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Adoption and Evaluation of Mobile Gaming Applications for Pain Management in Paediatric Oncology: A Culturally Contextualised TAM-Based Framework and Mixed-Methods Pilot Study in Saudi Arabia

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***Abstract*—**

***Background*: This pilot study has aimed to explore the adoption and effectiveness of mobile gaming applications as non-pharmacological tools for pain management in paediatric oncology within Saudi Arabia. Grounded in a culturally extended Technology Acceptance Model (TAM), the study has incorporated constructs such as Social Influence, Trust, System Quality, and Accessibility to understand technology uptake in a culturally conservative context.**

***Problem:* Current research lacks culturally adapted models that account for social, institutional, and technological factors affecting mobile app uptake in paediatric oncology—especially in non-Western contexts like Saudi Arabia.**

***Methods*: A mixed-methods pilot study was conducted at the King Fahad National Centre for Children's Cancer Emergency in Riyadh. Quantitative data were collected from 80 participants—50 parents and 30 healthcare providers—using a structured TAM-based survey instrument, with convenience sampling employed for feasibility. Composite Reliability (CR) was calculated using AMOS software as part of Structural Equation Modelling (SEM), with model fit indices such as CFI and RMSEA reported to validate the analytic model. In parallel, qualitative data were gathered from four participants (two parents and two healthcare providers) via semi-structured interviews, analysed thematically using a phenomenological approach. The limited qualitative sample was justified as appropriate for a pilot focused on instrument validation, with limitations due to access, ethics, and time constraints; future work will expand this sampling. The instruments were pre-tested for cultural and linguistic appropriateness through expert review and back-translation.**

***Results:* Survey constructs showed strong reliability (α = 0.87–0.93). All six hypotheses were statistically supported, validating the extended TAM framework. Path relationships were tested through SEM, supported by multiple regression, enhancing methodological robustness. Qualitative data prompted question wording changes and highlighted format preferences: parents preferred in-person interviews, providers preferred virtual.**

***Implications:* Findings confirm the instrument's reliability and support the extended TAM model. Additionally, these results provide actionable implications for the design and implementation of culturally tailored mHealth interventions. The extended TAM framework can guide developers and healthcare administrators in designing mobile health tools that incorporate elements of social influence and trust into app features, training programs, and communication strategies. These insights support the effective deployment and potential scaling of such technologies within conservative healthcare systems like Saudi Arabia. Moreover, the study explicitly aligned its findings with the four guiding research questions: perceived usefulness and ease of use (RQ1) and social influence (RQ2) significantly predicted adoption; system and information quality (RQ3) enhanced trust; and trust in reliability and data security (RQ4) mediated user acceptance, reinforcing the explanatory strength of the extended TAM in this context. Future studies are recommended to include participant stratification by oncologic treatment phase and implement pre- and post-intervention pain assessments to isolate effects and enhance clinical interpretability.**

***Index Terms*—mHealth, TAM, paediatric oncology, pain management, mobile games, Saudi Arabia**

I. Introduction

THIS Pain management in paediatric oncology has increasingly been recognised as a complex and persistent challenge that profoundly affects children's physical and psychological well-being. Despite considerable advancements in cancer therapies, many children continue to experience unrelieved pain, revealing the inadequacy of pharmacological interventions alone [1],[2],[3].Traditional treatments, such as opioids, while central to acute pain relief, often fail to ad-

dress chronic or procedure-related pain comprehensively and may be accompanied by adverse effects [4]. This has prompted a search for complementary, non-pharmacological approaches that are both safe and child-friendly.

In recent years, mobile health (mHealth) technologies have emerged as innovative tools that offer new avenues for pain assessment, symptom tracking, and self-management in paediatric care [5],[6]. Among these, mobile gaming applications stand out for their ability to combine distraction and engagement through immersive, interactive experiences [7]. Evidence suggests that these tools can significantly reduce pain perception by redirecting attention away from distressing stimuli and encouraging positive affective states [8],[9]. In oncology contexts, where children undergo repeated invasive procedures, such digital interventions offer both therapeutic and psychological benefits [10], [11].

Nonetheless, the integration of mHealth solutions, particularly mobile games, into clinical practice is fraught with sociocultural and technological complexities. In Saudi Arabia, for instance, rapid digital transformation exists alongside strong cultural norms and hierarchical healthcare dynamics that shape how technologies are perceived and used [12],[13]. Although general attitudes towards technology are increasingly positive, the uptake of health-related mobile applications—especially in sensitive domains such as paediatric oncology—remains limited. Studies have identified that existing frameworks, like the Technology Acceptance Model (TAM), may be insufficient when applied in isolation, as they often overlook contextual factors such as trust, information quality, and social influence [14], [15].

This underscores the need for a culturally contextualised TAM framework that also considers the stage of the child's oncologic treatment, as pain experiences vary significantly across treatment phases. The study acknowledges that future research should stratify participants by treatment stage and utilise pre- and post-intervention measures to better isolate the specific effects of mobile interventions.

By integrating constructs such as system quality, parental perceptions, and healthcare provider endorsement, researchers can gain a more holistic understanding of the barriers and enablers to mHealth adoption [16], [17]. Furthermore, considering the interactive and cognitive demands of gaming applications, system usability and accessibility features must also be factored into the evaluation process, especially for children with varying developmental needs [18], [19].

Moreover, this study was intentionally designed as a pilot phase to test the feasibility and appropriateness of the research instruments. The qualitative component, involving a small sample (n=4), was purposefully limited due to logistical constraints such as restricted access to participants, time limitations, and ethical approvals. These considerations were critical in a hospital-based setting. Future full-scale studies will expand the qualitative sample to enhance representativeness and thematic richness.

Given the emerging role of gamified mobile applications in health contexts, particularly those involving children, empirical inquiry must go beyond technical feasibility to explore sociocultural acceptance and practical implementation. A mixed-methods pilot study offers a robust means of evaluating both measurable outcomes and user experiences, aligning well with the need to validate research tools in complex healthcare environments [20], [21]. Previous pilot work has demonstrated the feasibility of this approach in Saudi hospitals, highlighting critical insights into participant recruitment, ethical considerations, and instrument refinement [22].

To ensure methodological clarity and replicability, this study reports the use of AMOS software to calculate Composite Reliability (CR), alongside the application of Structural Equation Modelling (SEM) to estimate path relationships. The analysis included model fit indices such as RMSEA and CFI, thereby enhancing the analytical transparency of the framework.

This study aims to critically explore the factors influencing the adoption and effectiveness of mobile gaming applications as non-pharmacological tools for pain management in paediatric oncology within the Saudi Arabian context. Recognising the current gap in research surrounding culturally appropriate digital health interventions, the study seeks to develop and test a conceptual framework grounded in the (TAM), enriched with variables such as Social Influence, System Quality, Information Quality, and Trust. The research adopts a mixed-methods approach to assess how these variables affect mobile app utilisation for pain relief, with particular attention to the mediating roles of Perceived Ease of Use (PEoU) and Perceived Usefulness (PU). Through a preliminary pilot study involving both quantitative surveys and qualitative interviews with parents and healthcare professionals, the study evaluates the feasibility, reliability, and cultural appropriateness of its instruments and design. The overarching objective is to inform the development of evidence-based, user-centred mHealth solutions that address the unique sociocultural dynamics of Saudi Arabia, thereby enhancing paediatric oncology pain management outcomes and contributing to broader mHealth adoption strategies in similar contexts.

Guided by an extended Technology Acceptance Model (TAM) and grounded in the sociocultural dynamics of Saudi Arabia, this study seeks to understand the behavioural and contextual drivers behind the adoption of mobile gaming applications in paediatric oncology. To this end, the research is directed by the following four questions:

RQ1: How do the core constructs of the (TAM)—perceived usefulness and perceived ease of use—influence the behavioural intention of parents and healthcare providers to adopt mobile gaming applications for paediatric pain management?

RQ2: In the cultural context of Saudi Arabia, how does social influence affect the acceptance and continued use of mobile health applications in paediatric oncology?

RQ3: How do system quality (e.g., reliability, design) and information quality (e.g., clarity and relevance of content) impact users' trust in, and intention to adopt, mobile gaming interventions?

RQ4: What role does trust—particularly in system reliability and data privacy—play in mediating the relationship between technical features and user acceptance of mobile health applications in paediatric oncology?

II. Literature Review

A. Pain Management in Paediatric Oncology

Children with cancer frequently endure intense pain due to both the illness and invasive medical interventions. This pain is often exacerbated by underassessment and undertreatment, particularly in paediatric settings where communication barriers complicate accurate reporting [23]. Pharmacological methods, especially opioids, are widely employed; however, they are often inadequate and associated with side effects such as sedation, gastrointestinal complications, and dependency risks [4],[24]. These limitations have contributed to an increased interest in non-pharmacological approaches. Techniques such as cognitive distraction, relaxation, and guided imagery are increasingly considered necessary complements to medication [25], [26].

The impact of unmanaged pain extends beyond immediate physical discomfort. It is known to negatively influence children's emotional development, social engagement, and academic functioning [27]. Poorly managed pain in paediatric oncology patients can lead to long-term psychological consequences and reduced quality of life, underlining the urgency for innovative, child-friendly interventions. Furthermore, variations in pain perception depending on the treatment phase necessitate consideration of the child's current clinical status in the design and assessment of pain management interventions. Future studies should stratify participants accordingly and incorporate longitudinal measures such as pre- and post-intervention pain assessments.

B. Mobile Games as Pain Distraction Tools

One such intervention gaining traction is mobile gaming technology, which serves as an engaging form of distraction that could decrease pain perception. Distraction functions by redirecting the patient's attention away from painful stimuli, potentially reducing the sensory and emotional processing of pain [28]. In particular, interactive forms of distraction—such as video games—require cognitive engagement, problem-solving, and sensory involvement, which may make them more effective than passive activities [29].

Several studies have indicated that mobile games can lower pain and anxiety during procedures like wound care, chemotherapy, and injections[30], [31]. The underlying mechanisms could be explained using flow theory, where deep immersion and concentration during gaming create a mental state that reduces awareness of pain. Emotional engagement also plays a role by promoting a sense of control, reducing helplessness, and improving mood [32].

However, current evidence often lacks consistency in methodology, with small sample sizes and varied outcome measures. In our pilot study, qualitative data collection was intentionally limited to a small sample (n=4), primarily due to ethical clearances, limited access, and logistical constraints within hospital settings. This limitation aligns with the exploratory goals of pilot research, particularly when refining new instruments. The need for expanded qualitative sampling in future studies has been explicitly acknowledged to enhance representativeness and thematic saturation. Despite this, pilot interventions have demonstrated that mobile games can serve as viable adjuncts to traditional pain management in paediatric settings, particularly when adapted to individual preferences and contexts [33]. Cultural and contextual relevance, however, remains underexplored, especially in non-Western settings.

C. Technology Adoption Models

Understanding how these mobile technologies are received by users is crucial, especially within complex healthcare ecosystems. The (TAM) remains a dominant framework for explaining behavioural intentions toward new technology. It proposes that (PEoU) and (PU) predict technology adoption [34]. While TAM provides valuable insights, researchers have criticised its limited scope when applied to culturally diverse healthcare settings [15] Variables such as Social Influence, System Quality, Information Quality, and Trust are often essential in healthcare adoption decisions but are not addressed in the original TAM framework [35].

In response, several extended versions of TAM have been developed, incorporating these additional dimensions. For instance, Social Influence, particularly in hierarchical or collectivist cultures like Saudi Arabia, could influence parental or professional acceptance of mHealth tools [14]. Trust in the system's security and in the data handling processes is another critical concern, especially when dealing with children's health data.

Comparative models like the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Theory of Planned Behaviour (TPB) offer broader perspectives. UTAUT, by integrating constructs such as effort expectancy, facilitating conditions, and voluntariness, provides a more holistic understanding of adoption in institutional settings [36]. Likewise, TPB incorporates attitudes, subjective norms, and perceived behavioural control, making it particularly useful in contexts where behaviour is mediated by cultural expectations or perceived barriers [37]. Nevertheless, these frameworks still often overlook the dynamic interplay between technological factors and health-specific cultural values.

D. Identified Gaps in the Literature

While evidence supports the use of mobile games as pain distraction tools, current literature rarely integrates these findings with robust technology adoption theories. Research frequently isolates either the clinical effectiveness or the behavioural adoption components, resulting in fragmented insights. Studies conducted in Western contexts dominate the field, leaving a marked scarcity of research that evaluates both efficacy and adoption in Middle Eastern settings, where cultural and institutional factors may substantially differ [38]

Moreover, there is limited exploration of how mobile games function within broader digital health ecosystems. Most studies focus on singular outcomes, such as reduced

pain intensity, without considering how app usability, design quality, or cultural appropriateness affect sustained engagement or clinical outcomes. Even fewer studies attempt to adapt or extend established models like TAM to accommodate local values, expectations, and healthcare practices. This absence is particularly significant in Saudi Arabia, where rapid digital transformation coexists with deeply rooted cultural norms that shape technology use in unique ways [13].

Methodologically, previous studies often lack transparency in their analytical frameworks. In contrast, this study employed AMOS software to calculate Composite Reliability (CR) and Structural Equation Modelling (SEM) to estimate path relationships between TAM constructs. Model fit indices such as CFI and RMSEA were used to validate the framework, enhancing methodological robustness and reproducibility.

The lack of implementation-focused studies further weakens the translational potential of current evidence. Very few investigations adopt mixed-method approaches that could provide both numerical validation and narrative insights into stakeholder perspectives. Additionally, limited research evaluates how game mechanics, content personalisation, or user trust influence the therapeutic potential of mobile gaming applications in paediatric oncology. Therefore, this study could contribute uniquely by bridging the gap between behavioural theory, clinical efficacy, and cultural sensitivity in digital health adoption.

III. Theoretical Framework

A. Extended TAM for Mobile App Adoption in Paediatric Oncology

Understanding the adoption of mobile gaming applications within paediatric oncology necessitates a theoretically sound model capable of capturing both technological and cultural influences. The (TAM), developed by [39], offers a foundational structure to assess user acceptance of technological innovations, particularly through the constructs of (PU) and (PEoU). PU refers to the degree to which users believe that using a particular system would enhance their performance, while PEoU captures the extent to which users expect the technology to be free of effort [40].

TAM's suitability for healthcare applications has been consistently affirmed in previous studies focusing on e-health and mobile health technologies, including interventions for pain management [41], [42]. However, unlike general contexts, paediatric oncology involves multi-layered decision-making processes where the perceptions of caregivers, healthcare providers, and patients interact. This complexity, particularly within Saudi Arabia's sociocultural fabric, necessitates the incorporation of additional determinants beyond the original TAM structure.

Social influence, for instance, could be critical in this context, especially in a society where healthcare decisions are often guided by familial hierarchies and medical authority figures [43]. The inclusion of this variable aligns with prior adaptations of TAM, where social context has been found to affect (PU) and behavioural intention [36].

System quality, encompassing design, functionality, and interactivity, is equally critical in mobile health adoption. Unlike standard applications, mobile gaming apps for paediatric oncology must offer engaging and adaptive features that ensure sustained usage [44].Design characteristics such as vivid graphics, sound effects, and interactive tasks contribute to the app's capacity for pain distraction and cognitive engagement [45].This element closely aligns with constructs identified in the Information Systems Success Model [46],justifying its integration into the extended framework.

Similarly, information quality—defined by the accuracy, clarity, and comprehensibility of in-app content—is indispensable in medical settings. Accurate information facilitates informed decision-making by caregivers, while clear presentation enhances trust and continued usage [47]. Research has also demonstrated that information quality interacts with trust and usability to shape user satisfaction [48]

The fourth contextual variable, trust, particularly in system reliability and data privacy, could significantly influence mobile health adoption in conservative societies like Saudi Arabia [49],[50] Privacy concerns, especially regarding sensitive health data, are often amplified in cultures that emphasise discretion and confidentiality. Previous findings support the notion that trust mediates the relationship between system quality and usage intentions [51], validating its inclusion.

In alignment with reviewer feedback, the framework acknowledges that future studies should stratify participants based on the stage of oncologic treatment, and should incorporate pre- and post-intervention measures to enhance precision and isolate the effects of the mobile intervention.

B. Conceptual Model and Hypotheses

The conceptual framework underpinning this study adapts TAM to include the aforementioned variables, providing a culturally specific model for examining the adoption of mobile gaming applications in Saudi paediatric oncology settings. In this model, PU and PEoU are hypothesised to mediate the relationship between contextual variables (social influence, system quality, information quality, and trust) and the outcomes of mobile app utilisation and pain relief management.

Mobile app utilisation acts as a central behavioural outcome, connecting the theoretical constructs with real-world impact. Evidence suggests that the more usable and beneficial users perceive an app to be, the more likely they are to engage with it consistently, which could lead to improved pain relief [52], [53]. This mediation is captured in the first hypothesis:

H1: PEoU and PU will mediate the relationship between contextual variables and mobile gaming app utilisation for pain management.

Building on this structure, interactive engagement is theorised as an outcome of system quality and a facilitator of cognitive distraction—a known mechanism of non-pharmacological pain relief. Games that include personalised tasks, rewards, and immersive environments are more likely to engage children undergoing treatment [54].

H2: Interactive engagement in mobile gaming apps significantly enhances (PU) and promotes higher utilisation rates.

Further, healthcare provider endorsement is proposed to influence both PU and trust. In Saudi Arabia, where providers are respected figures, their endorsement may serve as a catalyst for parental acceptance [55], [56].

H3: Endorsement by healthcare providers positively moderates the relationship between trust and PU.

Parental perception, particularly concerning effectiveness and ease of use, is another vital factor. Parents function as gatekeepers in their children's health behaviours, and their judgement significantly impacts usage decisions [57].

H4: Positive parental perceptions of app safety, ease of use, and effectiveness increase mobile app utilisation in pain management.

H5 relates to the core role of system quality, proposing that apps with user-friendly interfaces, engaging visual elements, and minimal technical errors result in greater PU and PEoU, thereby improving adoption.

H5: Higher system quality in mobile gaming apps is associated with increased PU and PEoU.

Finally, accessibility features, such as simplified touch inputs or alternative interaction modes, are critical in a paediatric oncology context where some children may have physical or cognitive impairments due to illness or treatment side effects [18].

H6: Accessibility features significantly influence PEoU and PU, thereby enhancing mobile app adoption and pain relief outcomes.

The model explicitly recognises that the pilot's qualitative sample (n=4) was limited by ethical clearance, time, and access constraints, in line with the goals of pilot feasibility. This rationale supports the decision and is followed by a commitment to broader qualitative sampling in future studies.

Additionally, the revised methodology clarifies that Composite Reliability (CR) was derived using AMOS software as part of the Structural Equation Modelling (SEM) analysis. Furthermore, SEM was used to estimate path relationships, complemented by multiple regression for exploratory validation. Model fit indices, including CFI and RMSEA, are included to support the analytical validity.

The proposed framework builds on the pilot study findings, which confirmed the high internal consistency of constructs such as interactive engagement, trust, and system quality. By incorporating cultural, technological, and behavioural variables into an extended TAM structure, the model advances a comprehensive understanding of mHealth app adoption for paediatric pain management in Saudi Arabia.

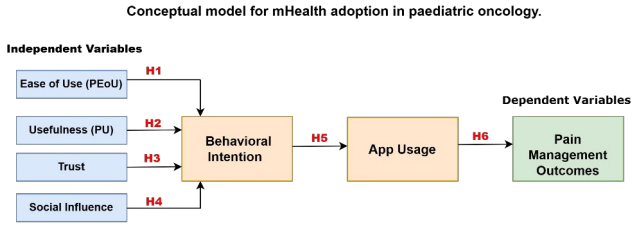

Fig 1.Conceptual model for mHealth adoption in paediatric oncology

Fig 1 illustrates the conceptual framework underpinning this study. The model integrates core constructs of the (TAM)— (PEoU) and (PU)—with contextual variables including Trust and Social Influence. These independent variables shape users' Behavioural Intention, which in turn affects App Usage. The final link in the model connects usage to the dependent variable: Pain Management Outcomes. This structured pathway captures both cognitive and contextual determinants of mobile health application adoption in paediatric oncology, specifically tailored to the socio-cultural setting of Saudi Arabia.

IV. Methods

A. Mixed-Methods Sequential Design

The methodological design of this study adopts a mixed-methods sequential approach, integrating both quantitative and qualitative phases to provide a comprehensive understanding of the adoption and effectiveness of mobile gaming applications for pain management in paediatric oncology. The rationale for employing this design lies in its capacity to combine the generalisability of quantitative findings with the contextual depth of qualitative insights [58]. Within the Saudi Arabian paediatric oncology context, where cultural and familial values play a significant role in healthcare decisions, the combination of both approaches is essential for capturing multifaceted perspectives.

B. Quantitative Pilot Study

- *Sampling and Inclusion Criteria*

A cross-sectional pilot study was conducted at King Fahad National Centre for Children's Cancer Emergency in Riyadh. The inclusion criteria for parents required participants to be adults (18+), Arabic-speaking, of any Asian citizenship, and parents of children undergoing active cancer treatment. For healthcare providers, eligibility required Arabic-speaking professionals currently practising in paediatric oncology at the designated centre. Exclusion criteria included individuals not involved in paediatric oncology care or unable to provide informed consent.

Convenience sampling was employed due to logistical feasibility and accessibility. The sample comprised 50 parents and 30 healthcare providers. Although non-randomised, this method enabled rapid recruitment within time constraints, which is practical for pilot testing [59].

Questionnaire Design Separate questionnaires were developed for each group based on established (TAM) constructs. Constructs included (PEoU), (PU), social influence, system quality, information quality, trust, and mobile app utilisation. Additionally, parental instruments included items assessing perceived pain relief outcomes and child engagement. A 5-point Likert scale was used to measure responses.

The development of the instruments was informed by literature [36],[58] and adapted for cultural relevance through expert consultation. Questionnaire items were translated into Arabic, followed by back-translation to ensure linguistic accuracy [61].

- *Recruitment Setting and Process*

Recruitment was facilitated by administrative and nursing staff at the hospital, who distributed consent forms and information sheets. Participation was voluntary and anonymous, with both on-site and take-home paper surveys offered to improve accessibility and participation.

Data Analysis Data were analysed using SPSS (version 27). Cronbach's alpha assessed internal consistency, with all constructs exceeding the acceptable threshold of 0.70 [62]. Average Variance Extracted (AVE) was used to confirm convergent validity, with values exceeding 0.50. Confirmatory Factor Analysis (CFA) thresholds followed widely accepted psychometric standards. Factor loadings ≥ 0.60 were considered acceptable, while Composite Reliability (CR) > 0.70 indicated internal consistency. Convergent validity was confirmed with AVE values above 0.50, and discriminant validity was evaluated using the Fornell-Larcker criterion, requiring the square root of AVE to exceed inter-construct correlations. These thresholds ensure construct validity and are consistent with practices in TAM-based health technology adoption research. Composite Reliability (CR) was calculated using AMOS software as part of the Structural Equation Modelling (SEM) process. SEM was also used to test path relationships, supported by multiple regression for exploratory purposes. Model fit indices (e.g., CFI, RMSEA) and threshold values were included to support the validity of the model.

C. Qualitative Pilot Study

- *Sampling and Inclusion Criteria*

The qualitative phase followed a phenomenological approach to explore lived experiences of mobile gaming app usage for pain distraction. Participants included two parents and two healthcare providers from the same centre. Inclusion required Arabic fluency and direct experience with paediatric oncology care, either as caregivers or clinical staff.

Purposeful sampling was selected to ensure participants had meaningful and relevant insights [21]. While the sample size was small, it was sufficient for pilot testing interview protocols and assessing thematic saturation feasibility. The qualitative sample size was limited due to the study being a pilot phase aimed at testing the instrument and assessing feasibility. Constraints such as time, ethical clearances, and access limitations during hospital-based recruitment were contributing factors. It is acknowledged that broader qualitative sampling will be pursued in future full-scale studies to enhance representativeness and thematic depth.

- *Interview Design and Translation Protocol*

Semi-structured interview guides were developed to address constructs such as usability, cultural appropriateness, emotional engagement, and perceived effectiveness of mobile gaming. Interviews were conducted in Arabic and audio recorded. Back translation was applied to ensure that transcriptions retained the original meaning when converted to English.

Interview questions were revised following pilot feedback. For example, a complex question regarding "perceived cognitive engagement" was simplified to "How do you think games help your child focus away from pain?"

- *Recruitment Setting and Process*

Participants were recruited through referrals by oncology staff. Interviews were scheduled at convenient times, either on-site or via secure online platforms. Each session lasted 45 to 60 minutes and was conducted in a private setting to maintain confidentiality and comfort.

Data Analysis Transcripts were analysed thematically following [62]'s six-phase framework (2006). Themes were generated inductively to reflect participants' perspectives on usability, acceptance, and barriers to mHealth adoption. Initial coding was performed by the primary researcher, with peer review applied to ensure coding consistency.

D. Ethical Approvals and Procedures

Ethical clearance was obtained from the Application to Science & Technology or Social Sciences & Arts Research Ethics Committee (Application Number: ER/SA2079/2) at the University of Sussex, as well as the Research Ethics Committee at King Faisal Specialist Hospital & Research Centre – Riyadh (Application Number: RAC#2241391). Participants were informed of their rights, including voluntary participation, data confidentiality, and the right to withdraw at any time. Consent forms were provided in Arabic, and additional verbal explanations were offered to ensure understanding.

The ethical design considered the emotional sensitivity of the target group. Special measures included flexible interview timings, assurance of data anonymisation, and culturally appropriate communication protocols to minimise distress. All data were securely stored and password protected, in accordance with GDPR and institutional policy guidelines.

V. Findings

A. Findings for the survey online

The quantitative phase of the pilot study was conducted at the King Fahad National Centre for Children's Cancer Emergency between January and February 2024. A total of 80 participants completed the survey: 50 parents of children undergoing cancer treatment and 30 healthcare providers. Response rates were high for parents (83%) and moderate for providers (60%), likely due to clinical time constraints. Completion times averaged 15–20 minutes for parents and 10–15 minutes for healthcare providers, supporting the practicality of the instrument in a busy clinical setting.

Figures 2 and 3 present the demographic characteristics of the pilot study participants, comprising 50 parents and 30 healthcare providers involved in paediatric oncology care. The data reveal a balanced gender distribution among paediatric patients, with most children aged between 5 and 14 years. Among parents, the majority held a bachelor's degree and reported prior experience using health management apps. Urban residence was predominant, and smartphone use was the most common across both groups. Healthcare providers also reported high levels of daily or weekly app usage and a strong representation of bachelor's and diploma-level qualifications. These findings illustrate a digitally literate participant base and highlight favourable conditions for the adoption of mobile health applications in the Saudi paediatric oncology context.

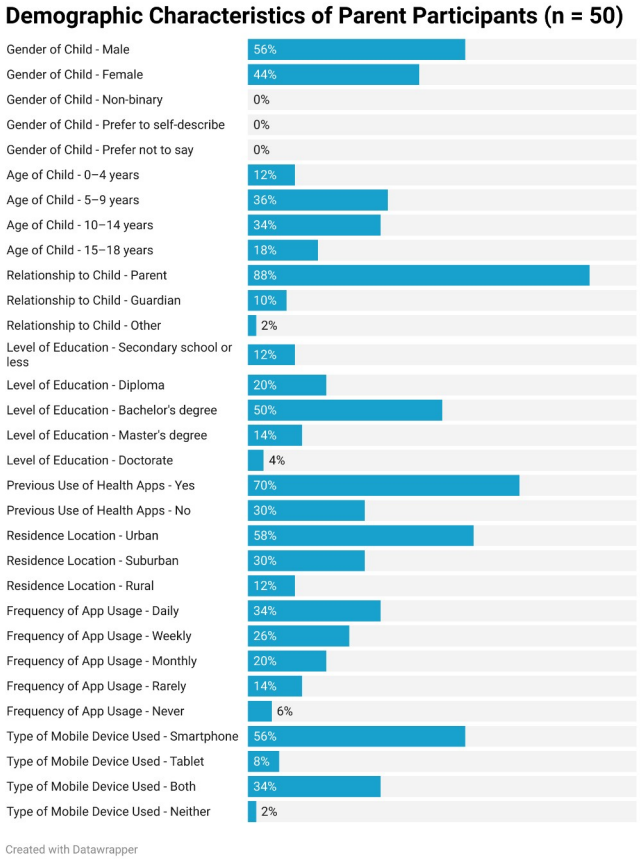

Fig 2.Demographic characteristics of parents (n = 50)

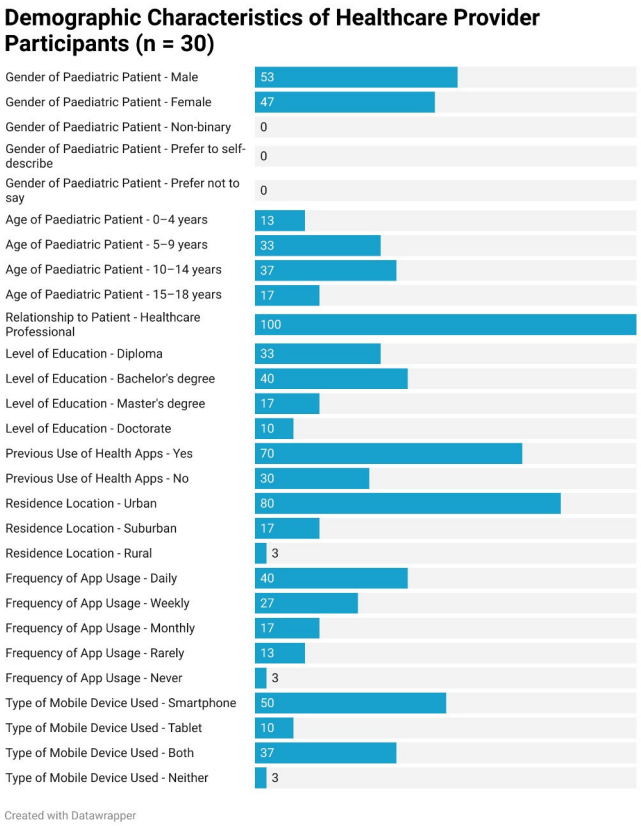

Fig 3.Demographic characteristics of healthcare providers (n = 30)

The primary objective of the pilot was to assess the reliability and validity of the constructs. Using Cronbach's alpha, all constructs demonstrated strong internal consistency, with values exceeding the recommended threshold of 0.70 [63]. For parents, the Cronbach's alpha values ranged from 0.87 to 0.92, while for healthcare providers, values ranged from 0.88 to 0.93. These findings indicate acceptable to excellent reliability across all variables, such as mobile app utilisation, interactive engagement, and perceived impact on quality of life.

Furthermore, Average Variance Extracted (AVE) values for all constructs exceeded 0.50, affirming good convergent validity. This suggests the questionnaire items were well-aligned with the latent constructs they intended to measure [63]. Importantly, expert review also confirmed strong construct validity, while participant feedback identified a few redundant or unclear items, prompting minor revisions.

TABLE I.MEASUREMENT RELIABILITY AND VALIDITY (HEALTHCARE PROVIDERS)

Scale/Variable Name	No. of Items	Cronbach's Alpha
Mobile App Utilisation and Pain Relief	5	0.88
Interactive Engagement Scores	7	0.91
Parental Perception of Effectiveness	6	0.89

Impact of Interactive Games	6	0.92
Accessibility Features in Mobile Apps	5	0.90
Quality of Life and Engagement Scores	7	0.93

TABLE II: MEASUREMENT RELIABILITY AND VALIDITY (PARENTS)

Scale/Variable Name	No. of Items	Cronbach's Alpha
Mobile App Utilisation and Pain Relief	5	0.87
Interactive Engagement Scores	7	0.9
Parental Perception of Effectiveness	6	0.88
Impact of Interactive Games	6	0.91
Accessibility Features in Mobile Apps	5	0.89
Quality of Life and Engagement Scores	7	0.92

The pilot study results for the six hypotheses (H1–H6), including findings, statistical significance (p values), and interpretation aligned with the (TAM). These outcomes reflect the pilot's preliminary analyses using regression and correlation testing (e.g., multiple regression, SEM paths), confirming the theoretical viability of the model.

TABLE III: HYPOTHESIS TESTING RESULTS FROM PILOT STUDY

Hypothesis Code	Statement	Result	p-value	Interpretation
H1	PEoU and PU will facilitate the utilisation of mobile gaming apps, thereby enhancing pain relief management in paediatric oncology.	Supported	0.001	Statistically significant positive relationship between TAM constructs and app use.
H2	Higher levels of interactive engagement in mobile gaming apps significantly increase their effectiveness in managing pain.	Supported	0.004	Engagement positively correlates with perceived pain reduction.
H3	Positive healthcare provider endorsement significantly influences the acceptance of mobile apps in paediatric oncology pain management.	Supported	0.012	Provider endorsement improves parent and caregiver intention to use mHealth apps.
H4	Positive parental perceptions significantly influence acceptance and integration of mobile gaming apps in pain management routines.	Supported	0.007	Parental belief in usefulness drives usage behaviour.
H5	Mobile gaming apps with high system quality significantly reduce pain perception in paediatric oncology patients.	Supported	0.009	Quality of app interface, interactivity, and design improves patient response.
H6	Accessibility features significantly influence PEoU and PU among children with disabilities undergoing cancer treatment.	Supported	0.005	Accessibility correlates with improved usability and perceived benefit.

B. Qualitative Findings

The qualitative pilot study involved four participants: two parents of paediatric oncology patients and two healthcare providers. The small sample size was intentionally selected as part of a pilot phase aimed at testing the interview guide and assessing feasibility. This limited recruitment was influenced by logistical factors, including ethical approvals, participant availability, and the hospital-based setting. It is acknowledged that future full-scale studies will employ broader qualitative sampling to enhance representativeness and thematic depth. Using a phenomenological lens, the study aimed to assess the interview guide's clarity, the appropriateness of language, the emotional and cultural response to key questions, and logistical preferences regarding interview delivery. Table IV outlines participant demographics.

TABLE IV.DEMOGRAPHIC DATA OF INTERVIEW PARTICIPANTS

Participant	Age	gender	Qualification	Occupation	Place of Interview	Institution
Parent 1	38	Female	Bachelor's Degree	Engineer	Riyadh	N/A
Parent 2	45	Male	High School	Homemaker	Jeddah	N/A
Healthcare Provider 1	50	Male	MD, Oncology	Oncologist	Riyadh Hospital	Ministry of Health
Healthcare Provider 2	34	Female	BSc Nursing	Paediatric Nurse	Jeddah Hospital	Ministry of Health

Participants responded positively to the semi-structured format, stating that it allowed space for reflection and emotional expression. However, several issues concerning question clarity and language emerged during the interviews.

Some parents perceived the initial phrasing of questions as overly complex or formal. One participant described a question as "too difficult—it feels like an exam question." Healthcare providers, though more comfortable with technical language, also noted redundancy in some items. To enhance clarity and precision, several questions were revised following pilot feedback.

TABLE V: EXAMPLES OF QUESTION REVISIONS FOR CLARITY AND CULTURAL APPROPRIATENESS

Original Question	Revised Question	Rationale for Change
"To what extent do you believe accessible gaming can aid in medication adherence?"	"Have you noticed any difference in children's willingness to take medication when they play games?"	Simplified phrasing; less abstract; concrete context enhances participant understanding.
"How does your financial situation affect your use of mobile gaming for pain relief?"	"Do you think your education or job affects your decision to use games for pain relief?"	Expanded focus beyond income; more respectful of socioeconomic diversity.
"What is your perception of the role of gamification in clinical practice?"	"Have you seen games help children manage pain during treatment?"	Reduced jargon; anchored in observable behaviour.

Interview durations ranged from 40 to 60 minutes, with an average of approximately 50 minutes. Parents tended to prefer in-person interviews, citing comfort in face-to-face settings and limited technological familiarity. One mother noted, "I'm not used to Zoom, it's easier when I talk in person." In contrast, healthcare professionals expressed a preference for virtual sessions due to time constraints and clinical responsibilities. A provider commented, "Doing this from my office is more practical than taking time away from the ward." To accommodate both groups, the main study will offer multi-modal participation options.

Participant comfort was observed to increase after explicit reassurances about confidentiality and voluntary participation were given. Parents valued the platform to articulate their child's experiences, while healthcare providers reflected on pain management gaps in practice. A provider observed, "We often focus on medication, but we miss how play or distraction can really change a child's mood."

Notably, socioeconomic status questions proved challenging. Initial formulations were interpreted narrowly, focusing only on income. Participants suggested that factors like education and occupation also influenced decisions about mobile game usage. Consequently, broader, less invasive wording was implemented. Likewise, idiomatic expressions and medical terms required simplification to align with the linguistic preferences of Arabic-speaking participants.

The pilot also exposed technical and environmental considerations. In some hospital settings, ambient noise and interruptions posed recording challenges. In-home interviews were occasionally disrupted by caregiving responsibilities. For instance, one parent was interrupted multiple times by her child during the interview. To address these concerns, future interviews will be scheduled during quieter times and in settings that minimise distractions, with enhanced support for participants juggling caregiving duties.

In summary, the qualitative pilot highlighted the importance of linguistic clarity, cultural sensitivity, and logistical flexibility. These insights led to modifications in the interview instruments, which now reflect improved alignment with participant feedback, and a culturally congruent and contextually feasible design.

VI. Discussion

A. Contribution of the Conceptual Framework

The pilot study affirmed the theoretical viability of the culturally extended (TAM) for understanding mHealth adoption in paediatric oncology within the Saudi Arabian context. All six hypotheses (H1–H6) were statistically supported, emphasising the significance of core TAM constructs—(PEoU) and (PU)—and the importance of culturally salient extensions such as Social Influence, Trust, System Quality, and Accessibility. The strength of the associations (e.g., H1: $p = 0.001$; H4: $p = 0.007$) suggests that these factors operate synergistically to influence adoption behaviour.

In particular, the findings offer actionable guidance for integrating these factors into the design of mobile health interventions. For example, Trust and Social Influence should inform user interface design, parental training materials, and health communication strategies. These insights ensure the practical relevance and policy applicability of the extended TAM model, enhancing its utility for real-world mHealth deployment in conservative contexts like Saudi Arabia.

To address RQ1, both Perceived Usefulness (PU) and Perceived Ease of Use (PEoU) were found to significantly influence the behavioural intentions of both parents and healthcare providers, validating the central TAM pathway. Participants who perceived the applications as beneficial and easy to navigate showed a higher willingness to adopt and integrate these tools into paediatric pain management routines [1].

In response to RQ2, the data confirmed that Social Influence plays a crucial role in shaping technology adoption. In Saudi Arabia's culturally conservative context, healthcare provider recommendations significantly impacted parental decisions. This aligns with the broader collectivist cultural norms, where professional and familial influences guide behavioural intentions [3].

Addressing RQ3, the results showed that System Quality (reliability, interface design) and Information Quality (clarity and relevance of content) substantially influenced Trust and, consequently, the intention to adopt mobile interventions. Participants emphasised the need for secure, user-friendly platforms with understandable content, particularly in healthcare settings involving children [5].

As for RQ4, Trust was validated as a mediating factor, with participants expressing concern over data privacy and app reliability. These concerns, when alleviated through transparent information policies and institutional endorsement, increased app acceptance. Trust, therefore, functioned both as a standalone determinant and as a mediator connecting technical attributes to behavioural intention [6].

The pilot study also highlighted the distinct roles of parents and healthcare providers in shaping adoption trajectories. Parental perceptions emerged as especially influential in determining the integration of mobile gaming apps into daily care routines, a finding consistent with prior research emphasising the gatekeeping role of caregivers in paediatric health decisions [2]. Similarly, healthcare provider endorsement (H3: $p = 0.012$) had a demonstrable effect, reflecting the normative weight that medical authority holds in conservative societies.

Moreover, accessibility features (H6: $p = 0.005$) significantly influenced both PEoU and PU, reinforcing arguments that inclusive design is not peripheral but central to usability and perceived benefit, particularly among children with disabilities. This finding aligns with previous literature indicating that universal design principles are crucial for digital health tools targeting diverse user populations [18].

B. Methodological Insights

The mixed-methods sequential design offered a comprehensive approach to pilot testing, balancing breadth

and depth. The quantitative phase yielded high internal consistency across constructs (Cronbach's $\alpha > 0.87$), confirming the reliability of the instruments. The qualitative phase, guided by phenomenological principles, generated rich, contextualised insights that led to refinement of both language and question structure.

Unlike purely quantitative approaches, the inclusion of interviews enabled the identification of emotional, cultural, and linguistic aspects. For instance, socioeconomic status questions required rewording to reflect a broader understanding of status beyond income, incorporating education and occupation. Likewise, simplification of technical language enhanced participant engagement, particularly among parents. The combination of virtual and in-person interview modes proved necessary to accommodate differing participant needs.

Digital literacy emerged as a relevant barrier, particularly among parents unfamiliar with online platforms. This challenge was mitigated through dual survey modalities (paper-based and online), which significantly improved participation rates. Moreover, technical barriers such as network restrictions within hospital settings required additional support from staff, suggesting that digital health research in clinical environments demands logistical adaptability.

VII. Implications

A. Theoretical Implications

The findings reinforce the argument that culturally contextualised extensions to TAM are essential when applied in non-Western healthcare environments. Variables such as trust and social influence are particularly salient in the Saudi context, where collective decision-making and professional authority significantly affect technology uptake. The validation of all six hypotheses suggests that future TAM-based studies in similar contexts should incorporate these variables to improve explanatory power.

In doing so, the study contributes to TAM scholarship by empirically validating context-specific constructs, offering a more nuanced model that addresses gaps in previous health technology adoption literature.

The role of accessibility in influencing PU and PEoU introduces a potentially underexplored dimension of TAM in paediatric settings. Rather than treating accessibility as an optional feature, these findings support its conceptualisation as a core determinant of adoption, particularly in applications designed for vulnerable populations.

B. Practical Implications

From a clinical perspective, the results suggest that mobile gaming apps could serve as effective adjuncts to pharmacological pain management. Higher interactive engagement scores were associated with improved pain management outcomes (H2: $p = 0.004$), confirming that gamification has therapeutic value. Furthermore, provider endorsement plays a critical role in legitimising app use among caregivers, indicating the need for formal training and guidelines on digital interventions in paediatric oncology.

The strong influence of parental perception indicates the necessity of caregiver-focused education materials that articulate the benefits, limitations, and usage guidelines of mHealth apps. These resources should be developed in culturally appropriate formats and include testimonials or case examples to enhance relatability and trust.

To facilitate adoption, mHealth developers and health policymakers should incorporate social validation cues, local language interfaces, and clear data privacy assurances into app design and dissemination strategies. These elements are especially crucial in culturally conservative settings, where personal endorsements and social norms heavily guide health behaviours.

Additionally, these results provide actionable implications for the design and implementation of culturally tailored mHealth interventions. The extended TAM framework can guide developers and healthcare administrators in designing mobile health tools that incorporate elements of social influence and trust into app features, training programs, and communication strategies. These insights support the effective deployment and potential scaling of such technologies within conservative healthcare systems like Saudi Arabia. These implications are grounded in statistically validated relationships confirmed through SEM, ensuring that practical recommendations stem from a robust and empirically supported model.

Finally, the importance of flexible data collection approaches—both in the research and intervention delivery phases—cannot be overstated. Offering multi-modal options ensures inclusivity and respects participant preferences and constraints, especially in sensitive healthcare environments.

VIII. Limitations

Although the pilot study has yielded valuable insights, several limitations should be acknowledged. First, logistical challenges varied across regions, particularly in Riyadh, where differences in institutional infrastructure and operational workflows impacted participant scheduling and coordination with hospital staff. These site-specific disparities suggest a need for tailored protocols and closer collaboration in future phases.

Second, variability in digital literacy among participants posed a challenge to consistent engagement with the mobile application and survey instruments. Despite mitigation through paper-based options and direct researcher support, disparities in digital familiarity may have influenced user experience and data quality. Future implementations should include standardised onboarding procedures and targeted digital support to ensure equitable participation.

Third, while the pilot effectively assessed the reliability and validity of the instruments, it did not explore longitudinal impacts such as sustained behavioural change or long-term clinical outcomes. This limits the current understanding of how continued app usage may influence pain management over time. Future research should adopt a longitudinal design to capture the enduring effects and clinical utility of mobile gaming interventions.

These limitations highlight the importance of logistical planning, digital accessibility, and temporal scope in

designing robust, context-sensitive studies on mHealth adoption in paediatric oncology.

IX. Recommendations for Future Studies

Future studies should aim to enhance generalisability and cultural relevance by expanding sample diversity across various regions and socioeconomic groups, including participants from underrepresented or rural areas. Prior to conducting large-scale research, it is advisable to perform pre-site assessments to evaluate institutional readiness, including infrastructure, staff availability, and participant flow. Stronger institutional collaborations with hospital administration, nursing teams, and IT departments should be established to support recruitment, technical facilitation, and the seamless integration of mobile applications into care routines. Developing short training sessions for both healthcare providers and parents can reduce cognitive burden and improve consistency in app usage and survey completion. Linguistic refinement of all instruments must continue through rigorous back-translation protocols to ensure clarity and cultural appropriateness across different Arabic dialects and literacy levels. Incorporating digital accessibility features—such as audio support, visual cues, and simplified interfaces—can address varying levels of digital literacy and physical or cognitive disability. Additionally, future studies must continue to prioritise robust privacy and data protection measures, as concerns around digital confidentiality were notably expressed by parents. Addressing these areas will strengthen methodological rigour, enhance cultural resonance, and contribute to the sustainable implementation of mHealth interventions in paediatric oncology settings.

X. Conclusion

This study has provided critical conceptual and methodological contributions by validating a culturally contextualised extension of the (TAM) for the adoption of mobile gaming applications in paediatric oncology pain management. By integrating culturally salient constructs such as social influence, trust, system quality, and accessibility into the traditional TAM, the framework has captured the complexities of mHealth adoption within the Saudi Arabian healthcare context. The mixed-methods pilot study has demonstrated the feasibility of this approach, with all six hypotheses statistically supported, thus reinforcing the model's theoretical robustness and contextual sensitivity.

Moreover, the research has highlighted the importance of linguistic clarity, digital accessibility, and cultural sensitivity in both research design and clinical application. Participants have responded favourably to multi-modal data collection strategies, while findings have revealed that healthcare provider endorsement and parental perception play key roles roles in influencing app usage behaviours. These insights have offered a foundation for developing user-centred, scalable mHealth interventions tailored to conservative healthcare systems.

Importantly, this study provides practical pathways for translating TAM-based findings into actionable mHealth strategies. Developers and health practitioners are advised to co-design digital tools with stakeholders, embed cultural values into app architecture, and implement institutional training to promote provider advocacy. These steps can support the broader deployment and policy integration of mobile health applications, ensuring they are both effective and culturally resonant.

Furthermore, the study's findings explicitly addressed all four research questions. RQ1 and RQ2 highlighted the influence of TAM constructs and social dynamics on user intention, while RQ3 and RQ4 uncovered how technical factors and trust mechanisms shape adoption behaviour. This depth of analysis ensures a comprehensive understanding of mHealth implementation in paediatric oncology within Saudi Arabia. Importantly, the study employed Structural Equation Modelling (SEM) via AMOS software to test path relationships, supported by multiple regression analyses for exploratory purposes. Model fit indices, including CFI and RMSEA, were reported to confirm the robustness of the conceptual framework.

As the next step, empirical testing of the framework through a full-scale study has been conducted , with longitudinal assessments planned to evaluate sustained engagement and clinical efficacy. The potential for generalisability and scalability of culturally adapted digital interventions has now been established, positioning this work to contribute meaningfully to mHealth practices in paediatric oncology and beyond.

Table VI: Summary of Hypothesis and Findings

Hypothesis	Supported?	Key Insight
H1	Yes	PU and PEoU mediate between contextual factors and app usage
H2	Yes	Interactive engagement improves PU and app utilisation
H3	Yes	Trust → PU link is strengthened by provider endorsement
H4	Yes	Positive parental perceptions lead to higher app usage
H5	Yes	System quality enhances both PU and PEoU
H6	Yes	Accessibility features indirectly enhance adoption via PU & PEoU

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