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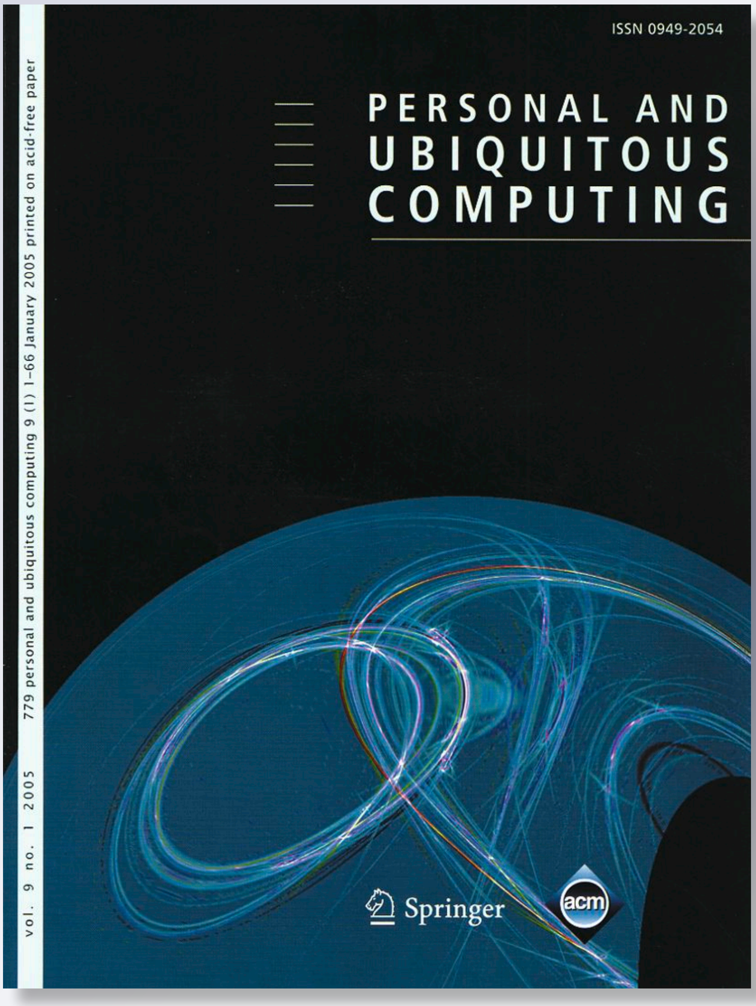
Julie A. Kientz

Personal and Ubiquitous Computing

ISSN 1617-4909
Volume 16
Number 2

Pers Ubiquit Comput (2012) 16:209-221
DOI 10.1007/s00779-011-0380-6



Springer

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ORIGINAL ARTICLE

Embedded capture and access: encouraging recording and reviewing of data in the caregiving domain

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Received: 16 August 2010 / Accepted: 4 April 2011 / Published online: 27 April 2011

Abstract The use of ubiquitous computing to aid in the capture of everyday experiences has been a commonly studied application area. Previous systems have enabled the capture of classroom lectures, meetings, or surgical procedures. However, many of these systems saw infrequent access to captured data, mostly because accessing the data required a high-need situation in order to go through the trouble of finding the specific situation. We believe that if access was made more ubiquitous, people would be more inclined to use it. In this article, we present the notion of embedded capture and access, which aims to make both data capture and access ubiquitous, thus encouraging better reflection on captured data. We provide a description of the notion of embedded capture and access and describe how we applied this technique to two domains of caregivers: therapists working with individuals with autism and parents collecting developmental data on their young children. Through the development of fully functional prototypes, we were able to show that technologies using embedded capture and access are a successful means to supporting data recording and review.

Keywords Ubiquitous computing · Capture and access · Caregivers · Human–computer interaction · Autism · Children

J. A. Kientz (✉)
Human Centered Design and Engineering and The Information School, University of Washington, 413 Sieg Hall, Box 352315, Seattle, WA 98115, USA
e-mail: jkientz@uw.edu

1 Introduction

The role of data collection and its review is crucial to many domains where decisions must be made or progress must be evaluated. The fields of healthcare and education are two primary examples where data collection is often required to make progress on treating a disease or assessing how well a student is learning a particular skill. Ubiquitous computing has the potential to make data collection for these domains much more intuitive and integrated into work practices, which will improve the likelihood of their success.

Technology that is unobtrusive, easy to use, and easy to share with others has the potential to assist these caregivers in the decision-making process. Thus, we have explored the design, development, and evaluation of a class of applications we call embedded capture and access. Embedded capture and access involves the use of technology for data recording (capture) and review (access), especially in such a way where the technology is seamlessly integrated into existing work practices and is unobtrusive to everyday activities. The data capture and its access can be accomplished through automated data recording and indexing, peripheral or proactive notifications of trend information, or by taking advantage of existing motivations. Embedded capture and access expands upon the traditional notion of capture and access defined by Abowd and Mynatt [1]. These traditional systems have enabled the capture of classroom lectures, meetings, or surgical procedures. However, many of these systems saw infrequent access to captured data, mostly because accessing the data required a high-need situation in order to go through the trouble of finding the specific data needed. We believe that if access was made more ubiquitous, people would be more inclined to use it. Embedded capture and access ensures that not only the data capture is ubiquitous, but both the data capture and the access portions of applications are ubiquitous.

We have explored two specific domains in this research: the evaluation of treatments for children diagnosed with autism or another developmental disability and the evaluation of young children's developmental progress. These domains present several interesting challenges for technology design and evaluation, due to the complex and diverse nature of treatment types, wide range of caregivers, and differences in the level of knowledge about the care process by the caregivers. They also present high-need situations where data have the requirement to be accessed as part of natural work practices, whereas previous capture and access applications usually only captured data in the event that it might need to be accessed later.

In this paper, we first describe related work in the areas of capture and access, technology for record-keeping in health, and technology for individuals with autism. We then introduce the concept of embedded capture and access and describe its nature and components. We go further into the area by describing two case studies of designing embedded capture and access applications for therapists of children with autism and parents tracking development of young children. Finally, we discuss aspects of this process that are crucial to the success of embedded capture and access applications and provide implications for future designs in this space.

2 Related work

In this section, we outline related work in this space along three key areas. These include capture and access, ubiquitous computing and healthcare, and domain-specific related work in the areas of technology for autism and early detection of developmental disorders.

2.1 Capture and access

The concept of capture and access has been one of the key application areas of ubiquitous computing research over the last decade, with the first definition by Abowd and Mynatt [1]. A recent article by Truong and Hayes [38] goes in-depth in a literature review of this space; thus, we provide just a brief sample of the different application areas most related to this work. Typically, capture and access applications have focused on both capture and access aspects of specific domains or experiences. These include classroom lectures [7], office meetings [29, 31], surgery in an operating room [11], or researchers collecting data in the field [40] or in the laboratory [4]. Others have focused more generally, such as using capture and access to record unplanned events in a space [16], as a temporary memory aid [14] or to support creativity [9]. For our work, we have chosen to also focus on designing for a particular specialized domain rather than more general purpose for both of our projects, as we believe that for embedded capture and access to work, a solid understanding of the domain is necessary.

2.2 Ubiquitous computing and healthcare

Using ubiquitous computing technologies to "embed" data capture and access into health practices has become a popular topic in recent years. A regularly held workshop on "UbiHealth" at the Ubicomp Conference [5] has brought together a large number of research projects, including work on supporting surgeons in the operating theater [11], coordinating triage tagging of disaster scenes [26], and supporting information exchange between nurses at a hospital [35]. Additional work has explored how technology can be used to support individuals with diabetes in managing their own health [25] and individuals requiring kidney dialysis to track the foods they eat [33]. Our work contributes to this larger space of applications by applying it to the domain of autism therapy and tracking developmental progress in young children.

Of particular, motivation for this work is Morris et al.'s study of embedded assessment, which seeks to collect data by embedding technology in games or activities in which adults already engage [27]. In fact, we draw the term "embedded" in embedded capture and access from their usage of it. Their work focuses on measuring several aspects of health in individuals of advancing years who may be susceptible to a wide range of diseases. These aspects include monitoring for changes in health, compensating individuals for any declines they see in health, and preventing further illness by encouraging healthy behaviors. The main difference is that our focus is on both unobtrusively capturing data and ubiquitously providing opportunities for review, thus increasing opportunities for access of data to support decision-making and better awareness of the captured data. Thus, there are different considerations in the design phase of embedded capture and access, as well as different target stakeholders. In addition, our research is on caring for children, who often have limited or no input into the care process and thus, relies heavily on external caregivers, whereas Morris et al.'s work focused on healthy individuals who often have input into their own health and well-being.

2.3 Technology for autism therapy and early detection

The two embedded capture and access prototypes we developed cover the domains of the care of children with autism and the early detection of developmental disorders. There has been a growing interest in exploring technology to assist individuals with autism, with much of the work focusing on developing applications for use directly by individuals with autism, rather than in support of their caregivers. These systems include Simone Says, a system using voice recognition technology to teach and analyze language skills [24] and Hailpern et al.'s work on using visualizations to encourage vocalizations for children with autism [10]. The Discrete Trial Trainer [37] is a commercial software product that attempts to replicate the role of the therapist in discrete trial training by administering similar therapy and education through the computer. These types of applications have the ability to ease caregiver burden by allowing a computer to administer parts of therapy, which can enable caregivers to handle other aspects of care or engage with students in new ways.

Other technologies have focused on how to teach individuals with autism social skills and aid in communication. Tartaro has explored storytelling with virtual peers to teach social skills to children with autism in a more comfortable setting [36], while researchers at MIT have looked at how images of people can be emphasized to help understand subtle emotional cues [17]. Recent work by Piper et al. has explored how a tabletop, multiplayer game, called SIDES, can be used to encourage children with autism to learn social interactions and turn-taking [30]. These types of social applications can be used in conjunction with caregivers to provide a more rich education in social skills, which again leaves the caregivers with more time for other, more demanding care issues. The main difference between this work and the work we have conducted is the focus on the use of technology by individuals with autism, rather than supporting their network of caregivers.

The most closely related application to this area of work is CareLog, a capture and access system developed by Hayes et al. [12]. CareLog is similar in spirit to helping caregivers collect better data for decision-making and seeks to support teachers in a classroom in diagnosing the causes of children's behavior by allowing retroactive video capture of events (through selective archiving [15]) to help support systematic decision-making on the cause of the behavior. Our work builds upon this by using a similar method of capturing video for the purposes of decision-making, but focuses more on the access side, by providing more spontaneous opportunities for decision-making and allowing caregivers to make decisions based on more data.

Previous work in the area of using technology for early detection of childhood disorders is more specifically related to the Baby Steps prototype we developed. Most of the previous work in this space has been limited to a focus on automating the process of identifying early warning signs. The Human Speechome project [32] uses an extensive recording infrastructure throughout a house to gather linguistic data to help researchers ascertain how children acquire language. Fell et al. examined ways to analyze baby babble as early indicator of speech-related disorders [8]. Westeyn et al. augmented toys with sensors to try to automatically identify developmental milestones in young children [39]. The Baby Steps project seeks to support early detection using a more holistic approach, by using many different indicators for development, rather than focusing on a single domain or constrained set of clinical signs.

3 Embedded capture and access

Embedded capture and access integrates simple and unobtrusive capture and useful access, including trending information and rich data, into existing work practices. We believe that by embedding both capture and access within the environment of use, it will encourage more frequent access of the recorded data. This can help heighten awareness of data and make users more aware of the data being captured, and within the field of caregiving, can help caregivers to make better decisions. Existing capture and access systems within the field of ubiquitous computing have traditionally done a good job of embedding capture and making it seamless with the users' actions, but have had less success in doing the same with access interfaces. With embedded capture and access, both the capture and the access activities are moved from the users' main attention and focus and more to the periphery. Figure 1 illustrates the primary difference between traditional capture and access systems (top) and embedded capture and access systems (bottom). Figure 1 also lists how the techniques between traditional capture and access systems differ with those of embedded capture and access systems, which we further describe elsewhere.

3.1 Embedding capture

The techniques for embedding capture within a user's environment are very similar to that of traditional capture systems, which were already the ubiquitous aspects of the system design. Much of the time, the focus was on allowing live experiences, such as class lectures [7] or meetings [29, 31], to be recorded uninterrupted. With embedded capture, we adopted many of the similar goals and techniques. Thus, the primary mechanisms for capture in these systems include the same components as traditional capture and access systems. Specifically, this includes using rich media capture devices, such as audio and video recording devices, to collect detailed records of experiences. Because these rich media files are often

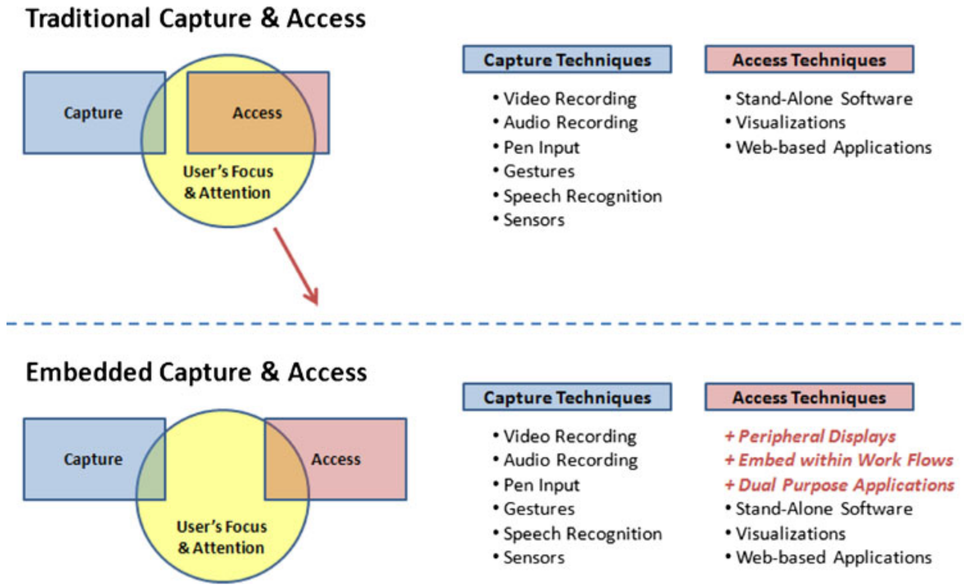

Fig. 1 Illustration depicting the primary differences between traditional capture and access systems and what we are defining as embedded capture and access systems. The primary difference is the change in the focus of the access of data and in the addition of new access techniques, which are highlighted

difficult to access, they also typically involve some kind of solution for indexing the video ubiquitously, such as through pen input while writing, gesture input, speech indexing using recognition techniques, and also sensors to somehow indicate when meaningful events have taken place. Nearly all aspects of capture should be seamless, so as not to interfere with the live experience itself, and the technologies used for indexing should be natural to the user and not interrupt conversations, thoughts, or require large amounts of attention.

3.2 Embedding access

The primary difference between traditional capture and access systems and embedded capture and access is the way that data are accessed. In traditional systems, because the focus was on preserving the live experiences as much as possible, most of the effort was made into making capture more ubiquitous. The access systems, on the other hand, were primarily more traditional software systems or web-based applications that allowed for the conscious and intentional review of previously recorded data. Because access requires a more explicit action, previous research-based capture and access systems often did not see high levels of access, except in high-need situations (e.g., students accessing recorded lectures just before a big test [7]). With embedded capture and access, the goal is to make access ubiquitous as well, to encourage better awareness of recorded data and also allow for more spontaneous reflection upon captured data. This means that in addition to the more traditional software and web-based applications with visualizations of captured data for more conscientious and intentional review, we propose to also show users' data in more peripheral ways, such as making visualizations of data shown while users are completing other tasks. This could also take the form of ambient displays, which may show more abstract views of data to help users reflect and reduce information overload. Another way to make access more embedded is to integrate the review of data into the workflows of target users. For example, if a job requires certain actions, such as completing daily forms, review integrated into the required actions will allow for more spontaneous viewing of data. Finally, we propose one other method in allowing access to be more ubiquitous, which is through the use of dual-purpose technologies. By integrating access of data through activities, the user wants to or needs to be doing anyway, such as viewing pictures or surfing the web, users will also be more exposed to data, which may increase the rate of reflection.

4 Case studies

We aimed at testing the notion of embedded capture and access in two data-intensive, high-need domains, both of which are related to autism. Both domains involved caregivers working to collect information to help make decisions about care. In this section, we outline the two case studies of the design, development, and evaluation of two embedded capture and access applications for the caregiving domain. The first, Abaris, is a tool for teachers of individuals with autism working on teaching life skills, and the second, Baby Steps, is a tool for parents and pediatricians to track developmental progress in young children for the purposes of identifying developmental delays, such as autism.

The full details of the Abaris system and its evaluation in the home can be found in several previous publications [18, 20, 21], as can the formative work and design and details of the Baby Steps system and its evaluation [19, 22, 23]. Thus, in this paper, we provide a short summary of the formative work, the design of the fully functional prototype and how it meets the requirements of embedded capture and access, and then describe the relevant results of a field study with each and how the system enabled the better recording and reviewing of records. This paper provides the first introduction of notion of embedded capture and access and the first synthesis of the findings from these two systems.

4.1 Abaris

Abaris is an embedded capture and access tool designed to support a type of therapy common for children with autism, called discrete trial training (DTT) therapy. This type of therapy is typically used to teach both academic and life skills in a one-on-one setting using the well-defined and studied technique of Applied Behavior Analysis (ABA) [2]. Discrete trail training therapy is considered one of the most important instructional methods for children with autism [34].

4.1.1 Formative work

We conducted an extensive study of the process of discrete trial training therapy to understand how technology could be used to support this practice [13, 18, 20]. The formative work included in-depth interviews with therapists and educators who work with children with autism, parents of children with autism, and interviews with domain experts. There was also a large participant observational portion, in which members of the research team joined a discrete trail training therapy team to become trained as therapists and participate in the process for a 6-month period. In addition to observing the home-based team, we also wanted to gain a better understanding of how DTT worked in school settings as well. Thus, we teamed up with the Experimental Education Unit at the University of Washington, a research-oriented educational setting that was using DTT therapy in its classrooms with children with autism. We interviewed teachers who worked with the children and did an artifact analysis of the materials used by teachers within the classroom. We also observed several therapy sessions between teachers and students to get a better understanding of the differences in dynamics between the home and the school settings. Overall, we learned that the process of DTT is a very paper-intensive one in terms of both capture and review of data, and thus, any system we designed would need to respect that practice in order to be successfully embedded.

4.1.2 Embedded capture and access prototypes

In total, we developed two different prototypes of Abaris. The first prototype was designed based on a home therapy team's protocol of DTT therapy. Based on our observations, we determined that therapists were trained to conduct two very consistent behaviors each time they had the child attempt a skill they hoped to score and record. The first behavior was always saying a specific phrase as a prompt to the child, such as "give me the red truck." The second behavior was that immediately after the child did the task, the therapist would write down how well the child did on a sheet of paper. Thus, there were two natural activities that could be leveraged as indices for a capture system: 1) using phoneme-based speech recognition by Nexidia [28] to index the beginning of a trial and 2) pen input using an Anoto digital pen and paper system [3] to index the end of the trial. These indices were linked to a video recording of the therapy session to allow therapists to review specific trials between the therapist and the child (see Fig. 2).

For the access system for the home version, we knew from our formative work that the primary need for reviewing data was during the team meetings in which all therapists met every 2 weeks to discuss the child's progress and make decisions regarding the future course of action with therapy. The original practice was driven by hand-drawn graphs of the child's progress on different skills. Thus, we designed the access system as a stand-alone software interface that followed the current work practices of the therapists by providing a meeting agenda order with automatically generated graphs being the main way of accessing the recorded data (see Fig. 3, left). More detailed data could be accessed naturally by mousing-over the data points on the graphs, and the videos could be accessed by clicking on the data point, where the video would be automatically cued to the approximate moment of the therapy session in which they were interested in reviewing (see Fig. 3, right).

Due to the success of our initial system design, we also built a second version of Abaris that would be appropriate for school settings. The basics of capture using digital pen and paper to record time stamps (see Fig. 4, left) and automatically calculate scores and generate graphs were consistent in both versions, but the value of the speech recognition was not enough to include in this version. Our formative work indicated that there were some distinct differences between the home and the school setting. For example, teachers did not have regular group meetings where they discussed student data like they did in the home setting, and thus, we had to think of another way of embedding access into their existing work practices. In analyzing the process, we determined that therapy could not be done without data sheets, since that is what teachers

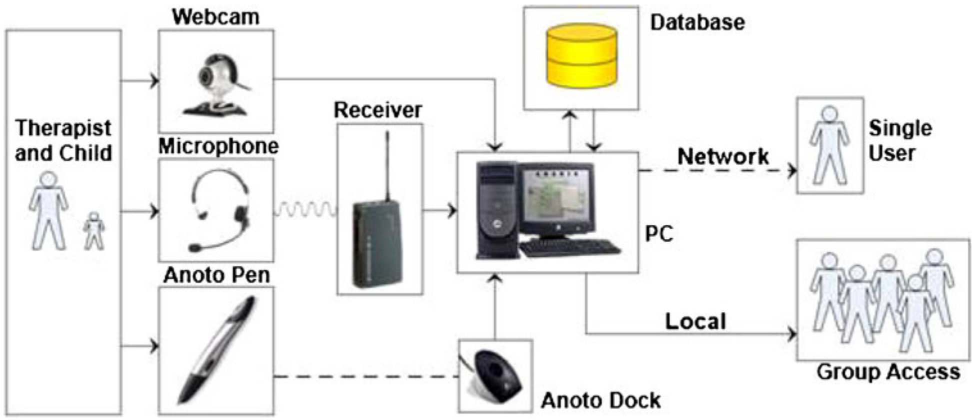

Fig. 2 System architecture of home version of Abaris system. The capture system uses video, speech recognition, and digital pen and paper input

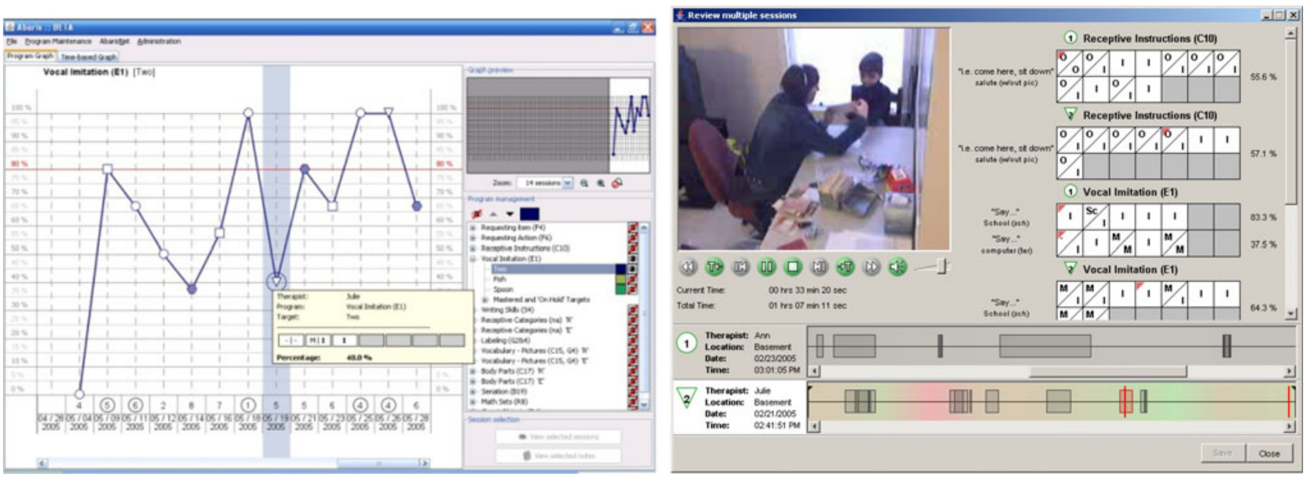

Fig. 3 Screen shots of access interface of the home version of Abaris. The *left* shows the main screen where graphs drive the agenda of the meeting, and the *right* shows the more detailed view with indexing and videos

used to do therapy. We decided to peripherally show graphs and snapshots of previous therapy sessions within the process that therapists used to generate and print data sheets for their daily therapy sessions (see Fig. 4, right).

4.1.3 Deployment studies

The evaluation of Abaris took place across two independent studies with the two groups we had studied as part of our formative work. The home-based study was a deployment study that lasted approximately 4 months and was used by a single team consisting of 3 regular therapists, 1 lead therapist, a consultant, and the child's parents (see [21] for details of this study). We compared aspects of the therapy sessions and meetings with Abaris to therapy and meetings without Abaris. The main dimensions of study were how much time was spent doing therapy versus paperwork, how many artifacts were accessed during the team meetings, and how much each therapist participated in the meetings. Overall, we found that therapists spent less time doing paperwork overall (22% of their time, vs. 31% previously). We also analyzed the use of different data with and without the use of Abaris and found that they accessed data in a higher percentage of discussions in meetings while using Abaris, including graphs (81.9% vs. 56.0%), datasheet data (45.2% vs. 20.5%), and videos (45.2% vs. 0%) than without Abaris. We also found that the therapists were more engaged and active in discussions during the meetings where Abaris was used through a coding analysis of their interactions (2.44 vs. 1.88, with 3.0 being the highest possible collaboration score). Therapists also reported a high level of satisfaction with the system during post-deployment interviews, stating, "I loved being able to have a more engaged team" and "people were able to visually see [the data during meetings], and I think make better comments. The quality of comments maybe went up and maybe the number too."

For the study in schools, the new version of Abaris was used for approximately 5 weeks by a team of 6 teachers and 15 students. The main criterion for evaluation was whether teachers changed the activities on which students worked more frequently, indicating a quicker mastery of

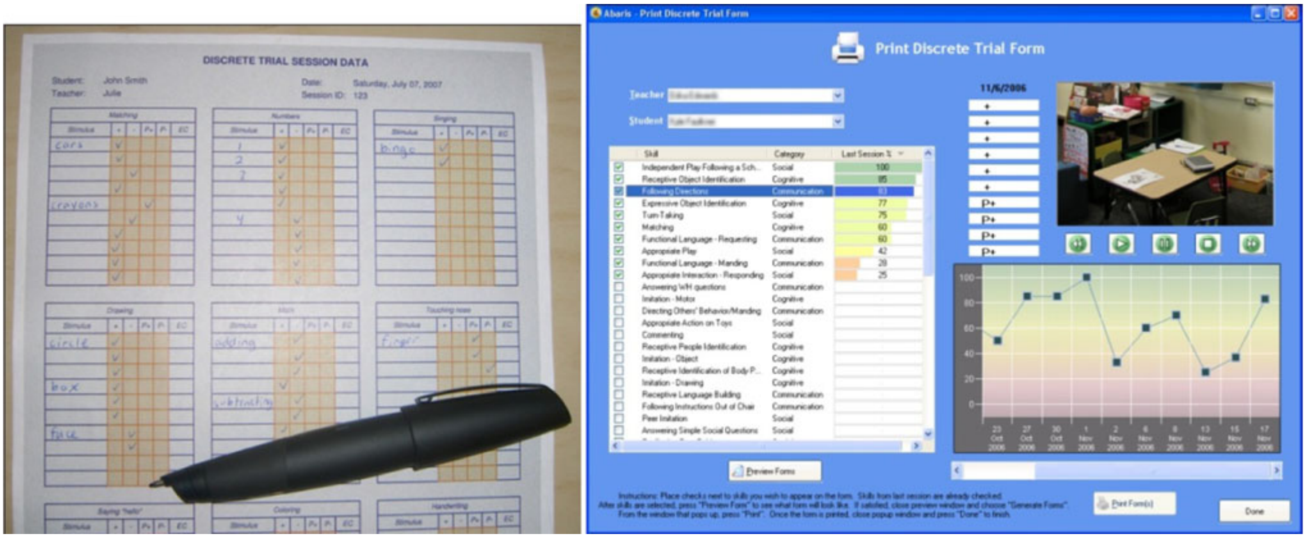

Fig. 4 Capture and access aspects of the school version of Abaris. This version used digital pen and paper primarily for capture (*left*) and integrated peripherally displayed access of graphs into the process of printing forms needed for therapy (*right*)

skills and more frequent review of data. We found in our formative studies that before Abaris, teachers would often wait several months to graph and review data, just before their meetings with the head teacher. With Abaris, the process of graphing was done immediately and could be viewed while they were doing normal parts of their jobs. We found that teachers had students moving through skills more quickly with Abaris, with an average of 38.8 days spent per skill without Abaris and 23.4 days spent per skill with Abaris. However, due to the shorter length of the study, we did not have enough data for statistical significance. Interviews with teachers after the study confirmed that they did access the children's graphs more frequently and did switch out skills as soon as they realized the student had worked on them enough for them to be considered mastered.

4.2 Baby steps

Baby Steps is an embedded capture and access system we designed to support parents tracking developmental progress in their young children. The motivation behind this system was to help parents and pediatricians identify signs of developmental delay or developmental disorders like autism by systematically tracking and reviewing developmental milestones that all children meet as they grow from birth through age 5. The goal is to use sentimental record-keeping as a dual-purpose application to take advantage of existing motivations of parents to reduce the anxiety of tracking developmental progress by focusing on the fun activities, rather than tasks that seem more medically oriented.

4.2.1 Formative work

To help understand the problem space in designing for new parents, we conducted interviews and focus groups with four stakeholder groups, including new parents, experienced parents, secondary care providers, and medical professionals [19]. Through this formative work, we uncovered key design issues, rationales, and functional requirements to consider in making technology designs both useful and motivating to use. The primary stakeholders interviewed included new or expecting parents, experienced parents (including parents of children with special needs), pediatricians and nurse practitioners, and secondary caregivers. In total, we interviewed and conducted focus groups with 35 participants from varying family situations and determined design requirements for using technology to assist with record-keeping for parents. This formative work was essential in understanding how an embedded capture and access system would fit into existing work practices or be designed as a dual-purpose technology. One of the key findings was that parents are already motivated to keep sentimental records on their children, such as taking photographs or keeping baby books. Thus, this would be a prime area to explore for a dual-purpose embedded capture and access application.

4.2.2 Embedded capture and access prototypes

Using the findings from the qualitative study, we designed a computing technology aimed at supporting parents in capturing and recording their child's developmental milestones [23]. The technology was a desktop software

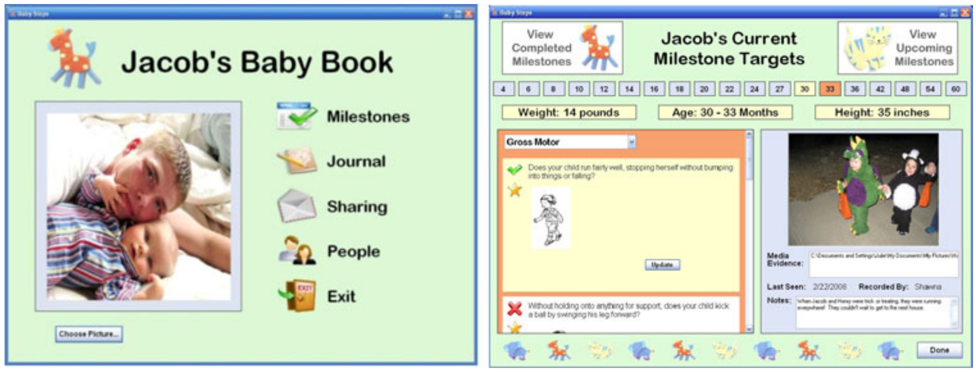

Fig. 5 Baby Steps desktop application main menu (*left*) and milestone recording tool (*right*)

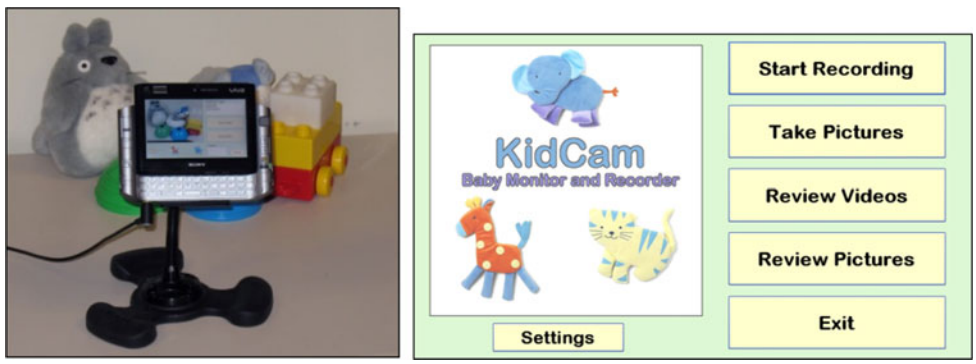

Fig. 6 KidCam prototype on a Sony VAIO (*left*) and a screen shot showing the main menu of KidCam's interface (*right*)

application that used the metaphor of a baby book (see Fig. 5), which allowed parents to capture developmental milestones along with sentimental records, such as pictures, videos, favorite toys, favorite foods, etc. The application also allowed them to import pictures and videos, generate keepsake newsletters to print or e-mail, and print medical reports to bring to their pediatrician during Well Child Visits. The numbers across the top of the main interface showed a peripheral, abstract view of the child's progress through color coding.

In addition to manual capture of developmental milestones as part of a dual-purpose application, we also designed a rich media capture device, which we called KidCam that could semi-automatically capture spontaneous events within the child's life [22] by using selective archiving [15]. The device was prototyped on a Sony Vaio-U UMPC (see Fig. 6) and also functioned as a baby monitor, in which many of the parents in our formative study indicated they already used. The photographs and videos recorded with KidCam could easily be automatically synchronized with the Baby Steps system using WiFi.

4.2.3 Deployment study

We evaluated the use of this technology to determine its effectiveness in encouraging parents to record more milestone information, review information more often, improve confidence in reporting, improve communication with their pediatrician, and increase the timeliness of the data recording [23]. To study this, we conducted a 3-month deployment study with 8 families, in which we deployed two different versions of Baby Steps. We recruited families through a local pediatrician's office who had agreed to participate in the study. Half of the families received the full version of Baby Steps including all of the sentimental record-keeping features, and the remaining four families, which served as a control, received a version of Baby Steps that only allowed them to record developmental records. The families were recruited in pairs of similar demographics and randomly assigned to either the control or the experimental group. We collected data via surveys on confidence and parent–pediatrician collaboration [6] before and after the deployment of the software, interviews before, during, and after the deployment, and logs of all interactions conducted with Baby Steps.

The results of the experiment showed that the version of Baby Steps that combined the sentimental record-keeping with developmental record-keeping was successful along most of the criteria upon which we evaluated it. We found that on average, families in the experimental group recorded an average of 90.5 milestones over the 3-month period compared with the control group, who only recorded 40 milestones. We also found that parents reported higher confidence in milestones at the end of the study than at the beginning of the study for both the experimental and the control groups, which was a result of capturing data and accessing it. Parents in the experimental group also accessed the data more often, using the Baby Steps application an average of 17 days over the 3-month period, compared with 9 days for the control group. Finally, parents in the experimental group had a statistically significant increase in the perception of their pediatricians for the patient–pediatrician interaction survey (+0.51, $\sigma = 0.34$ on a 5.0 scale), whereas the control group did not (+0.18, $\sigma = 0.31$). Similarly, pediatricians also rated parents in the experimental group (+0.14, $\sigma = 0.36$ on a 5.0 scale) higher at the end of the study than they did the control group (−0.11, $\sigma = 0.31$).

5 Discussion

In this section, we provide a discussion of the findings from our experience in designing and evaluating the two embedded capture and access applications. We describe some specific lessons for designers interested in embedded capture and access applications and discuss future areas for research.

5.1 Lessons learned

The deployment studies of both versions of Abaris and Baby Steps were shown to have value to the target caregiver users, and most of the design was successfully embedded within their working environments and existing motivations. Here, we provide an active reflection upon our experiences and describe some lessons learned from our experiences and how they might be taken into consideration in future designs.

5.1.1 The importance of truly understanding the domain

Throughout all of this work, it became clear that in order to be successful in designing technology for the domains we were targeting, it is extremely important to have a good understanding of the goals, practices, and expectations of the different domains. This is not a new claim, as many who have worked in developing technology for use in the real world have called for an extensive understanding of the users before designing technology. However, this is particularly relevant to developing embedded capture and access applications in that a good understanding of existing work practices was needed to determine how technology would be best embedded into the working environments we were studying. As an example, we believe that for the Abaris home study, the design of the application better suited the needs of the therapists because we were so engaged with the team due to our 6-month participant observation study. However, the Abaris school application was missing some fundamental features (e.g., the ability to annotate graphs) because as the designers, we did not have the ability to spend as much time with the teachers due to a long distance collaboration. Thus, we were not as engaged with them on a daily basis like we were with the therapists involved in the home therapy application design. There still remains an open question of how much is "enough" understanding of a domain. For example, it is possible that the Abaris home version could have still been successful without us spending quite so much time working directly with the therapists.

5.1.2 The difficulty of capturing rich media of children across diverse spaces

One of the incidental findings of our research has shown that rich media of children still remains a major challenge. Despite the fact that video, audio, and photographs can be very beneficial, it remains difficult to design and implement systems that effectively support this. We believe children are harder to capture than other subjects. Children are often non-cooperative subjects, especially those that are young or who have cognitive disabilities and are often highly mobile and reside in many different locations. This problem is exacerbated when multiple children are involved. The video capture for the Abaris home study was successful, because therapy only occurred with one child in a fixed location. With Abaris in the school setting, video capture became more difficult because many teachers were working simultaneously with multiple children across a large classroom space, and thus, the video recording feature was not used often. With the Baby Steps and KidCam project, the informal nature of childcare and the desire to capture quality video made it even more difficult to capture rich media of children, and parents often lamented that they still missed important moments in their child's lives that they would have wanted to capture. We think that this remains an open issue in designing effective sensing and capture systems.

5.1.3 The social impacts on caregiving

One of the goals of these research projects was the focus on teams of caregivers collaborating. The impact of technology can have some interesting effects on the social impacts related to teams of caregivers, such as impacting the balance of power between different care team members or reducing the concept of plausible deniability. For the Abaris home study, there were various social dynamics that changed within the team of caregivers, such as the how the control of the individual artifacts during meetings and how video was used as a substitute for someone not being able to make meetings. In the Abaris school study, having the technology encouraged more informal collaboration and also helped less experienced therapists realize the importance of graphing data regularly. Finally, the Baby Steps and KidCam studies showed that the technology can have an impact on parents' satisfaction with their pediatrician, and the pediatricians were also more satisfied with parents using the full version. Thus, there is evidence to show that technology has an impact on the social dynamics between groups of caregivers.

5.1.4 *It is very important to not expect caregivers to be retrained*

Despite having the child's best interest at heart, many times caregivers go by their own instincts and have to do things quickly. In the case of trained therapists, the way they learned to do therapy was very much ingrained in their habits. Parents are often taught concepts of parenting from their friends and family at an early age, and thus may be fairly set in their ways. Any technology designed to support these types of caregivers should take into account the fact that it may be difficult to retrain caregivers to change their habits. Because therapy is fast-paced and becomes a very intuitive process, anything that would require therapists to change their habits would be very difficult to use. Additionally, since parents are already busy and likely to forget things, having something that requires a large amount of time and attention would also have a lower likelihood of success.

5.2 Guidelines for effective embedded capture and access systems

Based on our experiences, we have determined a number of things that seemed to have contributed to the success of our embedded capture and access systems. Thus, we provide a list of guidelines to help designers to understand what they can do to ensure the design of an effective embedded capture and access system for both other caregiving domains and other application areas.

5.2.1 *Capture as much automatic data as possible, within reason*

It is often difficult for users to know what might or might not be useful until they see it being viewed in a way that is easy to process and understand. Thus, we recommend designing systems to capture as much data and as many different types as possible, as long as it would not interfere with the users' primary duties or create extra work. This includes rich media, such as video and audio, timing data for everything, and data from sensors or other automatic sources.

5.2.2 *Manual data capture by users should be kept to a minimum*

Data that require explicit attention and input by a user should only be required when it is absolutely necessary for carrying out the primary tasks. In our experience, manual input was very difficult to obtain and thus, as much as possible should be automated. If manual input is required, it should be integrated into the primary task of the individual or motivated by making it enjoyable.

5.2.3 *Provide multiple levels of detail for data access to reduce information overload*

Although we recommend capturing as much data as possible, with that approach, it is possible to overwhelm users with too much data. Thus, we recommend working with users to explore different ways of providing access to data, such as only showing the necessary data and providing raw data as a backup as needed. It may be necessary to allow for some customization or tweaking to determine how much is too much. Providing different levels of views can help with information overload, such as a high-level abstract display that does not require explicit access, which can then be interacted with to view additional data. Both Baby Steps and Abaris used three different levels of views.

5.2.4 *Build in effective privacy mechanisms that still preserve the integrity of the data*

In the caregiving domain, data capture, including capture of rich media, is fairly typical and many users may be comfortable with a number of different types of data capture. However, there are still reservations some users in other domains may have or circumstances that would call for the easy removal of data. We recommend adding in privacy preserving aspects, such as easy deletion of recorded data that does not destroy the entire data archive. For example, allowing the deletion of just the necessary portion of the video rather than the entire day's video stream would be ideal. Another consideration is to make sure that "holes" in the data as a result of deletion are handled gracefully and do not affect the outcome of any review or decision-making process (e.g., a missing data point counts against a child's learning progress, leads to an inconclusive health result, or otherwise results in an unusable data set).

5.3 Future research in embedded capture and access

The two domains we studied for use of embedded capture and access systems have helped to define the parameters of what these types of systems entail. We believe there is much promise in shifting the focus of making both capture and access truly ubiquitous; however, there are still areas where this concept can be refined and explored further. In this section, we describe several open research questions based on the findings from the case studies described in Sect. 4.

5.3.1 What does it mean to be "embedded"?

One of the main aspects of the technology we developed as part of this work was the ability for capture and access applications to be seamlessly embedded into the existing work practices of caregivers. There are many ways that technology could be embedded into an environment. The main definition of embedded we use is to take advantage of existing motivations and work technology ubiquitously into the environment, making it as unobtrusive as possible. To make the capture portion of technology embedded, this may include using unobtrusive sensors, digital pens, or automated video recording. For embedded access, technology designs can incorporate the use of ambient or peripheral displays, proactive notifications such as daily e-mail summaries of results, or displays shown while the caregiver is doing another task. One of the most useful times to embedded access is during the points where a caregiver is making a decision, which is the most likely time that the data may have a more likely impact. For example, with Abaris, we peripherally showed graphs of student progress at the point where the teacher was choosing skills to work on that day. Thus, the data shown at that moment could help influence their decision on what to work on. In addition, access should be embedded at times when the caregiver has time to look over the data, rather than at times when they are rushed. However, there are other opportunities to promote access of data that may yet be unexplored. There may also be differences between caregivers of different types or even individual differences in what they consider to be "embedded," since what may be an existing motivation for one person may be a chore for another. Thus, we believe that more work must be done to help understand this aspect of embedded capture and access.

5.3.2 Extending embedded capture and access beyond the caregiving domain

The use of caregivers as the subjects of these projects had some implications for how users can be supported with embedded capture and access. For example, the nature of caregiving, especially that of young children, is effectively a more nurturing environment than other decision-making domains. For example, in the care of young children, caregivers are often working toward a common goal of wanting what is best for the child. Oftentimes, caregivers may be willing to sacrifice their own personal privacy or comfort for the benefit of the child. In the case of Abaris for the home, while therapists were at first uncomfortable with others watching videos of their therapy sessions, they often would sacrifice that comfort as long as they felt it was benefiting the child. In other domains, this may not be the case. Workers in nursing homes or mental hospitals are often underpaid and overworked and thus may be less likely to make such sacrifices. Outside of the caregiving domain, there may be even more problems with supporting decision-making in that many stakeholders may have differing goals and opinions, and the environment may not be at all collegial. Some ideas for how technology might support non-collegial decision-making could be to develop technology where everyone can choose from a set of goals and try to come to a consensus on mutual goals or a compromise. Also, making decisions over a neutral, asynchronous medium rather than face-to-face may eliminate some of the difficulties with face-to-face discussions where people can say things out of emotion rather than thinking them through first. Because we did not have to encounter these issues in our work, there are some limitations of this work in that it focused on only caregiving domains. Whether the findings can generalize to other domains remains an open area of research.

5.3.3 When to require full attention versus ubiquitous access

One of the biggest design decisions we had to make in these two system designs is how much attention we could require of users. Because the whole purpose of embedded capture and access is to ensure that access is as ubiquitous as possible, we were very hesitant to require much of the users' attention or explicit interactions. One of the aspects of access is making data more visible, which may inherently disrupt existing practices, but may be instrumental to improving care. There is still more research that can be done into determining which aspects of embedded capture and access technology should be more explicit and which of those should remain at the periphery of the user. Future studies will look at varying the amount of effort expended by users to review data. In particular, we believe it would be good to explore access that is even more ubiquitous and on the users' periphery, such as by using more ambient technologies, and comparing it to access that is entirely in the users' explicit attention.

6 Conclusion

In this article, we introduced the notion of embedded capture and access and described how it differs from traditional capture and access systems by making both the data capture and the information access aspects of systems ubiquitously integrated into the work practices of the domains for which they are designed. In particular, we showed how the notion of embedded capture and access could be successfully applied in case studies of two domains relating to autism: discrete trial training therapy and developmental milestone tracking for the purposes of early detection of developmental delays. The use of a full user-centered design process in both domains demonstrated that both capture and access could be successfully embedded into existing work practices and motivations. Though this article focused on caregiving domains, the notion of embedded capture and access can be extended to a number of other domains where traditional capture and access has been previously applied, as well as for new domains which have not yet been studied. We believe that using an embedded capture and access approach can lead to successful designs that enable data to be recorded and reviewed more frequently, efficiently, and effectively.

Acknowledgments This work would not have been possible without the gracious support and assistance of many individuals. We thank in particular Gregory Abowd, Gillian Hayes, Rosa Arriaga, Mark Harniss, Susan Sandall, Khai Truong, Shwetak Patel, Sebastian Boring, Roman Savryn, Stefan Puchner, Yi Han, Arwa Tyebkhan, and the other members of the Ubiquitous Computing Group at Georgia Tech and the Experimental Education Unit at the University of Washington. This work was supported by research grants from Cure Autism Now and the National Science Foundation.

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