 77-79, 2001.
[16] B. Brown, "Gender differences in chttps://www.overleaf.com/children's pathways to independent mobility," *Children's Geographies*, vol.6, no.4, pp. 385-401, 2008.
[17] B. Shaw, B. Frauendienst, A. Redecker and M. Hillman, "Children's Independent Mobility: Comparative study, London," *Policy Studies institute*, 2013.
[18] T. Thamaraimanalan, R. Pathmavasan, T. Pradeep , N. Praveen and R. Srija, "IoT based Safety Gadget for Child Monitoring," *9th International Conference on Advanced Computing and Communication Systems*, pp.1-4, 2023.
[19] N. Priyanka, D. Murugan, K. Srinivas, T. Sarveswararao and E. Kumari, "Smart IOT Device for Child Safety and Tracking," *International Journal of Innovative Technology and Exploring Engineering (IJITEE*), pp. 1-5, 2019.