Editorial

‘Lots done, more to do’: The current state of interaction design and children research and future directions

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A R T I C L E   I N F O

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A B S T R A C T

Child–computer interaction (CCI) is a multidisciplinary field of research that concerns the phenomena surrounding the interaction between children and computational and communication technologies. During the last two decades, several endeavors and contributions have significantly furthered CCI research. The pace of children-relevant technological advances and establishment of CCI venues has increased CCI scholarship, and furthered our knowledge and understanding about the relationship between childhood and technology. This editorial article provides an introduction and overview of the special issue on “review articles in child–computer interaction research”. The motivation of this special issue is to highlight review and survey papers that portray contemporary developments in the CCI literature. The contributions come from diverse contexts, cover a wide range of technological affordances, and address a variety of objectives and stakeholders (e.g., designers, learning scientists, policymakers, technologists). In this editorial, we present the background of CCI research, giving a brief overview of the contributions of the special issue, and conclude by highlighting potential emerging issues and challenges of the field.

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1. Introduction

Child–Computer Interaction (CCI) is a multidisciplinary area of scientific investigation that concerns the phenomena surrounding the interaction between children and computational and communication technologies (Read & Markopoulos, 2013). The research community that investigates this area combines perspectives from multiple scientific disciplines informing research and industrial practice around the design, evaluation, and implementation of interactive computer systems for children, and the wider impact of technology on children and society (Hourcade, 2015). During the last two decades we have seen dedicated conferences and journals evolve, grow, and accelerate CCI research (i.e., the ACM conference on Int. Design and Children-IDC and, Int. Journal of CCI-IJCCI) (Giannakos, Papamitsiou et al., 2020). In the CCI community there are regular discussions (e.g., workshops, panels) about advances, developments and future directions in CCI research. These discussions are organized (and hopefully will keep being organized) in the context of relevant conferences (e.g., IDC and The ACM conference on Human Factors in Computing Systems - CHI) and attract members of the CCI community.

CCI research has grown tremendously during the last decade with connections to various technologies, end-user groups, methodologies and approaches (Giannakos, Papamitsiou et al., 2020), so it is important to reflect on both its current state and future directions. To support and forge ahead the various discussions, this special issue invited CCI researchers to contribute with review and survey articles in various emerging and innovative areas of CCI. Each article is expected to include evidence-based discussion on the emergence of the topic, research methodologies used, analysis of major experimentations, emerging technological directions in the area, and vision for the future. Therefore, the accepted submissions of this issue provide an important set of works that describe the contemporary developments of the CCI literature, and explain the main topics and challenges of the field.

This special issue aims to serve as a unique resource, capturing the contemporary developments with regard to technologies, methods, processes and challenges, but also highlight promising areas for future work. The contributions come from diverse contexts to support a variety of stakeholders such as learning scientists, policymakers, designers and computer scientists, to mention a few. In this editorial, we introduce the reader to the special issue, by presenting the history of CCI and the various
ongoing challenges, giving a brief overview of the contributions of
the special issue, and conclude by highlighting promising future
research directions.

2. Background and brief history

The start of CCI as a field of research stems from the 1960s
when pioneering researchers such as Seymour Papert, Edith Ack-
ermann, Marvin Minsky, and Alan Kay explored computer sys-
tems to support children (Giannakos, Papamitsiou et al., 2020;
Hourcade, 2015). In the 1990s, CCI research produced a steady
flow of works stemming primarily from the Human–Computer
Interaction (HCI) field, but also from the fields of the learning
sciences and design. Since 2002 the IDC conference has been
established as an annual venue for research on “the latest re-
search findings, innovative methodologies and new technologies
in the areas of inclusive child-centered design, learning and in-
teraction”, joined in 2013 by the International Journal of CCI
(IJCCI), which focuses explicitly on CCI research. During the last
two decades, IDC has served as the annual gathering for CCI
researchers (although works and activities are also taking place
in other, usually HCI and learning/education events) and IJCCI has
served as the explicit journal of the field (although CCI related
works are published in other, usually HCI and learning journals).
The connection to both the HCI and the learning communities
becomes evident by looking at the keyword analysis of the IDC
and IJCCI published works conducted by Giannakos, Papamitsiou
et al. (2020). In Fig. 1, we visualize the CCI research space (inside
the HCI research space), and its connection with the various
application areas and technologies.

There have been several literature review works that summa-
rize and discuss CCI’s progress to date. An early notable work
comes from the Founding Editors of IJCCI, who conducted a brief
review of the CCI research and discussed its status (Read &
Markopoulos, 2013). They identified four future promising topics
for the CCI community, namely, closing the gap between theo-
ry and design, advance exploration of children’s participation,
the role of emerging technologies and affordances (e.g., mobile,
social, pervasive and tangible technologies), and potential risks
of children’s privacy and security with the use of some of these
technologies. Another notable contribution in the CCI literature
comes from Hourcade (2015) with the “Child-Computer Interac-
tion” book. This book took into consideration CCI works published
at the CHI and IDC conferences, and provided an overview of
CCI research targeted to graduate students, practitioners and
researchers wishing to get acquainted or catch up with the field.
Seven years after their first book, the new and the past editors
of IJCCI discussed eight areas of research in order to frame future
research and development in CCI (Giannakos, Horn et al., 2020).
They focused on areas including: children’s roles and participa-
tion in research, CCI research methods, emerging technologies
targeting children, child-specific application areas (e.g., learn-
ing, sociability, healthcare, play and behavior change), emerg-
ing computational capabilities for children, responsible and eth-
ical research, bridging “artefact-centered research” with “theory
construction”, and advancing literacies for children.

In the next section, we present a deeper view of how different
review works have shaped contemporary CCI research in order
to set the stage for this special issue. We look at prior work
through the following lens: participation and methods, applica-
tion domains, technologies and affordances, the role of theories,
responsible and ethical research and future research agendas.

3. What have we learned and where do we go now?

3.1. Children’s participation and child-specific methods

One of the first literature review works published in IDC was
by Jensen and Skov (2005) who described the methods employed
in CCI and identified the shortcomings of these methods (e.g., im-
proper adaptation for children, limited children participation, and
limited reporting). A few years later, Hourcade (2008) conducted
a review of research on children’s cognitive and motor develop-
ment; moreover, he reviewed the design methodologies for
children’s technologies based on the roles children may play dur-
ing the design process. Poole and Peyton (2013) published an IDC
paper discussing the common pitfalls that can occur in research
and design of projects involving adolescent populations. They
highlighted that methods involving video data are appropriate
in helping us understand teen populations, and they described
their approach (called ‘mobile video collage’). Some years later,
Benton and Johnson (2015) published an IJCCI paper that not only
provided a review of the design methods and techniques that
have been used to involve children with special educational needs
and/or disabilities in the technology design process, but also
explored the impact of children’s participation on the resulting technology. In a more recent work, Tsvyatкова and Stormi (2019) investigated the potential roles played by children in the design process, and reviewed the various CCI methods, techniques, and tools that have been employed to support children’s involvement in design. The authors discussed the elements of these methods (e.g., settings, contexts, populations), with a focus in the co-design related papers, and provided discussions and summaries to support future CCI designers and researchers.

In addition to reviews, there have been influential works that highlight the importance of understanding the roles children can take in research and the need to adapt methods to children’s needs. For example, Druin (2002) proposed and discussed different roles children could have in research-oriented design processes (i.e., users, testers, informants and design partners). Read and MacFarlane (2006) proposed child-specific data collection methods involving visual aids (smileyometers) and analogs (fun sorters). Others have built on this call to engage children even more intensively in the design process, with new more active roles, through appropriate methods and approaches (Iversen et al., 2017; Xie et al., 2008). These methodological advances have also been offered through courses, tutorials and open training materials (e.g., Anthony, 2019; Giannakos, 2022; Read & Glütz, 2016; Read & Markopoulos, 2014) contributing towards a fruitful discussion, dissemination and competence development in CCI research.

3.1.1. In this issue

Due to its multidisciplinary nature, the CCI field employs a wide variety of design and research methods. In this issue, Lehnert et al. (2021) analyzed CCI papers and investigated the interplay of children’s and adults’ roles across different methods, and the patterns of triangulation employed. Triangulation is very frequently used in CCI research (two-thirds of the papers), especially in qualitative studies (e.g., observation combined with interviews). Although there is a clear focus on children in protagostic roles, we also see studies leveraging secondary users (e.g., parents, caregivers), either because of their expertise or because it is not possible to collect the needed data from the primary user (e.g., toddlers or other developmental groups).

3.1.2. Potential future directions

There is no doubt that CCI research has advanced its methods and approaches significantly during the last 15 years, with several review works in the area (Table 1). Children participation and methods is an area that CCI will continue to advance, given its importance, potential transformative impact, as well as complexity. Staying open to different approaches (e.g., inductive data-driven, deductive hypothesis-driven), research designs (e.g., qualitative, quantitative, creation/practice-based) and epistemic stances (e.g., positivist, post-positivist, social constructivist, transformative or advocacy, pragmatic) will allow the field to further advance its methods. What has yet to significantly carry over from HCI, yet have deep relevance for CCI, are third paradigm or successor epistemologies that acknowledge and foreground social, cultural, and physical situatedness of end-users and researchers (e.g., standpoints from gender, feminist, racial, indigenous and critical studies) (Harrison et al., 2011). Alongside epistemological diversity, the development and validation of methods that enable the collection of credible and reliable data across the variety of socio-technological contexts that children now interact with technologies are a key competence for future CCI researchers. Lastly, CCI researchers will likely continue to broaden our perspectives on the roles children can play in designing and developing technologies. For example, we need to take into consideration qualities arising from domains (e.g., child as a player, learner, patient, communicator, advocate), children’s (dis)abilities, and other contextual information (e.g., parent–child interaction, social situatedness, physically blended or mixed realities). Future research needs to focus towards a better understanding on what constitutes ‘child-centredness’, and supports CCI researchers sharpening their methodological competence even more, making appropriate design and research decisions, by employing methods that are relevant with appropriate forms of rigor.

3.2. Specific application domains

CCI research has focused on a variety of application domains, highlighting children’s unique roles as end-users in these domains. The areas focused on to date have been largely motivated by historical and pragmatic reasons (Giannakos, Horn et al., 2020). Domains related to learning and education (e.g. music, language literacy, programming) have been the most populous application domains in IDC and JCCI publications (Giannakos, Papamitsiou et al., 2020). Recently, new literacies have been added including media literacy and computational literacy. Beyond learning and education, other popular application domains have been entertainment, sociability, healthcare, play, and behavior change (Giannakos, Horn et al., 2020).

The thematic area of this subsection is significantly broader (compared to children’s participation and methods) due to its overlap with several disciplines with large research activity (e.g., K-12 education, entertainment, healthcare). Providing a comprehensive overview of application domains in CCI research at large would have been an elusive ambition. Nevertheless, we have selected indicative review works from the last decade portraying how CCI research has been advancing in different application domains, to set the stage for how application-focused review papers in this special issue further our understanding of research in application-specific areas.

Review works to date focusing on specific application domains, can be classified under two different categories. First, there are reviews that are not specific to any particular technology; that instead focus on revealing how a specific CCI-related domain has progressed independently of the kinds of technologies used. Second, there are reviews that focus on a single or group of technologies or affordances of a technology (e.g., Augmented Reality (AR), Social abilities of robots). In this case the reviews investigate how particular technologies or technological affordances have been used in a specific domain. In either the first category or the second, the focus is appropriately motivated, for instance it might be a relatively narrow domain (specific age group and goal) or a domain for which we do not yet have sufficient evidence in favor of a specific technology. For the second category, we might have some promising results on how a technology (e.g., sociability of robots) can support specific domains or populations (e.g., children with autism).

3.2.1. Specific application domains and technology (in a broad sense) for children

In the first category, we find several core CCI studies which have been published in the last decade. For instance, Börjesson et al. (2015) reviewed works on designing technologies for developmentally diverse children and summarized the lessons learned from those reviewed works. Papastafitiou et al. (2017) reviewed works on Making and identified benefits of making in students’ engagement, self-efficacy, learning and collaboration. In a more recent work, Spiel et al. (2019) reviewed technologies designed to support children with autism and identified a lack of focus on children’s interests, needs, and desires. The list of review works focusing on specific application domains is
large and such works have greatly contributed in understanding how the application domains have been transformed and their particularities.

In that vein, in the special issue we have three papers focusing on specific domains that consider technology in a broad sense (agnostically). First, Macrides et al. (2021) reviewed works that introduce programming in early-childhood education, and identified important considerations such as appropriate integration to curricula and proper teacher training programs, that require further development. Second, Skovbjerg et al. (2021) reviewed works on how to design for fantasy play, how to consider theories from different relevant domains, and support design decision making. Third, Torres et al. (2021) reviewed works on phygital (physical–digital) play technologies and identified how physical play promotes behaviors relevant for children’s self-monitoring, collaboration, decision-making, problem-solving and physical activity. Fourth, Cibrian et al. (2021) considered what and how technologies can support self-regulation skills for children with ADHD. Although they did not focus on one technology, they identified how different technologies can support different aspects in children with ADHD. For example, virtual simulations and serious games can support children’s social engagement and skill-building, and robots can provide physical engagement. All four works do not focus on a specific technology or affordance of a technology (although different technologies and their potential is being discussed), but provide a thorough exploration of the state of the art in learning programming in early childhood, design for fantasy play, phygital play, and self-regulation skills in children with ADHD.

3.2.2. Specific application domains and specific technology for children

Looking at the second category, we will find several studies that have motivated the investigation of a technology or technological affordance to support specific domains or populations. For instance, Boucenna et al. (2014) reviewed the advantages of social robotics (e.g., more natural and physical interactions, better communication, expression of emotion and social abilities) to empower robot–child interaction with children with autism. Five years later, Dawe et al. (2019) presented a scoping literature review indicating that social robots hold significant promise and potential to support children in different healthcare contexts, but emphasizing how further research is still needed to provide concrete evidence of this potential.

Moving to the learning and education domain, we see studies focusing on popular technologies, such as games, tangibles and AR to support learning domains. Hainey et al. (2015) reviewed the evidence of games in primary education and indicated that future work is needed to identify the benefits of 2D and 3D affordances of games in primary education children. Baykal et al. (2018) reviewed how tangible user interfaces can support children’s spatial learning (through learning patterns, behaviors and thinking strategies). Two last examples in the domain of learning were by Oranç and Küntay (2019) who reviewed the ways AR affects learning and development for young children (e.g., through realistic and fantasy themes in narratives, bridges between the real and augmented world) and Fan et al. (2020) identified how AR supports early language learning through three activities (i.e., word spelling games, word knowledge activities, and location-based word activities), and suggested that future AR applications for early language should also consider supporting socio-technical factors such as collaboration between teachers and learners.

In this special issue we have four studies focusing on how a specific technological affordance can support a specific domain. In the first paper, Theodoropoulos and Lepouras (2021) reviewed how AR technology has been employed to support programming education, with the contemporary studies indicating that AR affordances can empower various child characteristics (e.g., spatial cognition, situated cognition) and abilities (e.g., spatial, perceived presence). In the second paper, Bakala et al. (2021) explored how robots can be used to promote the development of CT skills in early childhood, and their promising potential to support high-level embodiment. In the third paper, Alberto et al. (2021) reviewed how action-based designs (e.g., principles of moving in a new way, signification, dialog) pose constructive challenges that allow children to discover and practice new embodied ways of which they master different mathematical concepts. In the fourth paper, Flynn et al. (2021) examined the links between game play and content learning, seeking to understand how content learning is facilitated through digital gaming in children. All the three contributions focus on how technological affordances (i.e., AR, action-based designs, game play) can support domains of learning (i.e., programming, mathematical cognition and middle schoolers).

3.2.3. Potential future directions

There is no doubt that CCI research has focused on, and intensified its collaboration with, different domains; with several recent review works depicting how different domains can be benefited (Table 2). Focusing on different application domains has been critical from the early days of CCI research. Employing different design principles, practices and technological affordances to support specific domains allows the community to be a central actor and “speak” with different communities within the HCI
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<tr>
<th>Focus of the paper</th>
<th>Domain</th>
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<td>Social robots enable more natural and physical interactions in terms of</td>
<td>Social robots and Autism</td>
<td>Boucenna et al. (2014)</td>
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<td>communication, emotion and social abilities, allowing researchers to develop</td>
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<td>settings that empower the interaction between children with autism and</td>
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<td>robots.</td>
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<td>When designing with developmentally diverse children, adults are involved</td>
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<td>more intensively, either as users, proxies, experts and/or facilitators.</td>
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<td>Guidelines for how to prepare and perform co-design sessions with these</td>
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<td>children often emphasize the need for a coherence of activities, a clear</td>
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<td>structure, both verbal and textual explanations, and active participation of</td>
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<td>caregivers, teachers and therapists.</td>
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<td>Although there is identified evidence of games in primary education, further</td>
<td>Learning in primary schools</td>
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<td>studies are required to investigate the benefits of using 2D or 3D games in</td>
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<td>primary education.</td>
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<td>Making approaches are employed in schools, mainly in the area of programming and</td>
<td>Making and coding</td>
<td>Papavlasopoulou et al. (2017)</td>
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<td>other STEM areas. The studies identified benefits of making in students'</td>
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<td>engagement, self-efficacy, learning and collaboration.</td>
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<td>Children's physical–digital interactions with spatial manipulatives provide</td>
<td>Early spatial learning</td>
<td>Baykal et al. (2018)</td>
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<td>in-depth insights into their learning patterns as well as their user behaviors</td>
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<td>and thinking strategies (focusing on spatial learning).</td>
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<td>Social robots hold significant promise and potential to support children in</td>
<td>Healthcare</td>
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<td>healthcare contexts, with future research required to quantify this potential</td>
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<td>(e.g., experimental designs and larger sample sizes).</td>
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<td>Review the ways that AR (through realistic and fantasy themes in narratives,</td>
<td>AR and Education</td>
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<td>and children's connections between the real and augmented world) affect learning</td>
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<td>and development for young children.</td>
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<td>Technologies designed to support children with autism embody normative</td>
<td>Autism and Agency</td>
<td>Spiel et al. (2019)</td>
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<td>expectations of a neurotypical society, which predominantly views autism as a</td>
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<td>deficit that needs to be “corrected”. Technologies need to focus more on</td>
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<td>children's interests, needs, and desires.</td>
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<td>Identified how AR supports early language learning through three activities</td>
<td>AR in early language learning</td>
<td>Fan et al. (2020)</td>
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<td>(i.e., word spelling games, word knowledge activities, and location-based word</td>
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<td>activities), and suggested that future AR applications for early language should</td>
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<td>also consider supporting socio-technical factors such as collaboration between</td>
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<td>teachers and learners.</td>
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<td>Action-based designs pose motor control problems using motion feedback to</td>
<td>Action-based designs for math</td>
<td>Alberto et al. (2021)</td>
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<td>facilitate learners to discover and practice new embodied ways of which they</td>
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<td>ground mathematical cognition.</td>
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<td>Explored robot-based activities to promote the development of CT in preschoolers.</td>
<td>Robots for CT</td>
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<td>Robots not only have the capacity to promote CT in early childhood, but also</td>
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<td>constitute a promising technology to support high-level embodiment during the</td>
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<td>development of CT skills.</td>
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<td>Technologies can support self-regulation skills for children with ADHD by</td>
<td>ADHD and self-regulation</td>
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<td>providing opportunities to practice behaviors and receive feedback in a safe</td>
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<td>environment.</td>
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<td>Brings cohesion to the literature by aligning how digital gaming can support</td>
<td>Digital gameplay for learning</td>
<td>Flynn et al. (2021)</td>
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<td>different content knowledge.</td>
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<td>It is possible to introduce programming in early-childhood education, both as a</td>
<td>Learning (programming)</td>
<td>Macrides et al. (2021)</td>
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<td>stand-alone subject or integrated into other curricula such as music, dance,</td>
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<td>art, science, mathematics, and literacy. Appropriate integration to curricula</td>
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<td>and proper teacher training programs still require further development.</td>
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<td>Three common strategies of theory clusters are employed in CCI research: for</td>
<td>play and enjoyment</td>
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<td>contextualizing the value of play, highlighting the outcome of play, and</td>
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<td>supporting design decision making.</td>
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<td>AR technology has been employed to support programming education; contemporary</td>
<td>AR for Learning (programming)</td>
<td>Theodoropoulos and Lepouras (2021)</td>
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<td>studies indicate that AR affordances can empower various characteristics (e.g.,</td>
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<td>Physical–digital play promotes behaviors relevant for children's self-monitoring,</td>
<td>play and enjoyment</td>
<td>Torres et al. (2021)</td>
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<td>collaboration, decision-making, problem-solving and physical activity.</td>
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<td>Various technologies are employed to support children with Down Syndrome,</td>
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<td>however, there are limited studies on newly emerging technologies. Most of the</td>
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<td>studies converge that the most important ability for which technology needs to</td>
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<td>be designed (or has been designed) is to support children's cognition or</td>
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<td>intellectual functioning.</td>
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*Part of this special issue.*
(e.g., the learning sciences, psychology, communication). Given that children are and will continue to be major “users” in those areas, it is important that future CCI research continues its intra- and multi-disciplinary work. This will allow CCI to remain relevant for both the IT/HCI field and the society (through improving children’s healthcare, communication etc.), and facilitate a process of understanding differences and commonalities between the various domains, resulting in a transformative impact on our society and children’s lives.

3.3. Technologies and their affordances

New technologies and technological affordances are a central element in how CCI research has progressed during the last decades. The appearance of tools such as robotics, 3D printing, microprocessors, ubiquitous computing, and environments such as intuitive programming interfaces are enabling very young children to not only use media differently (e.g., multimodal interaction, sociability), but also lowering the threshold for becoming creators with affordances such as programmability, printability and other forms of malleability. The previous section inherently connects with this one, since we saw several works in the intersection between the application domain and different technologies. In this section we will extend this focus by providing more on how the progress of specific technologies and technological affordances has contributed to the support of different facets of CCI research.

During the last decade we have seen some review works focusing on how certain technologies and technological affordances have supported, or are promising to support, children. Göttel (2011), reviewed how CCI works have materialized children’s collaboration practices in storytelling environments, and identified three main practices (remote authoring, collocated authoring, and enriched experiences) and how those practices can enable rich experiences. A year later, Zaman et al. (2012), in the context of an editorial, reviewed strengths and weaknesses of different types of studies that document the benefits of tangibility for children and discussed how tangibility can lead to greater usability for children and the need to go beyond the dilemma of “tangible versus virtual”. In the inaugural issue of IJCCI, we also find an invited contribution that focuses on certain technological affordances. The second is by Eisenberg (2013) who described the most prominent challenges of 3D printing in CCI research and practice, including challenges connected with methods for creating portable and ubiquitous printing devices, software techniques for specifying, altering, and combining 3D elements. He explained how overcoming those challenges will enable us to provide children with powerful and expressive means for creating artefacts. Recently Cresczenzi-Lanna (2020) conducted a systematic literature review on how multimodal data and learning analytics have been employed in studies with young children. The results showcase that, despite the complexity and the various ethical and practical challenges, multimodal data provide valuable insights in systems targeting young children (e.g., speech recognition systems).

3.3.1. In this issue

In this special issue we have two contributions focusing on how a specific technological affordance can support CCI. The first contribution by Sharma and Giannakos (2021) examines how sensor data (sensing capabilities) have been employed in contemporary CCI research, pointing out that CCI studies have used sensing to power four objectives concerned with, capturing and supporting children’s engagement, supporting children with special needs, understanding children’s behavior/attitude, and capturing children’s learning performance/experience. The authors also stress that future research should consider developing a framework to allow researchers to align the use of sensor data with ethical and social principles, and follow guidelines that allow the production of transferable knowledge (a certain degree of generalization). The second contribution by Sim and Bond (2021) focuses on how eye-tracking has been used in CCI research and future opportunities. The authors identified different uses of eye-tracking in CCI and discussed opportunities to further understand children by leveraging eye-tracking metrics such as pupillometry and blinks, with important implications for empirical research (e.g., capturing expressions of children’s experience such as cognitive load and arousal). Both contributions center on the recent development on the use of sensor-based analytics to support experimentation (through rich and unrobustive measurements) and interaction (through multimodal interaction). Both contributions also stress the key affordances of eye-tracking and other sensor technologies (e.g., temporality and direct access to new indicators of cognitive and affective processes), but also the need for future work on how we can put those affordances into practice in an ethical and responsible manner.

3.3.2. Potential future directions

New technologies, thanks to their various affordances (e.g., motion sensing, voice recognition, affective, affect detection), are amplifying children’s capacities to interact and communicate with the machine. Considering also the amount of data produced from children’s interactions and the available Artificial Intelligence (AI) techniques, we expect that advances on the technical front will continue shaping the CCI research and practice. Literature reviews conducted in the early 2010, focused on technologies that have already today proven their potential in CCI (e.g., storytelling, tangible interaction, embodied cognition and 3D printing) (Table 3). While recent literature reviews focus on the contemporary developments like big data, multimodal interaction and AI (Table 3), those promising capabilities still require future work to materialize their potential for CCI. These technological trends can affect CCI research in three directions: (1) enriching empirical research, by allowing us to gather insights from children’s cognitive and affective processes; (2) amplifying the interaction affordances of systems, by utilizing multimodal and sensor-based data to support richer interactions (e.g., through gestures, or gaze); (3) advancing the intelligence of systems, by utilizing rich data to power advanced AI algorithms. As with the rest of the technological world, AI-powered technologies will play a key role in CCI, helping institutions, educators, families and the respective industry to empower children. Therefore, future work should consider the methodological, practical and ethical challenges with respect to this, maybe, not-so-distant future transformation.

3.4. The role of theories

Historically, CCI research has been grounded, to varying degrees, in theories about how children develop, learn and play. For example, early work in computational literacy took a social constructivist stance and was grounded in theories of constructivism. Similarly, early works on learning through play and social interaction often drew from Vygostsky and Bruner. Within CCI, researchers have begun to explore other theoretical stances, including a research agenda based on advances embodied cognition (e.g., Antle, 2013), application of neuro-constructivism to children’s technologies for learning (Sirois et al., 2008) and advocacy for cultural theories to inform pedagogy in educational technology (Samy & Paris, 2017). Advances to theory have increasingly been the outcome of CCI research. By 2017, Barendregt et al. reported that just less than half the papers published at IDC from 2003 to 2016 were ‘artefact-centered’ papers (i.e., the design of an
artefact of a certain fidelity level accompanied by a form of evaluation) and highlighted the importance that CCI research focuses on the production of intermediate-level knowledge. In one of the most popular CCI literature reviews, Yarosh et al. (2011) analyzed the IDC papers published since 2010 and identified that the most popular theoretical groundings are: developmental theory, the cognitive theory of Embodiment, Piaget’s theory of cognitive development, and Constructivism and Papert’s Constructionism (learning while constructing artefacts). In general, we will see theories to be used to ground design decisions as well as embracing children’s culture, cognition, attitudes, perception, and behavior. Most of the works in CCI research use theories to better understand trade-offs between design, technology, and behavior (e.g., human development, cognition, social interactions), and support their decisions (e.g., design, research, sensemaking).

3.4.1. In this issue

In this special issue we have two contributions focusing directly on the role of theories, although other papers are also touching upon this thematic area. In the first paper Skovbjerg et al. (2021) reviewed works on how to design for fantasy play, and identified three theory clusters that are relevant for CCI research, namely for contextualizing the value of play, highlighting the outcome of play, and supporting design decision making. Moreover, the authors discussed how to consider theories from different domains, and support our thinking and design decisions. The second paper is by Torres et al. (2021) focusing on phygital play and the respective technologies; they reviewed the literature and identified principles underpinning the way in which phygital play technologies afforded child behavior, namely action regulation, social expectations, technical features of technologies, and goal–tool–action alignment. Both contributions offer useful approaches on how to improve the design for play, with generalizable insights that support generalizable knowledge.

3.4.2. Potential future directions

Artefacts correspond to novel designs (e.g., prototypes, interfaces, materials, or procedures) that carry a certain set of qualities such as functionalities and affordances. The evaluation of those artefacts help us to advance both empirical and theoretical knowledge, with each study having its own value and contribution by producing findings that can be reused (e.g., to support the design of future artefacts) (Sutcliffe, 2000). Therefore, there is nothing wrong with ‘artefact-centered’ papers, in fact those studies offer the primary knowledge and “data-points” needed to move forward to more generalized knowledge and insights (referred in the HCI literature as intermediate-level knowledge), at the same time it is important for CCI research to show its maturity and ability to develop knowledge that goes “beyond an artefact”.

From the inception of the IJCCI, one of the main objectives was to close the gap between theory and design/practice by developing models and guidelines that could guide the design of interactive artefacts for children (Read & Markopoulos, 2013). Although theory appreciation and theory borrowing from other disciplines is very popular in CCI research (as we can see from the selected review papers of Table 4), it is also important to bridge artefact-centered research with the construction of intermediate level knowledge. Following the discussions we have seen during the last years, future work needs to consider the development of models, theories and guidelines that could guide the design of interactive artefacts for children beyond particular artefacts, this is likely to accelerate the progress in our field but also allow us to broaden our methodological basis. Nurturing such works can be done with dedicated calls from top journals and even explicitly requesting such contributions from the main venues (e.g., IDC), in that way authors are becoming aware that such works will have fair treatment and will not be mistreated by the reviewers (e.g., maybe some reviewers expect that an IDC/IJCCI paper should always have an artefact design). The value of such progress can be better understood by considering the concept design of the Dynabook or the Logo Turtle, in the context of children’s learning. Both the Dynabook and the Logo Turtle embodied notions of constructivist learning in a concrete form, which are not categorized as either a theory or as an artefact (instance), and have guided several developments in CCI research and practice until now.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Summary of selected review papers on the intersection of CCI and technological affordances.</th>
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<tbody>
<tr>
<td>Focus of the paper</td>
<td>Technological Affordance</td>
</tr>
<tr>
<td>Reviewed children’s collaboration practices in storytelling environments, and found three concepts of storytelling (remote authoring, collocated authoring, and enriched experiences). He also identified that collaboration and storytelling often appear together, with a promise to enable rich experience to children.</td>
<td>Storytelling</td>
</tr>
<tr>
<td>Identified that tangible interaction in HCI is mainly concerned with the benefits of tangibility for adults. Reviewed strengths and weaknesses of different types of studies that document the benefits of tangibility for children and discussed how tangibility can lead to greater usability for children and the need to go beyond the dilemma of “tangible versus virtual”.</td>
<td>Tangible interaction</td>
</tr>
<tr>
<td>The author discusses the technological challenges that need to be overcome in making 3D printing accessible to children in the years to come.</td>
<td>3D printing</td>
</tr>
<tr>
<td>The author conducted a systematic literature review on how multimodal data and learning analytics have been employed in studies with young children, and highlighted the valuable insights in systems targeting young children.</td>
<td>Multimodal Data</td>
</tr>
<tr>
<td>The authors identified four objectives that the CCI research has been focusing on with the use of sensor data (i.e., engagement of children, recognition/prediction of special needs/behavior, explaining/understanding the behavior/attitude, and learning performance/experiences). The authors also stressed that future research should consider developing a framework to enable the alignment of sensor data with the ethical principles.</td>
<td>Sensing</td>
</tr>
<tr>
<td>This review work identified that there are clear opportunities to further understand children’s interaction with digital technology using eye-tracking metrics such as pupillometry and blinks; such information will allow us to capture complex but powerful expressions of children’s experience including cognitive load and arousal.</td>
<td>Eye-tracking</td>
</tr>
</tbody>
</table>

4 Part of this special issue.
3.5. Responsible and ethical research

Children’s participation is a cornerstone in CCI research. As we saw in Section 3.1 children can play different roles and provide various contributions. The involvement of and approval from an independent ethics committee is mandatory before conducting research that involves human-subjects, with children being considered as a category of special attention. In most of the times, it requires a clear justification for why involving children in research is necessary, for example the European Commission’s report on Ethics for Researchers states that “the involvement of children in the research must be absolutely necessary and, if so, all particular ethical sensitivities that relate to research involving children must be identified and taken into account” (European Commission, 2010, pp. 65–74). The CCI community has worked with the development of tools and processes to include children in research in an ethical and responsible manner, with constant discussions (e.g., Frauenberger et al., 2018) on areas for improving our practices.

Going back to Yarosh et al. (2011) who analyzed the first 9 years of IDC papers, one of the foci they examined was the values held by CCI researchers. This literature review also questioned whether researchers in CCI always identified or reported their real motivations for their work and raised concerns about the extent to which approaches used had undergone ethical scrutiny. The CCI field has significantly grown and several routines and policies have been established since that work. Several papers have been published in the area, and several events (e.g., workshops, panels) have been organized in the context of IDC and CCI. First, a similar literature review was repeated 9 years later by Kawas et al. (2020). This work analyzed IDC papers between 2011 and 2019 and identified how CCI research has evolved during the last years (e.g., CCI researchers consider both explicit (e.g., consent forms) and implicit (e.g., agency) ethical considerations and CCI papers are now more likely to make empirical contributions) and highlighted how the CCI research community surpasses the traditional standards of ethical research (based on surveying 20% of IDC authors). Another recent paper by Van Mechelen et al. (2020) explored how and to what extent ethics has been addressed within the CCI community (through IDC and IJCCI papers) and provided avenues for developing a more explicit discourse on ethics such as going beyond the standard description required from the IRBs to increase transparency and addressing issues related to design ethics and situational ethics. A more recent work from Stoitova et al. (2021) highlights that most of the work on ethics on children technology (online) use focuses on interpersonal safety, ignoring important potentially harmful aspects such as discrimination, exclusion, manipulation, exploitation and alike. Recent work from Antle and Kitson (2021) proposed six ethical issues of concern where children’s developing sense of self could be negatively impacted through long term use of bio-sensing devices (e.g. smart watches, trackers, fitbits). Those works depict that despite the fact that we have seen several developments with regard to children’s involvement in responsible and ethical research (e.g., policies, tools, approaches), we are still in need of efforts to ensure that children and young adults have access to technologies that are safe, and their participation is conducted in an ethical and responsible manner.

3.5.1. In this issue

In this special issue we have three contributions that address the issue of ethical and responsible CCI research. The first is by Radesky and Hiniker (2021), a vision paper that argues for shifting the responsibility (or part of it) from parents to platforms via policy development. Developing a systemic approach will allow us to establish child-centered design as the default. In the second contribution, Quayyum et al. (2021) reviewed the CCI literature with a focus on cybersecurity and summarized the cybersecurity risks for children and commonly used approaches for raising cybersecurity awareness among children. The authors highlighted the importance of developing a framework to support cybersecurity awareness and train children and their support sphere (e.g., parents, teachers) in important cybersecurity aspects. The third paper by Sharma and Giannakos (2021) recognizes the ethical concerns of employing sensor data in CCI research and practice. The authors also discuss that to be able to mainstream such advanced data in CCI, future work should consider the ethical and privacy concerns, and identify how to efficiently communicate the information provided by sensor data to the children and their guardians.

3.5.2. Potential future directions

Although we have divided this editorial into different strands, it is important to clarify that the different strands have interdependencies and most of the time we need to consider their progress as an interplay. For example, the ways children participate, research methods, technological affordances and application domains are progressing, playing a tremendous role in developing new ways of conducting responsible and ethical research. Different affordances (e.g., motion-based technology, audio interfaces) are already accessible to younger children anytime, anywhere. Al-powered technologies such as voice agents (e.g., Amazon’s Alexa and Google Assistant) allow children to perform complex
interactions. Children are growing together with these technologies and develop perceptions and habits that are significantly different from adults (the same way our habitat is very different from our parents). Therefore, these advancements pose novel and fundamental questions on how we as researchers should mediate ethical issues and dilemmas when designing interactive technologies with and for children. Future research in responsible and ethical CCI research should develop in parallel with the contemporary advancements of the field (e.g., technological) and support the necessary practice and policy in tackling potential ethical issues emerging (e.g., as we see in Table 5 about potential online harms, cybersecurity and sensor capabilities). Such continuous development is essential for the field’s success and proliferation, and being able to embrace novel developments (e.g., technologies, data collection methods) in a responsible and ethical manner.

3.6. Future research agenda

Almost every CCI paper is expected to discuss and propose some future research topics (e.g., as part of its future work), even more review and discussion/position papers. In the inaugural issue of IJCCI, we saw invited papers proposing a research agenda for embodied cognition (Antle, 2013), 3D printing (Eisenberg, 2013), alignment between values, epistemology and methodology (Iversen & Dindler, 2013) and an overview of the CCI landscape with a proposition for four promising areas for future research (Read & Markopoulos, 2013). Throughout the last decade we have seen several workshops, courses, panels and special interest groups organized as part of the IDC and CHI conferences, venues which have enabled discussions and statement papers for future research directions in CCI. Although several years have passed, the four areas proposed by Read and Markopoulos (2013) are still very relevant today (closing the gap between theory and design/practise, advance children’s participation, the role of emerging technologies and affordances, and potential risks of children’s privacy and security), and have been in the epicenter of this editorial and in some of the papers included in the special issue. Last year the past and ongoing editors of IJCCI extended those areas by including advancements in CCI research methods, focus on application areas (e.g., learning, sociability, healthcare, play), and advancing literacies for children (Giannakos, Horn et al., 2020). Although those areas for future research are generic and further scrutiny is needed (e.g., discussing specific research areas that are promising), they enable CCI researchers to position their work, and nurture discussions about future developments.

3.6.1. In this issue

With this special issue initiative we invited review articles in various areas of CCI. One of the goals of the special issue is to evaluate and understand its developments and current state, but we also invited works that discuss the vision for the future. The majority of the papers included in the special issue discuss avenues for promising future research, with three of them explicitly addressing the formulation of important future research topics (Table 6). First livari et al. (2021) review relevant CCI studies in light of the critical research tradition. These studies are summarized and the overlap between the CCI literature and critical research tradition allows the authors to identify opportunities for future CCI studies addressing the critical agenda. Those opportunities connect with the other strands of the editorial...
During the preparation of this special issue, the editor-in-chief of IJCCI, for his ongoing support, and guidance during the preparation of this special issue.

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References


**Papers included in this collection**


