Family Dynamics with Smart Voice Assistants and Implications for Child-Centered AI Design

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AI-powered technologies are becoming increasingly integral to children's digital experiences through devices like interactive toys, home automation systems, and apps, offering rich, personalized, and dynamic interactions. Despite their growing prevalence, how these AI-powered platforms can be designed to address the unique needs of children remains largely underexplored. Leveraging family interactions with Smart Voice Assistants (VAs) as a case study, we aim to explore how to approach child-centered AI (CCAI) design from a family perspective in this work. Specifically, we interviewed 20 parents and observed children's VA interactions in eight households in a non-Western context. Using the theoretical lenses of agency and family functioning, we provide empirical insights into family dynamics when interacting with VAs in a less studied cultural setting, such as variations in family interaction types around VAs, the autonomy exercised by different parties, and the family functional roles VAs played. Based on these findings, we argue that CCAI design should be understood as balancing children's agency, the roles and goals of other involved actors, and the contexts in which AI is used, and that it should focus on creating AI technologies that support positive outcomes for children in ethical ways while thoughtfully considering other stakeholders and their varying purposes for engaging with AI. In doing so, we offer a reconceptualization of CCAI and point to design directions for AI technologies that more meaningfully center child users in family contexts.

CCS Concepts: • **General and reference → Design**; • **Social and professional topics → Children**; • **Human-centered computing → Empirical studies in HCI**; **User models**.

Additional Key Words and Phrases: Smart voice assistant, family dynamics, child-centered AI design, joint media engagement

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1 Introduction

Artificial Intelligence (AI) technologies are becoming increasingly embedded in everyday life, transforming how people interact with the digital world. Among these technologies, smart voice assistants (VAs), such as Amazon Alexa, Google Assistant, and Apple Siri, have gained significant

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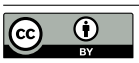

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popularity in family settings [65]. These AI-powered devices offer convenience, entertainment, and support for household tasks, making them increasingly important to modern family routines [24, 32, 63]. As VAs continue to evolve, their role extends beyond mere functionality, influencing family dynamics and the ways individuals, especially children, engage with AI (e.g., [29, 41, 45]).

Children are emerging as important and frequent users of smart VAs and other AI technologies in the home. Whether asking questions, playing games, or controlling smart home devices, children's interactions with VAs offer unique opportunities for learning, entertainment, and communication [32, 41, 68]. However, these interactions also raise critical questions about how AI systems should be designed to accommodate children's developmental needs and foster positive experiences. As a distinct user group with specific capabilities and vulnerabilities, children require AI systems tailored to their unique roles and interactions, making child-centered AI (CCAI) an increasingly important focus in child-computer interaction research, as well as in the broader fields of human-computer interaction and AI research [4, 18, 74].

Despite the increasing prevalence of VAs in homes worldwide, research on the implications of these technologies for family dynamics and CCAI design remains limited. For example, most studies on family dynamics involving VAs focus on understanding family members' interaction with the technology, such as exploring VA interactions in mixed-visual-ability families [66], children's speech patterns with VAs [41], and the integration of VAs into everyday family life [63]. While research on child-centered principles for AI design is gaining traction, addressing topics such as ethical considerations [75] and aligning AI design with children's cognitive and socio-emotional development [45], much of the current understanding of CCAI remains conceptual [12, 35, 43, 53, 61], highlighting the need for further empirical studies to validate and expand this emerging field, particularly from a family-oriented perspective. Additionally, existing studies on VAs are predominantly conducted in Western, particularly U.S.-based, contexts (e.g., [7, 63, 92]), which may not fully capture the diverse cultural and social dynamics of families in other regions.

In this study, we aim to address these gaps by exploring family interactions with smart VAs in a non-Western context and reflecting on their implications for CCAI design. Specifically, through interviews with 20 parents and observations of children in eight households in China, we aim to answer the research question: *How do children and parents interact with smart voice assistants in the family setting, and what are the implications of these interactions for designing child-centered AI?* Guided by the theoretical lenses of *agency* [30, 60] and *family functioning* [25], we analyze how children, parents, and AI express their agency during multi-party interactions in a family environment and how AI influences family functioning through these interactions. Our findings identify six types of family interactions with and around smart VAs, such as learning, childcare, and emotional support, where children, parents, and AI exhibit various agencies toward one another. Additionally, we demonstrate how the presence of AI in family settings reshapes family dynamics by supporting existing family roles and enhancing family members' functioning. Based on these empirical findings, we expand the conceptual framing of CCAI design, emphasizing the importance of designing AI ethically to benefit children while considering the social ecosystems in which it is used. By examining and clarifying the meaning of this emerging CCAI design concept within the context of real-world family experiences, we also contribute to strengthening the conceptual and practical foundation for designing more child-friendly AI technologies.

More broadly, our work makes three key contributions to the CSCW community. First, we empirically demonstrate how AI adoption in families constitutes a form of cooperative and collaborative work that spans multiple actors (children, parents, and AI systems), revealing how technology mediates coordination, communication, and negotiation in everyday domestic life. These empirical findings directly align with CSCW's core interest in understanding and designing for multi-party sociotechnical practices. Second, we bring a cross-cultural perspective (Section 5.1) that advances

CSCW's ongoing efforts to move beyond Western-centric accounts, showing how cultural context shapes the cooperative integration of AI technologies in households. Third, through our conceptual extension of the CCAI framework (Sections 5.2–5.3), we provide new theoretical grounding for examining human–AI cooperation in family contexts, thereby enriching CSCW's conceptual repertoire for studying emerging forms of collaboration with AI. Finally, by translating these insights into concrete design implications for child-centered AI in families (Section 5.4), we contribute to CSCW's longstanding tradition of connecting empirical findings with actionable socio-technical system design. Together, these contributions underscore the importance of viewing child–AI interactions not as isolated dyads but as embedded within collaborative family ecosystems, positioning our work squarely within CSCW.

2 Related Work

This section reviews the empirical and theoretical works that form the foundation of our work, including the related work on family interactions with smart VAs, designing child-centered AI technologies, and the design of AI technologies for family use.

2.1 Family Interactions with Smart Voice Assistants

Smart voice assistants (VAs), such as Amazon Alexa, Baidu Xiaodu, and Line Clova, are among the most common AI technologies found in households, offering a variety of functions to assist with family tasks, from providing weather updates to setting timers [63]. These devices also offer specific benefits for children, such as supporting language skill development [82] and serving as an outlet for emotional expression [31]. This growing trend has led to increased research on child-VA interactions [24, 29, 32, 41, 45, 49]. Common findings include children using VAs to access learning content [32], exploring and testing the functionalities of VAs [68], and forming emotional attachments to these technologies [41]. Recurring patterns in child-parent interactions around VAs have also been identified. For instance, families use VAs to strengthen bonds [7], collaborate in troubleshooting communication issues with VAs [66], or sometimes even hinder each other's access to and conversations with VAs [7]. Additionally, other studies have explored how parents interact with VAs for child-related purposes, such as using VAs to help answer children's questions [7] or to manage their attention, potentially reducing parental burnout [48].

Despite the growing interest in VAs, little research has specifically explored how their design can be tailored to support children's needs and interests within a family context. This gap underscores the need for further investigation to identify and understand the key factors shaping family, particularly children's, interactions with VAs. Additionally, much of the existing research is centered on families in Western cultures, particularly in the U.S. [31, 90], while family interactions around VAs in other regions remain significantly less understood. Moreover, few studies have specifically focused on the AI nature of smart VAs or discussed the implications of these interactions for CCAI design. Therefore, further research is needed to uncover the complexities of family dynamics involving VAs, particularly in non-Western contexts, and to develop culturally informed, evidence-based guidelines for CCAI design.

2.2 Designing for Child-Centered AI Technologies

As a growing field of research and design, several preliminary works have focused on advancing and guiding the design of CCAI, notably [4, 26, 61, 74, 75]. Recent scholarship has further expanded this conversation by critically examining child-centeredness from different perspectives, emphasizing issues such as trust in conversational AI [62], playful but ethically sensitive forms of child-AI systems [46], developmentally aligned AI grounded in child development science [44], child-AI co-creation in creativity support tools [13], and children's roles as interpreters, collaborators, and

resistors of AI systems [21]. These studies outline two key clusters of guidelines for designing AI technologies for children.

The first cluster emphasizes ethical and responsible practices, which include preserving children's fundamental rights such as fairness and inclusivity, transparency and explainability, privacy and safety, and system accountability. For instance, ensuring fairness and inclusivity involves mitigating biases against children by using child-specific datasets and reducing discrimination based on gender, race, and other factors [75]. Transparency and explainability require providing accessible, age-appropriate explanations of AI systems to help children understand the decision-making processes behind them [18]. Privacy and safety focus on minimizing privacy risks, such as limiting the collection of children's personal data [12], and preventing potential harm, including physical injuries, misinformation, or unhealthy child-AI relationships [18, 73]. Accountability involves conducting regular reviews and updates of AI systems, such as impact evaluations, to safeguard children's rights [75]. The second cluster addresses children's developmental stages, focusing on their evolving cognitive and socio-emotional skills. For example, designers must consider children's language abilities by avoiding complex vocabulary, long sentences, and overly challenging syllables [18, 45]. Additionally, AI technologies should account for children's socio-emotional needs to capture and sustain their attention, thereby enhancing engagement [18, 26, 53].

CCAI design, while rich in theoretical discussions, remains an emerging field lacking sufficient empirical evidence to support its conceptual understanding. Most existing studies approach child-centeredness through the lens of governmental AI policies, either directly, such as UNICEF's Policy Guidance on AI for Children [72], or indirectly, like ICO's Age Appropriate Design Code [22, 38, 75]. Other efforts have focused on organizing workshops to foster interdisciplinary dialogue on CCAI design, such as the CHI 2023 and IDC 2024 workshops on Child-Centered AI Design [12, 35, 53, 61, 74]. Complementing these initiatives, emerging frameworks such as PEARL-AI for child health [16], developmentally aligned design for early childhood contexts [44], and co-design methods with children for AI learning experiences [94] illustrate how sector-specific lenses are shaping the broader theorization of CCAI. These pioneering efforts have offered valuable theoretical insights into the concept of CCAI. However, the absence of empirical evidence raises questions about what truly defines child-centeredness in AI systems deployed in real-world contexts. Children's interactions with technology are often influenced by external factors beyond their intrinsic characteristics, such as parental regulation of access to and interaction with technology [19, 90]. To address this gap, we use the case of family interactions with smart VAs to explore the meanings of child-centeredness within the complex socio-ecosystem of family contexts, eventually providing empirical insights that can inform and refine the design of CCAI technologies.

2.3 Designing AI Technologies in the Family Context

Families play a significant role in children's digital experiences. It serves as the fundamental block of human societies, where one of the primary goals for technological advances is to support duties in family units [39, 57]. Meanwhile, families are the basic component of the microsystem of the ecological system around children [10], thus involving immediate influences on their physical and psychological development [25, 89]. Such critical roles of family render it a main context to examine technology consumption and have led to extensive studies on family interactions around technologies. For instance, the works on Joint Media Engagement seek to understand and support children's and parents' experience of using technology-based media together [27, 87, 90, 91]. Similarly, the research on parental mediation delves into parents' strategies to take full advantage of technologies while minimizing their potential risks to children [19, 88].

With the rapid adoption of in-home AI, families have increasingly embraced AI technologies to assist with various family-specific tasks. This shift has led to a growing body of research exploring

how family members interact with and around AI technologies (e.g., [7, 12, 15, 24, 48, 92]). Recent reviews emphasize that AI in the family context can influence parenting, communication patterns, and even family cohesion in both positive and detrimental ways [54, 69]. In particular, McDaniel et al. [54] highlight five overlapping themes of AI in family life, ranging from integration in daily routines to policy and ethical concerns, while Szondy and Magyary [69] analyze how AI reshapes family boundaries, roles, rituals, and parent–child communication. For example, Druga et al. [24] identified four primary ways children interact with smart voice assistants in family settings: assessing AI's intelligence, exploring its identity, using it for entertainment, and trying to understand its mechanics. Building on this line of work, later research conceptualizes the family as a "third space" for developing AI literacies, showing how parents and children jointly engage in learning and scaffolding roles when interacting with AI activities [23].

However, few studies have examined family-AI interactions from a design perspective, specifically, how AI can be designed to accommodate the complex, multi-agent dynamics of family life. While some prior research has offered design implications, these often align with general AI design principles, such as fostering interactive engagement and ensuring privacy in shared home environments [58]. More recent empirical and conceptual work shows that AI adoption intersects with deeper cultural and social dynamics. For instance, Alfeir [2] quantitatively demonstrated how AI dimensions such as accessibility, personalization, and language translation significantly affect family communication, whereas Farisal [28] identified tensions in Southeast Asia regarding how children's respect for parents may shift when parental authority is mediated by AI. Furthermore, Petsolari et al. [59] show through design fiction that parents simultaneously see potential benefits and substantial risks in AI parenting supports, raising questions about authority, agency, and surveillance in the family ecosystem. Together, these studies underscore that designing AI for families requires attention not only to usability and privacy but also to cultural norms, ethical safeguards, power dynamics, and respect within family relationships. Supplementing this line of research, the current study will explore CCAI design rooted in a family-centered perspective.

3 Methods

This section outlines our methods, including details about the participants, data collection, analytical frameworks, and data analysis processes. The study was approved by the Institutional Review Board of the authors' institution, and written informed consent was obtained from all participating parents for their own interviews and for their children's participation in observations and associated child interviews, with children fully informed about the observation activities.

3.1 Participants

We interviewed 20 parents from different families and conducted observations in eight of these households to explore how children interacted with VAs at home. Parents were recruited based on two criteria: They had at least one VA device actively used daily in their household, and their families included at least one child aged 7-12 years. We focused on this age group because children in primary and secondary school are at a critical stage where they begin to engage more intensely with technology but still require significant parental involvement, unlike teens and young adults who tend to have more independent media consumption [64, 86]. Table 1 presents our participants' demographic information. All households involved in this study were from different cities across mainland China and were reached with the assistance of social workers in the authors' networks. The 20 parents comprised both mothers (N = 16) and fathers (N = 4) and spanned different socio-economic statuses according to the 2023 McKinsey China Consumer Report [95]. The 20 families included a total of 33 children aged 7 to 12 (M age = 7 years and 8 months; N girls = 17, N boys = 16).

Table 1. Demographic information of participants in this study. F = female. M = male. VA = smart voice assistant. All age-related data are shown in years. "*" indicates the family participating in in-home observations.

#	Sex	Age	Education	Child's Sex & Age	Level of Annual Household Income	VA Used by the Family
P1	M	40	Master	M (10), F (7)	High income	A standalone VA (a Mi smart speaker) and an embedded VA (a smart lamp)
P2	F	43	Master	F (10)	High income	A standalone VA (a Mi smart speaker) and an embedded VA (a social robot)
P3*	F	34	Bachelor	M (7.5), M (6)	High income	Two standalone VAs (a Mi smart speaker with a screen and a Tmall Genie smart speaker) and three embedded VAs (a tablet, a smart reading pen, and a social robot)
P4	F	47	Middle school	M (9)	Low income	A standalone VA (a Xiaodu smart speaker) and an embedded VA (a smartwatch)
P5	F	39	Bachelor	F (8)	High income	A standalone VA (a Tmall Genie smart speaker) and two embedded VAs (a smartwatch and a social robot)
P6	F	45	Associate degree	M (7)	Low income	A standalone VA (a Xiaodu smart speaker) and an embedded VA (a tablet)
P7*	M	39	Master	M (10), M (6), M (1)	High income	Two standalone VAs (two Xiaodu smart speakers) and an embedded VA (a smart reading pen)
P8*	F	39	Associate degree	F (12), M (5)	Middle income	A standalone VA (a Xiaodu smart speaker) and two embedded VAs (a tablet and a smart reading pen)
P9	F	32	Associate degree	F (7)	Low income	Four embedded VAs (two tablets, a smart reading pen, and a smartwatch)
P10	F	49	Associate degree	F (8)	Middle income	A standalone VA (a Xiaodu smart display with a screen)
P11*	F	35	Bachelor	F (12), F (7), F (7)	High income	A standalone VA (a Tmall Genie smart speaker) and two embedded VAs (a tablet and a smart reading pen)
P12*	F	36	High school	F (12), M (7)	Low income	Two embedded VAs (a tablet and a smart television)
P13	M	48	Associate degree	M (12)	Low income	A standalone VA (a Xiaodu smart display with a screen)
P14*	F	36	Bachelor	F (12), M (1)	Middle income	Three embedded VAs (a tablet, a smart reading pen, and a smartwatch)
P15	F	46	High school	M (8)	Low income	A standalone VA (a Mi smart speaker) and an embedded VA (a smart reading pen)
P16	F	38	Bachelor	M (10), M (4)	High income	Four standalone VAs (two Tmall Genie smart speakers, a Xiaodu smart display with a screen, and a Celia smart speaker) and four embedded VAs (a tablet, a smart reading pen, a smart workstation, and a social robot)
P17*	M	41	Bachelor	F (12), F (9)	Middle income	Three embedded VAs (a tablet, a smartwatch, and a social robot)
P18	F	43	Associate degree	F (12), F (6)	High income	A standalone VA (a Xiaodu smart speaker) and two embedded VAs (a smart reading pen and a smartwatch)
P19	F	33	Associate degree	M (9), F (5)	High income	A standalone VA (a Xiaodu smart speaker) and two embedded VAs (a tablet and a smart reading pen)
P20*	F	34	Bachelor	F (7)	High income	Three standalone VAs (two Tmall Genie smart speakers and a Xiaodu smart display with a screen)

Regarding VA devices, 16 families had VAs that functioned as standalone devices (devices like the Amazon Echo Dot), with some also featuring an embedded screen, such as the Xiaodu smart speaker [5] and Mi smart speaker [78]. Additionally, 17 households reported having VAs embedded into other smart devices, such as smartwatches, smartphones, and tablets, rather than operating independently. Examples of these embedded VAs include Apple's Siri [3], Baidu's Xiaodu [6], and Huawei's Celia [37]. Figure 1 shows examples of the three types of VAs used by our participants.

(a) (b) (c)

Fig. 1. Examples of the three types of smart voice assistants (VAs) used by the participating families: (a) a standalone VA with a screen, e.g., Xiaomi XiaoAi Touch Screen Speaker [78], (b) a standalone VA without a screen, e.g., TMall Genie Smart Speaker [71], and (c) an embedded VA, e.g., Xiaomi Smart Kids Watch [77]. Photos were provided by some participants.

3.2 Data Collection

We conducted semi-structured interviews ($N = 20$) and in-home observations of VA interactions in eight of the interviewed families. The interviews took place in November and December 2023, using the participants' preferred language (i.e., Mandarin Chinese) via online video calls, each lasting approximately one hour. The interview questions were divided into three main categories: 1) participants' demographic information (e.g., sex, age, location, education level, household annual income, number of children, and the age and sex of each child) and details about the VA devices they used at home; 2) specifics of their interactions with VAs, including scenarios, goals, family dynamics, challenges encountered, and assistance received, such as *"Have you encountered any issues or confusion while using VAs?"*; and 3) parents' perceptions of their children's use of VAs, with questions, such as *"Would you encourage your child to use VAs?"* All interviews were audio-recorded, and each participant received a compensation of 200 Chinese Yuan (roughly 28 USD) after completing the interview.

To supplement and triangulate the interview data from parents, we invited those living in the same city as the researcher who conducted the interviews to participate in one-hour in-home observations. Eight families agreed, and the observations were conducted in the late afternoons (5 PM or later) when children were home from school and extracurricular activities. During these sessions, the researcher maintained a low profile to minimize disruption and observed from discreet locations within the home. To collect data, we used video recordings, photographs, and field notes to document the children's interactions with VAs and their parents' involvement. If children did not interact with the VAs for more than half of the observation period, the researcher asked them about their typical use and invited them to demonstrate their daily routines. At the end of the observation, the researcher conducted a brief 10-minute interview with the child about their use of VAs in daily life. Families who participated in the in-home observations were compensated with another 100 Chinese Yuan.

3.3 Data Analysis

3.3.1 Theoretical Lenses for Analytical Directions. To examine family interactions with VAs and guide our reflection on CCAI design, we draw on two theoretical frameworks to inform our analytical directions: *agency* [30, 40, 60] and *family functioning* [25], explained in detail below. We selected these two theoretical lenses to emphasize the agency of all parties involved, including children, parents, and VAs, rather than adopting the Parental Mediation perspective [19, 88], which primarily centers on parents' agency. Additionally, although the two theoretical lenses informed our analysis, this study remains exploratory in nature. Note that these lenses were selected at the

outset of the analysis process, following the transcription of our data. Therefore, we present the two lenses in this section rather than the background or related work sections. Situating them in the Data Analysis section clarifies that we use agency and family functioning primarily as analytical tools to guide coding and interpretation, rather than as stand-alone theoretical contributions, and directly links their description to the subsequent account of our analytic procedures.

Agency. Recent research highlights the importance of considering human factors in AI design by advocating for respect and equity for children [74], aligning with the theory of social agency in human-robot interactions [30, 40, 56, 60] that defines agency as the ability to act independently and make decisions within socially interactive environments. Building on this foundation, researchers have identified three key dimensions of agency: 1) *interactivity* (the extent to which an agent and the surroundings can act on each other), 2) *autonomy* (the extent to which they can change their state without directly responding to the interaction), and 3) *adaptability* (the capacity to modify internal rules that govern state changes). Inspired by the three dimensions of agency, our analysis of family dynamics around VAs focuses on the interactivity, autonomy, and adaptability of the involved parties: children, parents, and VAs.

Family Functioning. Epstein and colleagues [25] in their McMaster model of family functioning have suggested six dimensions that shape the extent to which a family system can effectively perform fundamental functions, such as providing physical and financial resources to the family members and promoting personal and family growth (e.g., children's learning and development). The dimensions are 1) *problem-solving*, i.e., a family's ability to fix instrumental and affective issues related to each member's physical and mental needs, 2) *communication* (whether information can be exchanged clearly and directly in the family), 3) *roles*, e.g., the degrees to which each family member's repetitive behavioral patterns can fulfill family functions, 4) *affective responsiveness*, which evaluates if a family unit can respond to given situations with appropriate type and amount of emotions, 5) *affective involvement*–the levels of interest and value that a family expresses to members' interests and activities, and 6) *behavioral control*, addressing whether the family's pattern of regulating its members' behaviors is standardized yet flexible in satisfying certain physical, emotional, and social needs. Despite some overlaps among these dimensions, this theoretical model offers a specific context to consider how a part of the family (e.g., VAs) can impact others (e.g., children and parents), their interactions, and the unit's overall functioning, warranting the understanding of family dynamics and guiding our data analysis.

3.3.2 Analysis Process. It is important to note that we did not treat the two theories as rigid frameworks in our analysis. Rather, we used them as high-level guides to inform the direction of our inquiry, acknowledging that the contexts in which these theories were originally developed differ from those of the present study. In practice, this position meant that the concepts of agency and family functioning acted as sensitizing lenses [8] rather than coding schemes: they provided us with questions about whose agency was visible in interaction and how VAs might contribute to or disrupt family functioning, while the actual codes and themes were generated inductively from the data itself. Accordingly, we adopted a bottom-up, inductive approach and conducted a Thematic Analysis [20] to explore the agency of children, parents, and virtual assistants (VAs), as well as the role of VAs in family functioning during interactions.

Four researchers (R1, R2, R3, and R4) participated in the data analysis. Before the formal analysis, R1, who conducted the interviews and observations, transcribed the data. To address our research question on family-VA interactions, we analyzed the three dimensions of *agency*–interactivity, autonomy, and adaptability following Thematic Analysis [9]. Here, the three theoretical dimensions acted as broad analytic categories that drew our attention to particular kinds of interactional evidence, while the detailed sub-codes and final themes were developed inductively from the

transcripts. Specifically, R1 reviewed all participant data to inductively identify moments of family interactions with or around VAs, summarizing these interactions with short phrases as initial codes (e.g., *"children using VAs to preview and review school content"* and *"parents using VAs to keep children busy"*). For interactivity, R1 initially categorized these interactions by purpose, such as education, entertainment, and communication. R1, R2, and R4 met regularly throughout the summer of 2024 to discuss, refine, and confirm the categorization of all interaction moments involving children. R3 occasionally joined these meetings to provide feedback from an external researcher's perspective, ensuring that the categorizations and labels were logical and clear. In cases of disagreement, all researchers reviewed the raw interview and observation data together to reach a consensus on understanding family interactions. Through these iterative and collaborative efforts, we identified six themes of interactivity based on the purposes of various interactions: *"learning," "entertainment," "miscellaneous management," "childcare," "communication,"* and *"emotional support."* For the other dimensions of agency, autonomy and adaptability, we applied the same analytical procedure, categorizing interactions that reflected the autonomy and adaptability of children, parents, and VAs.

In parallel, we employed the conceptual model of family functioning to examine all identified interaction moments, focusing on the roles VAs played within the family. As with agency, the six family functioning dimensions served as orienting concepts that helped us ask which aspects of family functioning were visible in each interaction, but the grouping of data into themes was still performed inductively. R1 initially grouped the interaction moments according to the six dimensions of the model: problem-solving, communication, roles, affective responsiveness, affective involvement, and behavioral control. Similarly, R1, R2, and R4 met regularly to discuss how VAs supported or integrated into the existing family functioning across these identified moments. Through continuous, iterative group discussions and validation, we developed three higher-level themes regarding the roles of VAs from a family functioning perspective: *creating new family functions, extending the family functioning of existing members,* and *supporting family members' functioning*. This process illustrates how the theoretical model framed the scope of our inquiry while the inductive process shaped the specific categories and higher-level themes. R1 then synthesized the relevant interactions in alignment with these themes, which were reviewed, revised, and finalized by R2 and R4.

Although parents were our primary interview participants, our analysis also incorporated children's perspectives indirectly through in-home observations and short follow-up demonstrations in which children showed how they used VAs in daily routines. These observational data, while more limited in scope than formal interviews, allowed us to capture children's practices and relate them to parents' accounts. Specifically, to integrate interview and observation data, we first coded parent interviews to identify themes related to family routines, parenting goals, and perceptions of VAs, then compared these themes with codes from in situ observations, looking for convergences (e.g., routines that parents described and that we subsequently observed) and divergences (e.g., playful or unsupervised uses that were less foregrounded in parental accounts). Analytic memos documented how observational episodes confirmed, nuanced, or complicated parents' narratives, and these cross-data interpretations informed the organization of the findings.

Additionally, our empirical data illustrate family-VA interactions through the lenses of *agency* and *family functioning* but do not directly address the design of CCAI. Instead, based on our findings, the authors collectively reflected on key considerations for CCAI design, such as how to conceptualize child-centeredness and promote children's agency during multi-party interactions with AI. These reflections are further elaborated in the Discussion section. Meanwhile, we did not conduct an inter-rater reliability check due to the highly interpretive nature of the data analysis and our relatively small sample size [55]. We ensured the robustness of our analysis by 1) involving

three different coders who collectively examined the data to reach a shared interpretation and understanding and 2) having an external researcher review the coding results. We also monitored for data saturation across interviews. No new subthemes regarding the interaction types (Column 1 in Table 2) and the associated activity types (Column 3 in Table 2) emerged after the eighth parent interview, although subsequent interviews up to P20 provided additional examples that reinforced the established themes. The eight in-home observations were conducted primarily to triangulate these interview findings and add contextual depth, while balancing feasibility and participant burden. Lastly, it is important to note that all transcripts were analyzed in Chinese by four members of the research team who are native Chinese speakers, in order to preserve participants' original expressions and ensure accurate interpretation of the data. For reporting, selected excerpts were translated into English by the bilingual research team, who work in English medium institutions (for example, the corresponding author obtained a Ph.D. in the United States). Translations were jointly checked to minimize loss of nuance, although we acknowledge that some subtle cultural meanings may not be fully captured.

4 Findings

We begin this section by first outlining family-VA interactions along the three dimensions of agency: interactivity, autonomy, and adaptability (Sections 4.1.1, 4.1.2, 4.1.3, respectively). In Section 4.2, we then present our findings on VAs' roles that aligned with family functioning.

4.1 Agency

4.1.1 Interactivity. Family members engaged in various interactions with VAs, which we categorized into six types based on the purposes for interactions: *learning*, *entertainment*, *miscellaneous management*, *childcaring*, *communication*, and *emotional support* (see Table 2 for a summary). These categories are listed by the number of families engaged, from most to least common.

Learning. VAs supported children's learning via three ways: *providing academic content*, *fostering the development of personal interests*, and *responding to questions to satisfy their curiosity*. First, VAs frequently served as a resource for children's learning of academic content, especially in areas of language and mathematics. For language learning, children often engaged with VAs to bolster their language comprehension and production, with an emphasis on phonological (e.g., pronunciations of spoken words), vocabulary (e.g., the words' semantic meaning), and orthographic (e.g., spelling rules) acquisition. Specifically, children practiced their phonological skills by learning pronunciations through songs and videos, expanded their vocabulary by listening to stories, poems, and novels to gain broader language exposure, and developed orthographic skills by using VAs to search for correct spellings. For example, P3 shared that she *"frequently plays English songs and stories for her children during fragmented times, such as while they brush their teeth and eat meals."* Beyond language, VAs also supported children in learning mathematics by helping with calculations and clarifying mathematical concepts, as seen when P17's daughter sought an explanation for the math term "set" from the VA. Moreover, VAs played a role in helping children complete their homework, though this had sparked mixed reactions from parents. Some disapproved of using VAs for obtaining direct answers for fearing it encouraged laziness, as P7 noted *"My son uses the VA to calculate math homework because he is too lazy to think...so I criticize him using VA to obtain answers and have banned its such use."* However, others saw this use of VAs as a pragmatic solution to free up the time for physical activities by speeding up homework completion– *"Using VA helps children quickly complete their homework and provides them with more time for physical activities"* (P13).

At other times, VAs helped children develop interests, mostly by offering the relevant learning materials and answering related questions, such as *"[my child] asking VAs how to paint something"* (P16). In addition, VAs served as knowledgeable teachers for topics that children were interested in.

Table 2. Six types of interactions among children, parents, and smart voice assistants

Type	Definition	Activity	Explanation	Example
Learning	Using VAs to support children's learning activities, often facilitated by parents	*Learning academic content*	VAs help children review school materials and support academic-oriented learning tasks at home.	*"Our VA is specifically for exposing our child to English. She listens to English stories and repeats along."* (P10)
		Developing interests	VAs support children in developing their interests by providing learning materials and responding to inquiries.	*"My daughter sometimes asks VA to teach her how to fold paper. VA can play tutorial videos, making her learn and create the crafts she likes."* (P20)
		Satisfying curiosity	VAs respond to children's spontaneous questions arising from daily experiences.	*"After learning about Yang Guifei from the Tang Dynasty, my child asked VA what her house was like and her life timeline."* (P16)
Entertainment	Using VAs for fun and relaxation	*Brokering entertainment content*	VAs provide entertainment content for family members.	*"When I want to listen to songs, I ask VA to play."* (P4)
		Fooling around VAs	VAs respond to children's tinkering and playful questions.	*"My son enjoys chatting with the VA, asking playful questions, such as how old are you?"* (P15)
Miscellaneous management	Using VAs to handle daily routines and chores	*Controlling devices*	VAs act as a controller for managing electronic devices at home.	*"My son controls my fan and the lights from his room using the VA."* (P16)
		Managing chores	VAs assist family members with domestic chores and everyday tasks.	*"I used my VA to set alarms in the morning."* (P3)
Childcaring	Using VAs to help parents manage and support children's daily activities	*Occupying children*	VAs keep children occupied, freeing parents from continuous monitoring and involvement.	*"When my child bombards me with endless questions, I direct her to ask VA."* (P14)
		Regulating behaviors	VAs serve as a supplementary tool in parenting to regulate children's behaviors.	*"When my son looks too close to the screen, VA reminds him not to."* (P3)
Communication	Using VAs as communication mediums	*Connecting individuals*	VAs are used to communicate between family members and others.	*"My daughter and her friends chat together by VA."* (P14)
		Mediating conflicts	VAs mediate conflicts between family members as a neutral party.	*"We asked VA how story characters resolve conflicts, improving our communication."* (P7)
Emotional support	Using VAs to satisfy affective needs	*Seeking guidance*	VAs provide emotional advice and comfort.	*"VA comforts with advice about understanding and tolerance."* (P14)
		Venting emotions	VAs provide an outlet for expressing negative emotions.	*"Instead of lashing out, you can direct anger at VA."* (P7)

For instance, P4's son was fascinated by military-related topics and asked his VA about specific gun models, where it *"provided detailed information about those guns"* (P4). Besides, VAs would satisfy children's curiosity by providing answers to their spontaneous questions about their surroundings, as noted by P18, *"The VA easily answers my children's whimsical questions when they arise."* P7's son likewise asked his VA about *"the difference between a wolf's howl and a dog's bark."* In summary, VAs aid children's learning by providing educational resources that support children in accessing academic content, cultivating interests, and fulfilling their natural curiosity.

Entertainment. Family members sometimes interacted with VAs for fun and entertainment, including *enjoying entertainment content from VAs* and *fooling around with VAs*. Our participants highlighted VAs' ability to deliver entertainment content that comprises both interactive forms, such as playing games, and non-interactive formats, e.g., auditory songs, stories, news, radio, and jokes. Such auditory content was nominated by parents as helpful in enhancing low-energy tasks like household chores, turning them into more enjoyable experiences. Children were also drawn to VAs' auditory content, e.g., enjoying stories during meals, which provides a captivating substitute

for passive screen time (P7, P8, P10, P11). Such non-screen-based entertainment was particularly favored by parents as an alternative to TV or smartphones for children, appreciating how it minimizes screen exposure and, by extension, the potential harm to their eyes. This echoes parents who carefully monitored their children's interactions with VAs with screen display, setting limits to *"frequency and duration of screen exposure each week"* after their children have achieved specific educational goals (P3). VAs also offered multi-sensory content, including word puzzles and rock-paper-scissors. Observations in P14's family showed how the VA encouraged children with playful taunts by saying *"Haha, are you ready to get stumped?"* (P14), which shapes an engaging game-play environment. This interaction sometimes initiated collaborative family activities, especially when a child needed help answering a question from VAs.

Additionally, children were found to enjoy fooling around VAs. That is, some children enjoyed prompting VAs to make funny sounds and react to silly questions. Over time, they learned specific commands that elicited humorous responses from VAs. For instance, during the observation of P11's family, the children repeatedly asked their VA *"What is the title of chapter three of the story?"* The VA humorously responded with *"stinky poo,"* which made the children laugh. In short, family members were entertained by enjoying VAs-provided playful content and tricking on VAs.

Miscellaneous Management. Family members leveraged VAs to *streamline daily routines* and *manage household chores*, where VAs could effectively orchestrate smart home systems and simplify daily chores. For instance, family members could give voice commands to VAs to control home appliances by activating automated household features (like curtains and fans) and adjusting application settings, such as audio levels. This voice control often acted as a stand-in for physical remote controllers, especially when they could not be found, leading family members to rely on VAs for help. Also, children occasionally used this control function to capture their parents' attention by *"remotely modifying lights and curtains in their parents' room"* (P16), creating moments of family fun. As to chore management, VAs proved useful by functioning as an interactive search engine, e.g., providing information on weather, time, and traffic conditions. They could also handle online purchases and set timers, making these tasks convenient through simple voice commands.

Childcaring. Parents mentioned often employing VAs to manage and support their children's daily activities. On the one hand, VAs captivated children with an array of entertaining content and their capacity to answer questions in real-time, effectively *keeping children occupied*. The natural curiosity of children led them to *"ask numerous why-questions of everything all the time, which can be overwhelming for busy parents"* (P14). In such situations, parents directed them to seek answers from VAs, granting themselves some much-needed "me" time. In addition, VAs could provide entertainment and companionship for children by *"playing some songs and stories"* (P19), further reducing interruptions for their parents.

On the other hand, parents employed VAs to help *regulate their children's behaviors*, serving as a supplementary tool for parenting. This behavioral guidance took two forms: initiatives led by parents and those driven by VAs themselves. Parents could subtly leverage VAs to impart lessons to their children, sidestepping direct confrontations that might result in resentment. For example, P16 noted, *"Sometimes my son talks dirty, so I tell him to talk to VA and see how it reacts,"* where the VA gently discouraged the child from using inappropriate language. Conversely, VA-driven features contributed to nurturing positive habits in children. For instance, parents described relying on VAs to keep children occupied or to remind them about posture and screen distance. After prolonged screen time, *"VA would remind them to do eye exercises"* (P16). Moreover, if a *"child's eyes are too close to the screen or if their posture is incorrect, the VA will prompt them to correct it"* (P1), thereby promoting healthier behaviors. Observation sessions provided concrete examples of these practices in action, such as VAs prompting eye exercises during homework time, which illustrated how caregiving and monitoring functions were woven into everyday routines.

Communication. Family members often used VAs as a means of communication. Often, VAs served as a tool for *connecting individuals*, fostering easy communication via messaging and audio or video-based calls among family members and others. Interestingly, VAs were also found to *mediate family conflicts*. That said, they aided in maintaining communication during times of heightened family tensions when direct conversations became challenging. When parents scolded their children, leading to a strained household atmosphere where neither side was ready to concede because of their pride, VAs came into play. For example, children first engaged with VAs to listen to stories as a way of calming down. Subsequently, they used these stories as a means to bridge the communication gap. An illustrative case is when a child approached their parents using a remark inspired by the VA's storytelling, for instance, *"Mi Xiaoquan's [the main character in VA's story] mother apologized in the story, why won't you apologize to me?"* (P7). By bringing up the story, the child opened up a channel for conversation, leading to a softening of relations and alleviating family tensions.

Emotional Support. Family members sometimes sought VAs to address affective needs. That is, they looked to VAs for *emotional guidance* to receive comforting words and advice on navigating bad feelings. For example, children would confide in VAs about emotions they were hesitant to share with their parents, finding solace and suggestions in VAs' responses. P14 mentioned that when her daughter was down, she would turn to the VA, which *"typically responds with encouraging and supportive messages"* that uplift her spirits. Simultaneously, VAs offer suggestions to handle negative emotions, such as when P14's daughter sought a VA for advice after an argument with her mother. The VA said, *"It would help to be more understanding and tolerant towards each other,"* prompting her to reflect on her actions and consider her mother's perspective. At other times, family members *vent negative emotions* to VAs, particularly when they feel unable to express their anger to others. For instance, P7 noted, *"You can't scold others, but you can vent your frustrations by scolding the VA."* Moreover, frustrations with the VA itself could also lead to emotional outbursts. For example, P14's daughter experienced repeated misunderstandings with the VA during information searches, leading to moments of impatience and scolds toward the VA. Despite such moments, the VA attempted to maintain a positive interaction, which gently reminded users like P14's daughter, *"Dear, please don't use foul language."* These interactions underscore VAs' roles in providing both emotional support and guidance in managing emotions within the family.

4.1.2 Autonomy. Autonomy means the extent to which an agent can change its state independently of direct interactions. In this section, we present cases from our interviews and observations that demonstrate the autonomy of children, parents, and VAs around children's engagement with VAs. Figure 2 shows an overview of autonomy embedded in family-VA interactions.

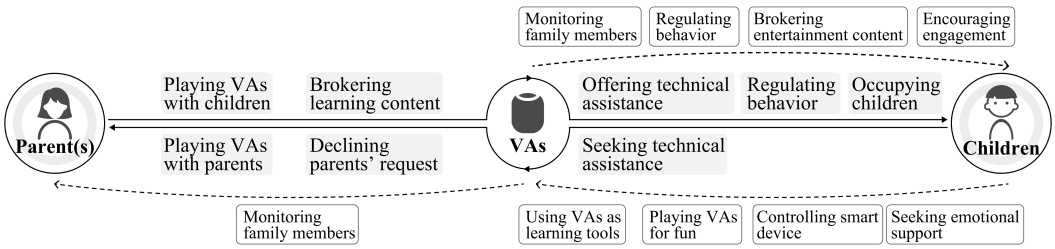

Fig. 2. Autonomy during family-VA interactions. The text blocks briefly describe the interactions, and the directions of the arrows indicate the flows of autonomy. For example, the arrows from children to VAs represent children's autonomy over VAs.

Children's Autonomy. Children exhibited autonomy during interactions with both VAs and parents. Their autonomy with VAs was evident through self-initiated engagements for a range of purposes, including learning, entertainment, and emotional support, as detailed above. This proactive engagement underscores children's autonomous use of VAs. In interactions involving their parents, children also showed autonomy in three primary ways. First, they would sometimes invite their parents to join their interactions with VAs, such as playing VA-mediated games together, especially when they were playing alone. For example, P4 mentioned that her son would often invite her to play word puzzle games together, saying *"It's usually my child inviting me to play together."* Second, when encountering technical difficulties, children actively sought assistance from their parents, asking for help in rephrasing questions or resolving other relevant issues about VAs. As P17 noted, *"Sometimes, my children could not clearly describe their needs to the VA by stammering and using vague expressions...so they seek help from us."* Third, we observed the instances of children manifesting autonomy by declining their parents' requests for certain interactions with VAs. As reported by P20, children might refuse their parent's requests to use VAs for learning; instead, they continue using them for entertainment activities.

Parents' Autonomy. Parents demonstrated their autonomy in managing children's interactions with VAs, primarily in forms of regulation practices aimed at ensuring healthy and effective use.

First, parents used VAs to monitor and regulate their children's in-home activities. For instance, P3 utilized a camera-embedded VA to remotely observe their children's activities *"to know what the children were doing,"* and P5 similarly used the VA to communicate with their daughter about her status remotely. Many parents (e.g., P6, P10, P16) also established rules that require children to seek permission before using VAs. Beyond access, parents also limited the content, especially entertainment-oriented ones, for which their children engaged with VAs. During P20's home observation, the mother advised her daughter to close short video applications on their VA device and suggested educational activities instead, stating *"too much short video content could harm her mental health, distracting her from studying."* Parents often emphasized that they tried to restrict children's entertainment oriented use of VAs. Our home observations both confirmed and nuanced this account: while some sessions showed parents actively redirecting playful requests toward educational content, we also observed children using VAs for songs and jokes when parents were in another room or focused on other tasks. Additionally, some parents strictly prevented their children from adopting VAs to search for homework answers, viewing this as a lazy and dishonest approach (P7, P8).

Second, parents actively brokered learning opportunities for their children through VAs. They expressed a preference for their children to listen to educational content during free time rather than entertainment ones (P7). Besides, parents frequently mentioned using VAs to play educational stories, poems (P10), and various courses surrounding core subjects at school (P9, P11) to their children. Moreover, when unable to answer children's questions, parents also guided them to ask VAs for accurate and professional responses (P14, P19). As P14 mentioned, *"My daughter asks me about historical questions that I don't remember the specifics of, but the VA can accurately provide detailed information about historical figures and events, giving a comprehensive explanation."* Sometimes, parents also directed children to engage with educational content using VAs because they were busy or wanted to avoid interruption from the kids (P14, P18).

Third, parents would actively offer technical assistance to their children during interactions with VAs. Before allowing their children to use VAs, parents set up the necessary configurations, such as *"network connections and account registrations"* (P16). During use, parents also helped resolve technical issues. For example, in P20's home observation, when the VA froze while their daughter was using her social media application, P20 assisted by restarting it. Lastly, parents sometimes engaged in playing games with their children using VAs, similar to how children invited them. P4

mentioned that she would proactively turn on the VA and play games with her son during free time.

VAs' Autonomy. VAs exhibited agency over family members in four ways, which feature their roles as regulator, content broker, and engagement initiator, as well as unexpected, autonomous interactions. Specifically, VAs acted as regulators by mediating children's behaviors. For instance, some VAs equipped with cameras could monitor children's postures and remind them to *"sit up straight while doing homework"* (P1). They also controlled and regulated children's engagement time. As P16 mentioned, *"After a certain period, the VA automatically shuts down and reminds my children to take a break."* As content brokers, VAs actively introduced new entertainment content to children, thereby attracting them to play. As P15 noted, VAs would *"actively introduce games and new functions to them without us direct prompting.* As initiators for engagement, VAs encouraged children's engagement by challenging them in game-plays using provocative statements like *"I bet you can't solve even one question, haha"* (P14's home observation), which prompted children to become more involved in the game. Lastly, VAs occasionally exhibited autonomy by unexpectedly responding to family conversations that were not directed at them, affecting the overall family dynamics. As P11 noted, VAs could *"be overly sensitive and wake up unnecessarily, causing us [family members] to be concerned about VAs monitoring our family interactions and potentially leaking privacy."*

4.1.3 Adaptability. Adaptability refers to the process in which children, parents, and VAs adjust their behaviors in response to each other's actions. This section provides explanations and examples of how each group adapted during interactions around children's engagement with VAs (see an overview in Figure 3).

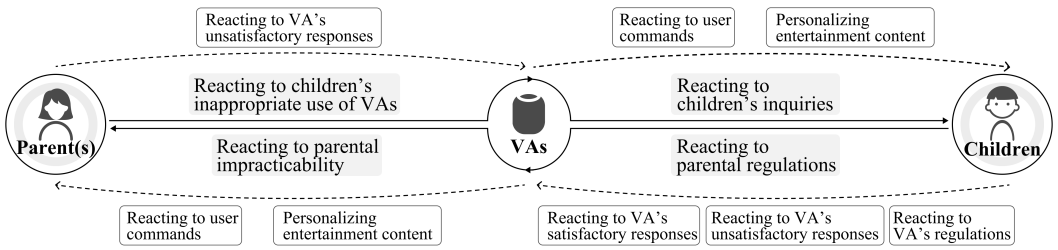

Fig. 3. Adaptability during family-VA interactions. The arrow directions show the adaptability flow. For instance, the arrows from children to VA indicate children's adaptability to VAs.

Children's Adaptability. We found that children adapted their interactions to both VAs and their parents. Their adaptability to VAs can be categorized into two areas: adjusting to VAs' responses and adhering to behavior regulation. When VAs provided satisfactory responses, children indicated a continual reliance on these interactions. Specifically, positive experiences led children to frequently use VAs for accessing information, entertainment content, and emotional support. As P14 reported, her daughter *"finds it easier and quicker to search for information using the VA than looking it up in books, making her less likely to search in books than before."* Meanwhile, the daughter would seek emotional support from the VA, as *"she feels better after receiving the VA's warm comfort"* (P14). However, responses from VAs were not always satisfactory. In such cases, children adapted to VAs by seeking parental assistance and adjusting their communication strategies. For instance, if VAs could not understand children's questions or provide accurate answers, children often *"ask their parents for help to rephrase questions"* (P16, P18). Regarding VAs' regulations of behaviors, children

generally complied with their guidance, like adhering to playtime limits set by VAs, following reminders of class schedules, and accepting health guidance. For example, P1 shared, *"The VA suggests eye exercises and posture corrections when my children use their eyes improperly or sit unhealthily, and my children would follow these suggestions."*

Children's adaptability to their parents was primarily demonstrated by following parental regulations and suggestions, as well as responding to parents' unavailability. When it came to parental regulations, like parents' limiting media access, media content, and screen time, children would seek *"parents' permissions to use VAs"* (P12) and *"report their usage."* In addition, when parents suggested interactions with VAs for learning activities like word games (P7, P10), children were reported to follow the suggestions. However, children occasionally resisted their parents' regulations, especially when they wanted to spend more time playing with VAs or were using VAs to assist with their completion of homework. For instance, to extend their screen time with a VA, P18 noted, *"My daughters act like a detective to find out the password of VA set by me, secretly extending their screen time."* Children also developed strategies to cope with their parents' unavailability or lack of knowledge. In such situations, they turned to VAs for assistance, like using VAs to learn English when their parents were not at home (P7) or were unable to teach them (P14).

Parents' Adaptability. Parents took several adaptive measures towards VAs to ensure their kids' interactions with VAs were smooth and appropriate, such as providing technical assistance and monitoring the content delivered by VAs. For instance, when children were faced communication breakdowns with VAs, parents helped rephrase their questions to facilitate effective communication (P4, P6, P17). We saw similar patterns during observations, where parents moved closer to the device, reformulated children's queries, or negotiated turn taking with siblings, highlighting how parental mediation shaped children's practical agency with VAs. In addition, some parents closely monitored the content provided by VAs to prevent exposure to inappropriate material. For example, during P11's home observation, parents intervened to stop the VA from playing adult jokes.

We found that parents also adapted to children's interactions with VAs by responding to their inquiries and regulating their inappropriate use of VAs. Specifically, when children had questions, they sometimes turned to their parents, who might direct children to ask VAs due to the lack of relevant knowledge (P3). If the VAs also could not provide satisfactory answers, parents would either try to ask VAs by themselves or use their phones to find answers for their children (P16, P20). Apart from addressing children's questions, parents also adapted to their kids' inappropriate use of VAs by regulating their behaviors. For instance, they stopped children from making noises using VAs (P11's home observation) and from cheating on homework by asking VAs to provide answers (P7). However, not all parents forbade their children from using VAs for homework answers. As noted by P13, *"At first, I did stop my child from using VAs to look up answers, but, as his grades did not improve, I stopped regulating it. I do not want my kid to be constantly burdened by schoolwork."*

VAs' Adaptability. VAs adapted to family members primarily by responding to their user commands and recommending personalized media content based on previous usage. More specifically, they demonstrated adaptability by adjusting their responses to specific requests and suggesting media content based on user's previous preferences. For example, if users had previously listened to certain songs, VAs would automatically recommend similar songs (P13).

4.2 Family Functioning

To deepen the understanding of family interactions with VAs, we further examined the roles of VAs from a family perspective. Built upon the *model of family functioning* [25], this section presents our findings on how VAs were involved in the functioning of a family unit by taking on three roles, including *creating new family functioning*, *executing existing family functioning*, and *assisting existing family functioning*. It is important to note that this section builds directly upon

the interactional evidence detailed in Section 4.1. Whereas Section 4.1 provides the descriptive accounts of family–VA interactions with supporting quotes, Section 4.2 takes a further analytical step by interpreting those moments through the theoretical construct of family functioning. In order to avoid repetition of the same quotes, we sometimes refer back to the interactions already presented in Section 4.1, which allows us to emphasize interpretive insights at the level of family functioning without unnecessarily duplicating raw data. We organized our findings under these three large themes by incorporating the six dimensions of family functioning proposed in Epstein et al.'s model [25] (detailed in Section 3.3).

4.2.1 Creating New Family Functioning. Creating new family functioning denotes VAs introducing novel family interactions that did not previously exist, emerging as a result of their integration into families. This role was observed in the functioning of *affective involvement*, *affective responsiveness*, and *communication*. Specifically, VAs became affectively involved in family interactions, almost like a new family member who engaged in both positive and negative affective involvement. For example, VAs would proactively recommend conversation-based games, bringing light-hearted enjoyment to families (P20's home observation). As also illustrated in Section 4.1.1 on *Entertainment,* P14's children experienced playful provocations from their VA during a word puzzle game, which encouraged sibling collaboration and laughter, showing how such interactivity could blossom into new forms of affective involvement. However, VAs were sometimes seen as unwanted monitors due to their overly sensitive activation, such as responding suddenly to family dialogues, eliciting fear among members, and thus raising privacy concerns (P6, P11). In terms of affective responsiveness, VAs offered positive responses to support family members' affective states. For example, when children felt isolated or unsupported after quarreling with their parents, they turned to VAs for emotional support, receiving comforting words and advice (P14, P16, P17). Such responses connect back to Section 4.1.1 on *Emotional Support,* where children described feeling better after receiving encouraging voice messages from VAs. Additionally, VAs sometimes served as judges and mediators to support family communication. For instance, when children misbehaved and parents were hesitant to criticize them directly to prevent straining their relationships, they would encourage their children to ask the VAs if their actions were appropriate. The VAs would then tell the children that their behavior was improper (P16). An echo of Section 4.1.1 (*Emotional Support*) can be seen in P7's account, where a child invoked a VA story character during a conflict to re-open conversation with his parents, demonstrating how VAs shaped family dialogue in ways that went beyond traditional parent–child exchanges. In this process, VAs guided potentially intense conversations in a more relaxed and diplomatic manner, preventing the tension between parents and children and ultimately promoting affective family dynamics.

4.2.2 Executing Existing Family Functioning. This theme describes the cases where VAs performed family members' tasks on their behalf, typically due to their lack of ability or willingness. This role was mainly observed to facilitate family functioning in the dimension of *problem-solving*. For instance, parents might be unable to respond to their children's problems due to being away from home, lacking time, or insufficient knowledge. Therefore, VAs were reported to often take on the teacher role by assisting children with learning-specific tasks that were previously supported by parents, such as searching for spellings and semantic meanings of English vocabulary (P11) or looking up pronunciations of Chinese characters (P16). As described in Section 4.1.1 on *Learning,* P3 regularly relied on the VA to play English stories while children brushed their teeth or ate meals, showing how VAs stepped into the teaching role in moments where parents were unavailable. Additionally, when parents were overwhelmed by their children's continuous questions, they used VAs to take over their babysitting duties, such as playing music (P11) and games to keep children busy (P14). This practice was also reported in Section 4.1.1 on *Childcaring,* where P14 redirected her

child's "why-questions" to the VA in order to secure some uninterrupted time. VAs also executed the family functioning related to *communication* by providing convenient long-distance connectivity. For example, P1 mentioned that his frequent business trips made it challenging to communicate daily homework to his children. However, with VAs, he could remotely send homework to the VA, which would then deliver it to the children on behalf of the parent. The VAs would then tell the children that their behavior was improper (P16).

4.2.3 Assisting Existing Family Functioning. Aiding existing family functioning refers to the cases where VAs were used to enhance the effectiveness of existing family functioning. In doing so, VAs primarily served as a supplementary tool for parents to monitor and manage children's behavior, thus supporting family functioning in terms of *behavioral control*. As mentioned in Section 4.1 (i.e., parents' autonomy to children), parents often use VAs as surveillance devices for tracking their children's interactions with the devices remotely, like managing access, screen time, and entertainment content (P3, P16). This point expands on Section 4.1.2 on *Parents' Autonomy,* where parents used camera-embedded VAs to observe their children's activities or to enforce rules on seeking permission for entertainment features. VAs were also used to assist family members in their *problem-solving* processes. Sometimes, parents could not answer their children's learning-related questions, so they used VAs to search for information and then solve problems for their children (P20), which resonates with examples in Section 4.1.3 on *Children's Adaptability,* where children asked parents to help rephrase questions for the VA, and the combined parent–VA effort helped yield appropriate answers. In these scenarios, VAs functioned as tools that supported parents in executing their functions. VAs' roles in assisting family functioning would further elicit family members' affective responses to one another, which contributed to the *affective involvement* of family systems. For example, VAs provided a wide range of entertainment content, bringing about joy to family members through shared media consumption, such as music and stories (e.g., P3, P11, P14). Section 4.1.1 on *Entertainment* also noted how auditory entertainment such as music and stories often turned routine tasks into enjoyable experiences for both children and parents, demonstrating how VAs assisted rather than replaced family practices. Moreover, VAs supported more convenient communication for video and phone calls. For instance, parents and children could easily initiate calls without the need for mobile phones through VAs' simple voice commands (P3's home observation). A broader pattern can be seen in Section 4.1.3 on *Children's and Parents' Adaptability,* where both children and parents incorporated VA features into their routines, showing how assistance evolved in tandem with adaptation.

5 Discussion

While prior work on family and child–VA interactions has focused on behaviors of individual children or dyads (e.g., playful probing or information seeking) [7, 24, 32, 48, 49], our work takes a step further by systematically theorizing how these interactions reshape broader family dynamics. Specifically, we contribute a dual-lens analysis drawing on *agency* and *family functioning* to organize family–VA engagement in a principled manner across dimensions of interactivity, autonomy, and adaptability, and across affective and regulatory roles within the household. This approach differs from prior accounts that largely presented thematic inventories of interaction types, as it foregrounds how children's engagement with VAs intersects with parental regulation and the semi-autonomy of the VA itself, thereby producing new family-level practices and tensions. By showing how VAs can *create*, *execute*, and *assist* family functions, our study reframes VAs from being merely technological artifacts used by children into actors that modulate family problem-solving, role distribution, and affective climate. This expanded focus on family dynamics provides a structured foundation for re-imagining CCAI design: instead of only examining if VAs are child-friendly, we

surface how they redistribute agency and reshape intergenerational relationships within families, a perspective that has been underdeveloped in existing literature [7, 32, 48].

In the following sections, we begin by discussing our empirical findings in relation to prior research on family–VA interactions and highlight how our study advances current understandings of family-VA interactions from a cross-cultural perspective (Section 5.1). We then summarize the challenges and biases AI may introduce for children in our data, along with their implications for navigating the complexities of integrating AI into children's everyday lives (Section 5.2). Finally, drawing on existing literature and incorporating new perspectives from our study, we reflect on the conceptual framing and implications of CCAI design (Section 5.3 & Section 5.4). It is important to note that CCAI design is an emerging field, and rather than offering definitive solutions for its practical application, we aim to raise thought-provoking questions intended to inspire meaningful conversation within the HCI community.

5.1 Deepening the Current Understanding of Child and Family Interactions with Smart VAs from a Cross-Cultural Perspective

Our study extends the growing body of work that investigates how families and children interact with smart VAs in everyday life. By examining family-VA interactions through the lenses of agency and family functioning, we contribute empirical evidence from a Chinese context and compare our findings with prior work conducted primarily in Western households. In this part, we discuss the similarities and differences across contexts and highlight our novel empirical contributions.

Across both our study and prior work in Western contexts, families frequently used VAs for *learning*, *entertainment*, and *managing routines*. Similar to what Beneteau et al. [7] and Garg and Sengupta [32] observed, our participants relied on VAs to play music, tell stories, set timers, and support children's educational activities (e.g., vocabulary practice, math). Children also demonstrated playful interactions with VAs, asking humorous or relational questions (e.g., *"How old are you?"*), echoing patterns reported by Druga et al. [24] and Lovato and Piper [49]. Moreover, similar to Lin et al. [48], we found parents often mediated or reformulated VA prompts to scaffold children's engagement. These similarities suggest that certain interaction patterns may be relatively universal across cultural contexts. One explanation may lie in the technological design of mainstream VAs (e.g., Amazon Alexa, Google Home, Baidu Xiaodu, Xiaomi XiaoAi), which affords a limited range of voice-based functions (music, Q&A, timers) that shape how families worldwide use them. Another explanation is rooted in children's developmental curiosity: across contexts, children are motivated to ask spontaneous questions and test the social boundaries of agents, a behavior aligned with theories of early question-asking and Theory of Mind development [17].

Despite these commonalities, our findings also reveal important differences compared to Western counterparts. First, while Western families often emphasized concerns about politeness and manners when children interacted with VAs (e.g., encouraging *"please"* and *"thank you"* [7, 49]), Chinese parents in our study more frequently leveraged VAs as *behavioral regulators*, for instance, reminding children to adjust posture, take breaks, or avoid inappropriate language. This difference reflects both the availability of region-specific VA features (e.g., posture detection, eye exercises) and culturally situated parenting practices in China that emphasize academic discipline, bodily health, and deference to authority [50, 83]. Second, our participants reported extensive use of VAs for *childcare support*, such as occupying children and offloading endless "why-questions," which we distinguish from the more occasional "babysitter" role reported in Western studies. In Beneteau et al., smart speakers acted as short term substitutes that entertained or calmed children while parents stepped away [7], whereas in our Chinese sample VAs were integrated into everyday caregiving routines (e.g., soothing, accompanying homework, monitoring behavior). This integration suggests a stronger and more routine reliance on VAs to relieve parental workload. Third, we observed that

children and parents adapted to VAs with a higher tolerance of VA autonomy (e.g., unsolicited recommendations, unexpected wake-ups). In contrast, Western families often frame such behavior as disruptive or privacy-invasive [32]. This contrast may be related to different cultural attitudes toward surveillance technologies and varying levels of trust in digital infrastructures, as well as the tendency of Chinese families to prioritize functionality and utility over privacy concerns [14, 33].

Building on prior literature, our study contributes three new perspectives. First, by framing VA interactions through *family functioning* [25], we illustrate how VAs not only extend existing parental roles but also create *new family functions*, such as mediating conflicts or serving as affective companions. While Lin et al. [48] identified triadic parent-child-agent dynamics, our work broadens this to family-wide functioning across dimensions like problem-solving, affective responsiveness, and behavioral control. Second, we highlight the dual lens of *agency* (children's autonomy, parents' regulatory autonomy, and VAs' autonomous interventions) and show how adaptability operates in these multi-party interactions. This perspective brings nuance to discussions of child-centeredness, moving beyond whether children perceive VAs as "friends" [24, 49] to how families negotiate power and control with semi-autonomous agents. Third, we contribute empirical evidence from a Chinese setting, revealing how cultural norms around education, discipline, and parental workload shape VA use in unique ways. This comparative perspective addresses calls in HCI and CSCW to diversify the cultural grounding of human-technology research [85].

In summary, our study confirms many universal patterns of family-VA interaction while surfacing context-specific practices shaped by cultural values and technological affordances. By grounding these practices through agency and family functioning, we contribute a new lens for CCAI design that foregrounds children's agency within family ecologies.

5.2 Navigating the Complexity of Introducing AI into Children's Lives

Our findings show that the introduction of smart VAs into family contexts can offer a range of benefits for children, from supporting children's learning activities to providing entertainment, aiding in childrearing, enhancing family communication, and offering emotional support. However, ***these benefits are accompanied by limitations and potential risks for children.*** Our data revealed key areas where the presence of VAs in family contexts introduced AI-related challenges or biases: (1) children engaged in cognitive offloading for academic tasks, often asking VAs for direct answers rather than engaging in problem-solving; (2) some children accessed or initiated conversations involving age-inappropriate content, such as dirty words and language related to violence; (3) children might develop excessive emotional attachments to VAs by seeking emotional support from them; (4) VAs contributed to excessive media consumption by recommending content that reinforced children's existing preferences; and (5) VAs occasionally acted as passive monitors of family conversations, raising concerns about privacy and surveillance. These privacy and security concerns echo broader work on smart voice assistants that highlights the risks of always-on microphones, unintended recordings, opaque data practices, and bystander exposure [1, 36, 67]. Families often have incomplete understandings of what data are collected, who can access it, and how it might be used, which can make it difficult for parents and children to make informed decisions about consent, data sharing, and access control [36, 42, 84]. These challenges and biases are already documented in broader AI literature beyond the child context. For instance, AI-generated responses can reinforce biases in educational content and learning environments [93], and students may become overly reliant on automated tools like ChatGPT, potentially undermining their metacognitive abilities and critical thinking skills [52]. Taken together, these issues suggest that the privacy, security, and developmental risks associated with VAs are not incidental side effects but structural properties of how current AI systems are designed, deployed, and governed in domestic settings. Building on this body of research that highlights the complex and multifaceted roles of

AI in people's daily lives, our study contributes empirical evidence of how these issues manifest specifically within family contexts for children through the use of smart VAs. As a widely adopted yet often overlooked form of AI, smart VAs reveal how such challenges and biases can emerge in everyday interactions in the household, indicating that these concerns are not limited to particular AI technologies or usage contexts, but instead point to broader, systemic issues in how AI is being integrated into children's lives.

Notably, these challenges and biases show that AI systems are not merely passive tools but actively and subtly shape children's knowledge, values, and decision-making processes [34, 79]. For instance, when children repeatedly turn to VAs for information, they may begin to trust AI-generated responses over other sources, potentially privileging certain types of knowledge, particularly that which is algorithmically curated or commercially motivated [93]. Such reliance raises important questions about *the neutrality and authority of AI content.* Are children learning to value efficiency and convenience over critical thinking and inquiry? *Furthermore, it is unclear to what extent parents are aware of the biases that may be embedded in AI-generated content,* such as stereotypical representations or skewed information that may inadvertently reinforce existing social or cultural assumptions. From a privacy and security standpoint, these concerns intersect with questions about data collection, profiling, and long-term data retention in child-directed and family-centred AI, where children's everyday queries and routines may be logged and analyzed in ways that are difficult for families to see or contest [42]. Although there is emerging research examining how children perceive and communicate with AI (e.g., [47, 81]), future studies should further *investigate how children develop trust in AI systems over time and how this trust influences their learning habits and worldview.* For example, do children begin to treat VAs and other AI systems as authoritative sources, and if so, how might that affect their interactions with human educators or caregivers? Relatedly, future work on child-centered AI design will need to consider not only how to scaffold healthy skepticism and critical engagement with AI content, but also how to build privacy- and security-preserving mechanisms, such as more transparent recording indicators, child-friendly privacy explanations, and usable parental controls, into the everyday interactions that children and families have with VAs [1, 67, 84].

Beyond these child-level concerns, our findings also suggest that the widespread presence of VAs could reconfigure family dynamics in subtle but influential ways. For example, some parents reported delegating disciplinary or educational roles to VAs, which may shift caregiving responsibilities and alter parent-child relationships over time. Similarly, children occasionally positioned VAs as mediators in family conversations, which raises questions about how reliance on AI might reshape communication patterns within households. These dynamics illustrate that VAs not only affect what children learn but can also redistribute roles, authority, and responsibilities among family members. Taken together, these patterns highlight that the integration of AI into homes is not simply an additive improvement but a complex sociotechnical transformation that may introduce new dependencies and reconfigure existing relationships. Given the scale and speed of smart speaker adoption, these transformations are unlikely to remain confined to a small number of early adopter households, which further amplifies the importance of integrating privacy and security considerations into child-centered AI design. A deeper discussion of AI's perceived autonomy and its role in shaping both child development and parenting practices is therefore essential. By critically examining these tensions at the levels of individual children, family systems, and cultural norms, we can develop more informed design strategies that leverage AI's benefits while also mitigating harms. Future research should continue to interrogate how different forms of AI alter family structures and intergenerational dynamics, and how design can safeguard children's well-being while supporting healthy family functioning.

5.3 Advancing the Conceptualization of Child-Centered AI Design

Based on our empirical findings on the agency of children, parents, and VAs, as well as the notion of family functioning, we advance our central argument for child–computer interaction and the broader human–computer interaction research communities that ***CCAI design should be understood as the outcome of balancing multiple, interacting dimensions of children's AI use within family and other everyday contexts.*** Prior CCAI scholarship has largely framed child-centered AI as the development of AI systems that are both ethically aligned (e.g., fairness, inclusivity, transparency, privacy, safety, accountability) and developmentally appropriate for children, often drawing on guidelines from governmental or professional bodies and conceptual design workshops rather than in-depth studies of everyday use [4, 22, 26, 43, 53, 74, 75]. While this body of work has provided important high-level principles, it has given limited attention to how child–AI interactions unfold within family systems or how different stakeholders' goals and roles shape what counts as child-centered.

Building on this gap, we reconceptualize CCAI design as the outcome of balancing four empirically derived dimensions: (1) **children's agency,** (2) the involvement of **relevant others** such as parents, siblings, and teachers, (3) the **diverse purposes of interaction**, and (4) the **contexts** in which AI is applied (e.g., homes, schools, cultural environments). Each of these dimensions is visible in our data. Children's agency emerged when younger children initiated playful use of VAs for songs and stories, and older children independently requested help with homework or translations. The involvement of others appeared when parents stepped in to rephrase questions or redirect children from entertainment to educational content, and when siblings joined VA games and turned solitary play into collaborative or competitive activities. Diverse purposes encompassed learning, entertainment, childcare, communication, and emotional support, such as redirecting children's "why questions" to VAs to secure quiet time, using VAs to accompany homework, or turning to VAs for comfort after family conflicts. Contexts included mealtimes, after-school homework routines, and fragmented transition moments in the home, with different settings shifting what parents and children considered appropriate or desirable VA use. Collectively, these examples surface deeper systemic questions about how AI adoption may alter family relationships and caregiving roles over time. For instance, parents sometimes delegated educational or disciplinary functions to VAs, while children treated them as conversational partners or mediators in family interactions. By grounding these dimensions in empirical family practices, our framework moves beyond abstract or generic framings and shows how CCAI design is negotiated in everyday life. These findings and the existing literature raise fundamental questions about the possibility of a universal definition of CCAI design. Specifically, when we refer to child-centeredness in AI design, what aspects of children are being centered? How should designers account for the agency of other stakeholders, such as parents, siblings, and teachers? When child-centered goals conflict with those of other stakeholders, for example differing priorities between children and parents, how should these competing interests be balanced? In our study, parents typically wanted children to use VAs for educational purposes and behavior regulation, whereas children often emphasized entertainment and emotional support. In such cases, what should VAs and other AI agents do? Given the limited empirical evidence, we cannot yet offer prescriptive guidelines, but our findings foreground the need to treat CCAI design as a dynamic and negotiated process rather than a stable checklist of ethical and age-appropriate criteria.

Integrating the various factors involved in children's AI use derived from our empirical findings, along with existing perspectives on CCAI (e.g., [22, 26, 43, 53, 75]), we propose that ***CCAI design should concentrate on creating AI technologies that promote positive outcomes for children in ethical ways while also thoughtfully considering other involved actors and***

their potentially varying engagement purposes within specific use contexts. By explicitly situating these dimensions in family-level interactions, including the redistribution of roles and authority, our framework provides an empirically informed and practice-oriented advancement that goes beyond prior high-level perspectives. It offers concrete guidance on how designers can navigate competing goals, shifting family dynamics, and contextual influences when developing child-centered AI. We believe this expanded conceptual framing of CCAI design goes beyond the limited focus on ethical considerations and age-appropriateness by reflecting the dynamic, context-specific nature of child–AI interactions and capturing a wider range of factors that shape the concept of child-centeredness and guide CCAI design. Meanwhile, it also highlights the need for a more holistic understanding of these critical factors within family and other use contexts. We hope our study serves as a foundation for future research to investigate, identify, and examine additional factors that influence child–AI interactions, thereby advancing the theorization of CCAI design with new insights from family settings and beyond.

5.4 Design Implications for Child-Centered AI in Family Contexts

The existing literature on guidelines for designing AI technologies for children primarily emphasizes two key considerations: ethics (such as fairness, transparency, inclusivity, privacy, and safety) [22, 43, 53, 75, 76] and developmental appropriateness (e.g., cognitive capabilities and socioemotional skills) [26, 75, 80]. Much of this work is grounded in Western policy and research contexts and tends to treat these principles as broadly universal. Our findings, based on children's interactions with smart VAs in Chinese family contexts and read in relation to prior Western studies, suggest additional design considerations that are specific not only to household dynamics but also to cultural values and parenting norms. Below we highlight three implications that directly respond to our empirical observations and make explicit their cross-cultural relevance.

Design for Interdependent Family Agencies. Echoing previous VA studies in family contexts (e.g., [7, 63]), our findings show that children's interactions with VAs were rarely solitary, but were dynamically shaped by the shifting agencies of multiple family members. As described in Section 4, parents acted as regulators and mediators, scaffolding or restricting children's use. Siblings often joined or disrupted playful interactions, turning individual engagements into shared, competitive, or collaborative ones. Children themselves demonstrated agency by resisting parental rules (e.g., secretly extending VA use) or by inviting parents into games. VAs, too, contributed agency by proactively introducing new content or regulating children's posture and screen time. In our Chinese context, these agency configurations were further shaped by cultural expectations regarding academic achievement, respect for parental authority, and the role of grandparents in caregiving, which influenced who felt entitled to intervene in VA use and when. These dynamics suggest that "child-centeredness" in AI design cannot be reduced to the dyad of child and technology. Instead, it must be conceived as a *family-centered practice* that accommodates the interplay of diverse agents in the household while remaining sensitive to locally specific family roles. To advance CCAI design in family contexts, systems should: (1) *surface alignment with caregiver goals* (e.g., balancing curiosity-driven use with parents' concerns about over-reliance on quick answers in high-pressure academic environments); (2) *adapt to role-specific and culturally inflected contexts* (e.g., offering different prompts when a sibling or grandparent is present or when homework time is prioritized); and (3) *support cooperative and negotiated use* (e.g., turn-taking prompts for family members or shared challenges that encourage joint learning). This family-centered design approach remains an emerging perspective in HCI research [11], particularly within CCAI design. By explicitly acknowledging the interdependent agencies of children, parents, siblings, and VAs observed in our study, this implication highlights how CCAI design should move beyond abstract

notions of "ecosystems" toward concrete strategies that respect the relational fabric of family life in different cultural settings.

Reimagine Family-based AI as Co-Caregivers that Share, Rather than Replace, Parenting Labor. Beyond mediating agency, our findings revealed that parents sometimes leaned on VAs as digital babysitters or behavioral monitors, such as playing songs and stories to keep children occupied or reminding them about posture and screen distance. In the Chinese families we studied, this tendency was particularly pronounced, with parents describing VAs as tools that helped manage high academic expectations and heavy work schedules. While practical, this reliance risks reinforcing dependency and reducing opportunities for meaningful parent-child interaction, and the degree and acceptability of such delegation may differ across cultural contexts. To address this, CCAI should shift from replacement toward co-caregiving in culturally aware ways. For example, when VAs deliver repeated childcare functions (e.g., telling multiple consecutive stories), they could proactively suggest ways for parents to re-engage (e.g., "Would you like me to create a short quiz you can discuss together?"), while also allowing parents in different cultural contexts to configure how frequently such prompts appear and how directive they are. Likewise, when regulating behaviors (e.g., screen-time reminders), smart social robots could provide companion prompts for joint caregiver child activities [70] (e.g., "Shall I suggest an eye exercise you can do together?") that can be tailored to local health and educational norms. These design features respond directly to our observation that VAs often substituted for parents, especially in our Chinese context, and propose how systems can instead facilitate shared caregiving practices that strengthen family bonds without universalizing one model of appropriate delegation.

Support the Family in Nurturing Children's Agency Over Time. Current literature on CCAI design emphasizes considering the unique developmental stage of children, especially their evolving cognitive capacities (e.g., [26, 75, 80]). Our findings show that children's interactions with AI, exemplified by VAs, varied not only by age but also through family dynamics and cultural expectations. Younger children (e.g., ages 5 and 7) often used AI playfully for entertainment and depended on parents for technical assistance, while older children (e.g., ages 11 and 12) engaged more independently for educational purposes, such as solving problems or translating words. In our study context with Chinese families, parents actively shaped these trajectories by setting strict rules, scaffolding learning, or negotiating entertainment time in ways that reflected strong value placed on academic success and appropriate behavior, and siblings sometimes co-shaped playful use. As such, child-centered AI design can consider scaffolding children's *longitudinal and evolving autonomy* in relation to family involvement and local parenting norms, that is, their ability and agency to progressively understand, critique, and govern AI interactions as they mature while caregivers gradually transfer responsibility in culturally acceptable ways. A novel design paradigm could embed "family-inclusive autonomy gradients," where AI systems: 1) gradually disclose their operational logic in age-nuanced and culturally sensitive ways (e.g., from *"I suggested this because you liked…"* for younger children to *"These patterns in your data shaped my suggestions"* for adolescents), 2) provide parents with companion prompts to co-engage with younger children and negotiation tools to collaboratively set boundaries with older children that match local expectations about independence and obedience, and 3) support retrospective reflection (e.g., providing adolescents with access to logs of past AI interactions to analyze how preferences and behaviors were shaped, while also offering parents opportunities to discuss these patterns with them). This framing situates agency development within culturally situated family contexts, shifting CCAI from a static "age-appropriate" design toward a dynamic, relational process that equips children to become reflective, self-regulating participants in AI mediated family life across diverse cultures.

5.5 Limitations & Future Works

This work has several limitations. First, we focused exclusively on traditional nuclear families comprising only parents and children. As a result, our findings may not fully capture interaction patterns with AI in households that include grandparents, extended relatives, or single parents. Second, there is a gender imbalance among the participating parents, with maternal perspectives being overrepresented and paternal viewpoints underrepresented. Third, although we directly observed children's interactions with VAs in eight households and invited them to demonstrate their typical uses, we did not conduct formal interviews with children. This approach limits the extent to which children's own interpretations of VAs are represented. We acknowledge this as an important direction for future research. Fourth, our observation sessions were relatively short (about one hour) in order to minimize disruption to family life. While this limited our ability to capture longer-term interaction patterns, the sessions were timed to coincide with after-school routines when VAs were most likely to be used, and they provided meaningful opportunities to observe children's behaviors in situ. At the same time, the one hour snapshot may bias the data toward routines that families chose to foreground for the researchers and toward high frequency uses that happened to occur during our visit, while missing less frequent, late night, or more private interactions. The observed episodes should therefore be interpreted as illustrative examples of family practices rather than exhaustive accounts of each household's VA use, which underscores the need for future longitudinal or repeated observations that can better capture variation over time. Fifth, our data from families in China limits the generalizability of the findings, as AI adoption and family dynamics may vary across cultural and socio-economic contexts both within and beyond China. Some of our themes are likely transferable to other contexts, such as the roles VAs played in supporting domestic routines, helping with childcare, and offering entertainment or learning scaffolds, as these reflect broader patterns of how families domesticate new technologies. Other findings may be more culture-specific. For example, families' emphasis on academic learning support and parents' strong expectations of children's educational achievement reflect Chinese cultural values, which may differ in countries where educational pressures or parental roles are structured differently. By making this distinction explicit, we recognize that our work contributes both potentially generalizable insights into child–VA interactions and situated understandings that are closely tied to the Chinese family context. Additionally, we did not analyze the data through the lens of parental mediation, as our focus was on the agency of all involved parties and the broader concept of child-centered AI design. Relatedly, our analysis did not foreground social boundary issues such as how VAs should behave when parents and children make opposing or conflicting requests, which have been identified as an important design concern for personal agents in the home [51]. We instead acknowledge social boundaries as an important direction for future work that can build on our empirical findings. Future research could more directly investigate how linguistic practices interact with social boundaries and agency in child–VA interactions. However, our insights are still valuable in understanding family dynamics with smart VAs and their implications for CCAI design. Future research can build on this work by (1) incorporating children as direct interview participants, (2) extending the duration and frequency of home observations to capture evolving routines, (3) examining more diverse family structures across different geocultural contexts, and (4) comparing how specific cultural values, such as educational priorities, shape families' adoption and everyday use of VAs, while also working toward more balanced gender representation.

6 Conclusion

The current paper is one of the first empirical studies to examine child-centered AI design from a family perspective in a non-Western context. By revealing and analyzing various family interactions

with and around smart VAs via the lenses of agency and family functioning, we offered new insights into family-AI interactions. Building on these interaction patterns, we advanced the conceptualization of CCAI design. We hope this study can fuel further research and design practices aimed at better understanding and supporting the creation of CCAI, contributing to more meaningful and beneficial child-AI interactions.

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