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# HCI and Innovation

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**Abstract**

The user-centered design (UCD) process in HCI has recently been criticized for not delivering breakthrough innovations in technology. In this paper we consider this critique through a literature review and two case studies of innovation. Our conclusions suggest that there is nothing wrong with the *attitude* of user-centered design which has probably been present in all major innovations down the centuries. Rather, the *practice* of UCD in HCI lacks attention to business factors and long term uptake of technology in society. This compromises its impact on products and should be incorporated into the study of HCI itself.

**Keywords**

HCI, STS, innovation, digital photography, audiophotography, family album, business factors.

**ACM Classification Keywords**

K.2 History of computing - Systems. People. K.1 The computer industry - Markets. Standards. K.4.0 Computers and society - General.

**General Terms**

Design.

**Introduction**

Something is wrong in HCI. No question about it. But what is wrong and how can it be fixed? These are the questions we will try to answer in this paper. To do so will require taking a longer and wider view of

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technology innovation than is usual in the field, and a more critical view of HCI's contribution - as Don Norman has done in two recent articles.

In the first article entitled *Technology first, needs last*, Norman argues that 'Design research is great when it comes to improving existing product categories but essentially useless when it comes to breakthroughs' [25], p38. His main point is that most of the major innovations of the last century were driven by technical inventions rather than social science or marketing research. He observes that 'user needs' often follow rather than lead inventions, as people learn uses and values for new things. Finally, he challenges the field to produce examples of 'research-first' innovations where HCI made a difference to the specification and success of a new technology.

In his second article entitled *The research-practice gap*, Norman suggests that one reason research has so little impact on innovation practice is due to their different aims and cultures [26]. Research by definition adopts a scientific approach to understanding technology use, while practice adopts a pragmatic and business oriented approach to developing products. Different people, disciplines and motivations are involved in each camp, and the application of scientific insight to design and business is poor. This leads him to recommend 'translational developers' who can mediate between scientists and practitioners and apply research findings to innovation.

These articles have caused quite a stir in the HCI community, not least because they critique a 'user-centred design' approach originally proposed by Norman himself [27]. The involvement of users

throughout the design and innovation process is really the hallmark of modern HCI practice, so to be told this doesn't work is controversial in the extreme. The backlash can be seen in a number of on-line blogs and discussion forums including one started by Bruce Nussbaum of Business Week [28].

Nussbaum argues that Norman is criticising an outdated mode of innovation in which users were not as closely involved as they are today. He distinguishes between invention and its 'socialisation' through innovation, and points out that some of the best inventors, such as Edison, have also been innovators concerned with the design and business aspects of technology. A mixture of subsequent responses endorse elements of both Norman's and Nussbaum's views, and generally point to the importance of design *and* technology contributions to innovation, and the influence of business factors. They also expose some confusion over the term 'design research'. Norman defines this as 'the research community within design' in his second article above [26] p9. This encompasses a combination of what several respondents variously call 'design thinking' and 'user research'.

Notwithstanding these definitional issues, the general consensus on most blogs is that Norman is right in calling attention to the difficulty of applying behavioural insights to design and to the host of 'other factors' involved in the evolution of successful products. They also fail to provide any convincing examples of research-first innovation. Our own view is that Norman has identified an important weakness in HCI regarding its role in innovation. At the heart of this weakness is an implicit belief in technological determinism, which assumes that individual technologies can be designed

to satisfy human needs and shape human behaviour - independently of the way in which they are packaged, marketed and assimilated into a technical and social context full of competing technologies. Because of this view, HCI activity lacks a historical perspective, and stops too soon in the innovation process, which continues for many years beyond early lab and field prototypes or design exhibits.

In the rest of this paper, we justify and develop this argument with respect to a literature review and two historical case studies of innovation in the domestic photography field. The first case study is an examination of the factors affecting the development of the photograph album [30]. The second is essentially an auto-ethnography by the first author of a research-first innovation in audiophotography [10]. We show that technical, business and practice factors have to 'line up' to turn an invention into a truly successful innovation. Modern HCI work has a key role to play in this, but always through a *series* of studies involving other disciplines over long periods of time.

### Related work

Norman's critique of HCI above did not come out of thin air. On the contrary it continues a line of self-critical articles within the HCI community itself and also connects with established work in Science and Technology Studies (STS). Here we briefly consider each of these literatures in turn for what they can add to the critique, before going on to examine the nature of innovation and the role of HCI in it.

The recent HCI literature contains numerous articles debating the definition and role of design in HCI and its relation to user research. These reflect the confusion

over the term 'design research' in the blogs mentioned above. A helpful distinction is drawn by Fallman [8] between 'design-oriented research' (DOR) and 'research-oriented design' (ROD). DOR is said to be

that done with the aim of generating knowledge about human interaction with computing, whereas ROD is said to be done with the aim of inventing new interactive things. The former can involve the design and testing of interactive prototypes but only as research probes to understand interactive behaviour better. Prototyping in the latter case is done as a more serious form of design proposition for an eventual new product. Zimmerman et al [35] endorse and extend this view, referring to prototypes in DOR as 'research artefacts' and those in ROD as 'design practice artefacts'. They highlight the creation of alternative design practice artefacts as a type of research in its own right, based on Christopher Frayling's notion of *research through design* [9]. This approach is discussed at length in a new book by Koskinen and colleagues who use the term 'constructive design research' to mark it off from the broader design research agenda [22]. Related critiques of HCI can be framed in either the DOR or ROD camps.

For example, several discussions of the use of ethnographic research in design stress its value for DOR and understanding human-technology interaction for its own sake. This is best articulated by Dourish [7] whose own literature review leads him to argue against a simple extrapolation of 'implications for design' from ethnographic work. Ethnographic analysis itself points to a complex creative relationship between technology design and everyday practice which cannot easily be reduced to recommendations for new designs. Its greatest contribution may be to provide a better

conceptual or theoretical understanding of how technology is used in a particular domain. This situation is further complicated when considering different *types* of ethnographies and analyses, each of which may deliver different kinds of insight for design [6].

A complementary argument is made by Whittaker et al [32] who criticize an overemphasis in HCI on radical invention at the expense of a cumulative understanding of interactive behaviours. They recommend a concerted focus on agreed 'reference tasks' in computer mediated behaviour so as to build up the science base in HCI. This is taken up in a more recent publication on the future of HCI, which advocates adding an 'understanding' phase to the conventional user-centred design process [18].

For those motivated by more applied ROD goals, the key issues for HCI are more pragmatic. What kinds of research best encourage empathic and creative forms of 'ethnographic imagination', about current and future lifestyles [12]? How can long term relationships between users, researchers and designers be set up to improve design [23]? At what level of granularity should usability evaluations be done so as not to stifle promising design ideas and forestall creative adoption within a culture [16]? This last point led Greenberg and Buxton to consider the poor usability of successful innovations such as the radio and early automobiles, which was forgiven by the market because of their great usefulness and long term potential.

The idea that the commercial success of a prototype can be predicted from small scale lab or field studies is further undermined by a large body of literature in the Science and Technology Studies area (STS) studying

the history of innovations (see MacKenzie & Wajcman [24] for an introduction). A consistent finding of many of these studies is that technology is *socially constructed* in various ways: not only through cultural influences on originating researchers and designers, but also through the selection and 'configuration' of potential users and their creative attempts to find a use for new technologies in their everyday lives [3][34]. Artefacts have *interpretive flexibility* and can be viewed in different ways by different groups of people [29]. Computational artefacts may also have functional flexibility, making them open to creative manipulation and re-configuration through various form of 'hacking' [17].

In addition to how they are interpreted, used and domesticated by end users, artefacts are also shaped by economic and market factors. The more successful a product is commercially, the more dependent people become in following its evolutionary path, irrespective of whether it is technically superior [2]. Hence some designs become dominant over others until a new disruptive technology comes along [1]. All these social and economic factors affect the eventual uptake and success of product concepts or prototypes that make it into product, however user-centred their design. The problem with HCI is that very few of them are studied within a classic user-centred design process, as the following case studies show.

### Innovation case studies

Building on the HCI critiques above and the STS approach in general we now examine the history of innovation within the domestic photography area, and the recent role of HCI.

The various activities involved in 'doing photography' in a domestic context satisfy all of the criteria proposed by Whittaker et al for reference tasks in HCI. They are performed **frequently**, sometimes with **critical** real-time consequences, they are **real** and embedded into everyday routines, and most have **not become obsolete** over a hundred years of technical innovation. However, a focus on the tasks themselves does not quite capture the breadth of analysis and theory we believe should be developed in HCI. So we propose instead that domestic photography be considered as a '*reference domain*' for HCI, comprising the entire activity system and infrastructure involved. In effect, domestic photography can be seen as a sociotechnical system in transition, and a fitting context in which to examine innovation and the role of HCI.

The history of innovation within domestic photography is a complex one which we have tried to tell in full elsewhere [30]. Here we draw on that history in a first case study which highlights the development of the family album. This illustrates the interplay of several factors mentioned in the STS literature, but especially the importance of business positioning of technology for its interpretation and uptake. Because this history takes place between about 1850 and 1950, it pre-dates the development of HCI as a field. To shed light on the role of HCI in digital photography innovation we draw on our own personal work in promoting audiophotography products and practices [10]. Although the core HCI studies have already been published and the intellectual property has been patented, the chronological story is told here for the first time and refers to other studies and activities which were critical to its commercialization, such as it is.

#### *The birth of the family album*

The origin of the family album lies in mechanical production of the printed photograph. The technology for projecting an image through a lens, the *camera obscura*, had been widely known for centuries before the invention of what is generally called photography. The *camerae obscurae* of the 19th century were small boxes with a hole in the front (or a lens) and a mirror in the back that would display the image to the viewer. What was lacking was a process that could record the projected image. Louis Jacques Mandé Daguerre is credited with inventing a reliable process for fixing a positive image on a copper sheet in 1839, but this built on previous work by Joseph Nicéphore Niepce and others using different materials. The resulting metal plates were called *daguerreotypes*. In the same year, William Henry Fox Talbot published details of an alternative process for fixing negative images on paper. These were called *calotypes*. To produce a positive image, the calotype negative had to be printed on another light-sensitised paper by exposing light through the negative. Importantly, unlike with the daguerreotype, one could produce numerous positive images from the same calotype negative – several copies could be made of a single photograph. This property eventually led to the domination of wet collodion glass plate negatives and albumen prints in the late 1850s.

High quality printing enabled mass production of photographs, and this led to the sale of landscape and urban photographs as well as human portraits. Around the 1860s the industry arrived at a common size and format for a photograph. This took the form of a 63 mm x 100 mm (2.5'' x 4'') albumen print pasted on a slightly larger piece of cardboard. Although this format

was used for selling a variety of images, the most popular was the studio portrait. At about the size of a business card, personal photographs were used as such, and took on the name of *carte-de-visite* (visiting card). *Carte* portrait photography became a new, big business in photography. This not only paved the way for snapshot photography and family albums but also anticipated some aspects of today's online social networking as we shall see.

The lucrative business of selling landscape photographs, and other photographs of public appeal had motivated the industry to streamline the production processes of prints. An efficient photography business could produce over 2,500 prints a day. An innovation by Andre Disderi in 1854 further reduced the production costs of a single image. Disderi's idea was that a camera could have several lenses so that it could capture several images at the same glass plate. A single plate could have several images (most often eight), and the time and effort required to print a single plate now produced several images rather than one. Also, with little extra effort, the eight images on the same plate could all have different exposures, which meant that a customer could have eight different portraits in one sitting (Figure 1). These tended to be sold together, bringing down the cost of a dozen cartes in the US to about \$2–3 compared to the average cost of a single daguerreotype at \$2.

The *carte-de-visite* thus became the portrait photography format for the masses. In its popular years between the 1860s and 1880s, hundreds of millions were sold in a form of 'cartomania' [33]. To help customers distribute and archive cartes effectively, photography companies sold books to keep them in.

The albumen *cartes* were kept in 'albums' for protection, and as a convenient way of showing and storing the images. Despite its name, the *carte-de-visite* was marketed not as a visiting card but as 'the album portrait'. Not only did the sales of albums create a parallel business (a British firm claimed to have sold almost a million albums by 1867), but the empty pages of albums encouraged the purchase of more cartes. The standard size of cartes was also important for the album business: it provided a standard format for images (portraits, landscapes, etc.), and albums could be made to support that specific format by cutting sleeves for inserting the cartes (Figure 2). Albums varied in their size, the number of images they could hold, and the decorations and illustrations printed on the pages. According to Wichard and Wichard [33], the albums intentionally resembled bibles and prayer books, and this gave the albums a feeling of respect, luxury, and prestige.



Figure 1. A *cartes-de-visite* sheet

Hence the family album was born and became a popular feature of the late-19th-century home. In Victorian Britain, no drawing room was considered complete without an album. The album contained

photographs of members of the family but also of friends, celebrities, royalty, statesmen, and well-known landscapes and scenes. The photographs of public figures and institutions at the front of the album told its viewers of the larger community and world the family subscribed to, effectively linking the family members and their relatives with eminent individuals of politics, power, and pedigree, as well as celebrated symbols of nature and 'high culture' [4]. In bookstores and magazine shops, portraits of aristocracy, celebrities, and other public figures were sold side by side, to be collected in albums at home or exchanged with friends. Some celebrities used the *carte* business to their own advantage: the mass production and sale of photographs was an entirely new channel of promotion and publicity.



Figure 2. A *carte-de-visite* album from the 1880s

Albums contained the images not only of public figures, and members of the family, but of friends and relatives as well. Effectively, the family album became a catalogue of who belongs to the family, who their acquaintances are, and the wider public context that the family wanted to associate itself with. Such albums took on a new significance as families were separated by increased mobility and industrialisation. The photo

album became the nostalgic compensation for the loss of close family and a romantic rural lifestyle [19].

We find this story amazing, because it pre-dates the development of personal snapshot photography (*i.e.*, people taking photographs themselves) at the end of the 19<sup>th</sup> century when George Eastman's company introduced the first consumer camera in 1888. The ensuing Kodak era of photography resulted in the disappearance of public images from the family album and a focus on the nostalgic recording of family life and social relationships. This was promoted through direct advertising campaigns targeted especially to women encouraging first the capture of outdoor leisure activities and vacations, and later the capture of domestic and familial scenes indoors. Consumers had to wait another 100 years for digital and internet photography to revive the practice of sharing images outside the family and representing social networks in visual form. Hence the online sharing of photographs via e-mail or Web services can be seen to serve the same function as distributing cartes-de-visite physically, while the profile pictures in online social networking services have the same function as carte-de-visite albums in demonstrating membership of a network or community.

The lessons of this history for understanding innovation will be considered explicitly in the discussion. For now it is enough to note that technical invention, smart design and user benefit were not enough in themselves to ensure mass market success. The technology had to be manufactured and sold at an affordable cost to make a profit, marketed to the right group of people, and integrated by customers with existing technologies and practices. In the next case study these factors emerge

again, but largely outside the frame of user-centred design as practiced within HCI.

*The success and failure of audiophotography*  
Audiophotography refers to a future technology, business and practice *vision*. It imagines a time when we all routinely record sound clips on our cameras and cameraphones for their sentimental value, alongside photographs, and creatively combine sound of various kinds with still image sequences, including music, voiceover and conversation. At the heart of this vision is the belief that audiophotographs themselves are a new media type lying somewhere between photos and video, with their own aesthetic, psychological and interactive properties. The observation that the current digital photography industry does not fully support this practice, underpins the belief that there is a business to be made in doing so.

A large number of people at HP Labs and elsewhere contributed to the development of this vision in various studies, design or technical explorations, and demonstrations. The story that follows has been written by the first author of this paper (David Frohlich) on behalf of this virtual team of people. Although the first person voice 'I' or 'we' will be used throughout what follows, readers should understand that this is an account by David, attempting to acknowledge the contributions of others but from a personal point of view. Because this kind of account is new in HCI, it makes anonymity difficult and raises questions about the authenticity of the account from others' point of view. The solution is for readers to treat what follows as a piece of auto-ethnography, written as an insider's view of an innovation process with all the personal bias that that entails [5].

The origin of the audiophotography vision couldn't have been more user-centred. It can be dated to an internal workshop on 'Home imaging' hosted at HP Labs in the summer of 1995. HP were just about to enter the digital photography market that year with the launch of a digital camera, photo scanner and photo printer under the *Photosmart* brand. This was referred to internally as Big Bang 1. The aim of the workshop was to consider what should come next if there were a Big Bang 2. Senior product marketing managers from all the associated divisions flew over for the meeting with key group managers, and met with labs staff to discuss it. An outcome of the meeting was an action on the user research staff at HP Labs Bristol to go away and investigate user interests and needs for new uses of images enabled by digitization. Support of audio and audiophotography was one of the main answers we came back with.

Three initial user studies were carried out towards the end of 1995 in pursuit of this aim. EG did a simple interview survey with analog camera users to explore the problems and delights of taking photographs. JB replicated the study for analog camcorder users. The findings of both studies were used to design a series of four focus groups on 'New uses of images' that JB and David then conducted, with younger and older men and women. The findings conspired to raise an interesting business opportunity for HP. The camera study showed that users were broadly happy with their snapshots despite the time it took to wait for their development and the poor technical quality of many of them. The camcorder study on the other hand revealed a great disenchantment with home video and a consequent neglect or resale of camcorder technology. The focus groups showed that consumers were more interested in



communication than manipulation of images, that they still preferred paper to screen based consumption, and that sound was the most popular medium they were interested in combining with images.

Putting these findings together in 1996 resulted in the idea of an 'audiocamera' supporting sound as well as image capture, and an audiophotograph that could be played from its paper 'audioprint'. This might support the enhanced communication of images with associated sound effects or storytelling. It would also differentiate HP cameras from others in market while leveraging its leadership of home printing in the direction of augmented paper. How that was to be done remained unknown at the time, but was a big enough business idea to justify continued effort on the technology for several years to come.

The next step was more exciting and took place around 1996/7. Mock ups were made of the audiocamera and audioprint concepts, and plans were made to run an audiophotography trial. After much deliberation, an analog audiocamera was created out of a Minolta compact film camera and a high end Lanier Dictaphone with external mic (see Figure 3). Although both media streams were not technically associated with each other, this provided maximum flexibility of use which exceeded all the competing digital prototyping options considered at the time. It also allowed us to move faster to a trial.

The audioprint mock up was equally rough (see Figure 4). Following informal conversations with engineers AH and GA, we made up a double-sided photographic print with the photo on one side and an optical encoding of the sound on the other. A hand-held scanner with

appropriate decoding software and integral speaker was then envisaged by PN and SP using a grey box. This had a slot cut into it to allow the photograph to pass through and a speaker in the top trailing an audiocable we plugged into a minidisc player. Its operation was demonstrated by pushing the photo into the box and pressing 'Play' on the minidisc to start playback of an associated soundtrack.



Figure 3. Audiocamera mock-up

Both mock-ups were used in a small scale audiophoto trial over the summer of 1996. ET was hired to work with David on the trial. Four families with 2 or 3 children living at home were recruited to take part (17 people). Each family was visited at home and interviewed about their interests in photographs and sound, before being given an audiocamera mock up to use at home and on their summer holidays. We later returned to review their audiophoto material before taking it away for digitization. Pairs of families were invited into the labs to review audiophotographs in a variety of paper and screen-based forms. These included a demo of the audioscanner above using families' own content from the trial, together with an audio-enabled photo frame, audio greeting card, PC and TV albums.



Figure 4. Audioscanner mock-up

The biggest impact of the study lay beyond the interview findings and preferences of families for different playback media. It resided in the audiophotographs themselves which contained a variety of different sound and image combinations, subjects and effects – together with the emotional reactions of authors and audiences we showed them to. Ambient sound added interest, texture, humour and depth to many photographs. New genres emerged for street music, noisy wildlife and landscapes, ambient conversation, audiophoto jokes and sequences. The effects were very different to video or photo alone, leading to the view that this was a new medium. In addition, the paper and screen playback options we showed were *all* seen as valuable for different playback contexts or people. Mothers in particular loved the audioprint demo for intimate photo sharings sessions in and out of the house. Fathers liked the idea of sharing audiophotos on the TV with larger groups, while children like the PC album. This was good news for the business case. It meant there was space in the market for a family of players and playback options, and the need for a technical infrastructure to allow consumers to move audiophoto material between them.

David and ET flew to Greeley and San Diego camera and imaging divisions to present the findings. The reaction was so positive we were asked to show the audiophotos to VJ who was head of the imaging group at the time. VJ liked it, and encouraged us to work with his team to commercialise it. This increased our motivation and delayed publication of our findings at CHI by two years [13]. With such high level backing, we switched our efforts away from exploring the user value to thinking through how it would actually be realised in product. It quickly became apparent this was not a point product idea, but a system innovation affecting HPs product family and beyond. If audiophotos were to take off, they needed to be supported downstream of the audiocamera in photo viewing and browsing software, photo websites, photo printers and ultimately photo format *standards*.

As much of this was beyond our immediate control, we initiated two parallel investigations on capture and playback. On the capture side, David and MH co-designed a demonstration interface for an audiocamera which showed how sound and image media could be combined with each other through a small screen interface. This eventually led to a patent application and a later labs prototype camera called 'Blink' (see Figure 5 in [11]).

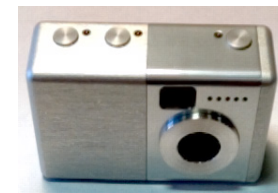


Figure 5. The 'Blink' audiocamera prototype

On the playback side, we knew that screen-based playback of audiophotos was trivial and merely required a change to HP's image browsing software. So we concentrated on finding a viable technical solution to the audioprint problem. Space and confidentiality prevents us from explaining the technical reasoning that led to the next prototype. Suffice it to say that the original idea of printing sound data on the back of a photo turned out not to be an optimal solution. Further experiments suggested that it would be better to write the data to an embedded chip in the paper. Two types of players were then made in different form factors and designed to work with chips embedded in laminated audioprints. The chips were mounted on substrate tabs sticking out from the edge of the paper which had to be inserted into a mouth on the player for recording and playback (see Figure 6). Recording was also envisaged on HP printers. Several patent applications were filed on this concept, and it was later published in the context of a fifth user study [14].



Figure 6. Two audioprint players

Around 1999 we had our first transfer to product. This happened almost accidentally through a parallel piece of work GA was doing for Singapore division on the design of a pocket PC camera attachment to HP's Jornada Personal Digital Assistant device (see Figure

9). It so happened that a custom photo browsing application was being written for the camera, and GA managed to persuade his colleagues in Singapore to add audio to it. This turned out to be implemented in quite a different way than we had been exploring for digital cameras and with quite different user values. The result was a simple audio annotation capability for digital photos, allowing mobile professional users to attach and playback a voice comment easily.

Other transfer successes followed in the form of sound capture on HP digital cameras and associated software. The divisional uptake strategy was to incorporate sound across the camera line rather than to launch a specialist audiocamera as we suggested. The first camera to support audiophotography was the high end Photosmart 650 in 2001. Feedback from this camera was used to simplify the process of audiophoto capture for rollout across all HP digital cameras from 2002. A new use model for audiophoto capture was patented in collaboration with the camera division. Users simply clicked the shutter button to take a picture and held it down if they wanted to add audio to it. On release of the button the sound file was stored inside the jpeg file format, which the jpeg 2000 standards allowed. The problem was, not all image viewers supported sound playback, so users could only exchange audiophotos reliably with other HP product owners using *Image Zone* – HP's imaging software.

This turned out to be a show stopping problem for the widespread practice of audiophotography. We knew from other work, that the main benefit of digital cameras over film cameras was immediate review and sharing of images, both on the camera LCD but also via email and web posting. The fact that receivers of jpeg

files with embedded sound couldn't easily play them back, compromised their value for senders. Ironically, HP's own website didn't support sound playback from audiophoto material captured on its own cameras. This was despite consistent lobbying by David since 1998, and a suggestion for 'audio-newsgroups' on photographs to support on-line discussion of audiophotos. This feature was later implemented in text by Flickr.

Despite the internal success of the audioprint player demonstration of Figure 6, the contact-based chip was considered not ready for market. Intrigued by the long term potential of a wireless embedded chip for this and other applications, HP Labs set up a team to develop one led by EM and JW. The resulting chip is called *HP Memory Spot* and was announced to the press in 2006 [20]. This invention has not yet been applied to the original audiophoto area. In the interim, David, GA and colleagues continued to explore the broader values of sound with photographs and search for other ways of playing back sound from paper. These included a new user study on audio annotation of photos, and the development of patents and demonstrations using audiopaperclips and an audiophoto desk [10] [15].

## Discussion

### *Case study lessons on innovation*

The case of the family album teaches us a number of lessons about the nature of innovation, while the audiophotography story indicates problems with the current role of HCI in innovation. Let us take each of these lessons in turn.

The fact that daguerreotypes took off so quickly in the market following their invention in 1839 was due to the fact that they extended an existing market in portrait painting. Photography essentially lowered the cost and increased the accuracy of reproduction at the same time. Existing 'users' didn't have to learn a new behaviour to benefit from photographs and new users were able to adopt a well known practice more usually reserved for the upper classes. The technology in this case initially acted as an *accelerator* for an existing business and practice, before leading to new businesses and practices later on.

The collection of cartes de visit in photograph albums was intimately related to the quality, format and cost of a carte. Image quality mattered in this market, as shown by the early success of the copper plate daguerreotype over the first printed photographs. However cost mattered too, as shown by the movement to albumen prints in the early 1850s, and then to the cheaper multiple prints enabled by Disderi's camera. Finally the standardisation of the size of a print at 2.5" by 4", and an accessible process of producing them, was the enabling technology which led to cartes de visit, cartomania and ultimately the family album itself. The association of portrait content with this format was the final key which led to the social convention of giving out personal cartes and collecting those of others. Hence the success of the technology was not due to any of these factors alone but to their alignment with each other and the social etiquette of the time. User benefit, business value, technology reliability and design effectiveness were all necessary to this success, and would have been useless on their own.

Interestingly, the family album itself emerged as a by-product of these developments. Albums were essentially an accessories business built on the success of the cartes. These solved a mundane problem of where to put all the cartes once collected by a family, but also encouraged their further collection. It is hard to say how much role they had in stimulating the social convention of collection itself, but once invented, they undoubtedly encouraged and shaped the practice in particular ways. Thus, albums can be seen as part of the initial *marketing* of cartes de visite technology, and very important to their eventual use. This was demonstrated again at the beginning of the Kodak era of photography, when family albums were deliberately marketed to women as repositories of memory.

The same process of aligning user, business, design and technology values can be seen at work in the audiophotography story. This took place through multiple studies, over a timespan of about 10-15 years from 1995. This is a remarkable amount of time in HCI terms, but entirely consistent with the history of most technologies which take many decades to embed themselves in industrial processes and everyday life. Indeed it might be argued that audiophotography may yet become a mass market practice in the future. Furthermore, the type of studies involved in the chain varied between user studies of core behaviours and values, design explorations of form factors, usage models and mock-ups, and technology experiments testing the feasibility and costs of core technology options. In addition, a kind of business research was going on throughout the story, to model the way the product would be positioned and sold. In HP, this was carried out mainly in Divisions, but labs staff had to understand and participate in this reasoning – initially

to justify continuation of internal work and eventually to justify product launch.

Key factors to success included alignment with HP business competences, compelling new media content, ownership of core technology through patenting, and personal relationships with divisional staff. Key factors in failure appeared to be the different rates of maturation of capture and (audioprint) playback solutions, a conservative marketing strategy across the camera line rather than launch of a specialist audiocamera, and incompatibility with the existing infrastructure; especially email and photo websites.

#### *What is wrong with HCI?*

Returning to Norman's critique of HCI, we can now see that the problem *doesn't* lie with a user-centred design approach to innovation at all. All innovation has to be user-centred at some level to ensure there is benefit to end users which justifies the cost of purchase. It is impossible to think of early professional photographers and photography companies *not* considering user benefit in the planning of their businesses, since all their actions were oriented to maximising benefit through invention, cost reduction and market positioning. In the audiophotography story we have a process that was consciously user-centred throughout, informed by modern practice and published in HCI conferences and journals along the way. To a large extent this was successful, but only insofar as it extended beyond the boundaries of conventional practice in considering business models and technical infrastructure through which the core inventions would have to be accessed by users.

Here then is the problem with HCI in innovation. It doesn't go far enough in addressing 'business factors' related to commercialization, nor does it study the uptake of technology in a market over time. This is a serious problem for research-oriented design (ROD) in HCI because it compromises the commercial impact of design on product. In addition to the application of behavioural insights to design, we need to be worrying about the application of behaviour, technology and design insights to business. It is also a problem for design-oriented research (DOR) in HCI. The understanding of human-technology interaction is incomplete without studying the business climate in which it takes place, and the way technology is socially shaped through it over time.

#### *How shall we fix it?*

Four kinds of research appear to be required in the innovation process as shown in Figure 7. User research is required to identify potential benefits of a technology and assess their realization in products. Technology research is required to develop technical solutions delivering those benefits at low enough costs. Constructive design research is required to integrate and present the technology in an attractive and accessible form. Business research is needed to position and market the technology to the right group of people at a cost they can afford. Innovation can spring up from insights at any corner of the diagram, but must ultimately align insights from all four corners to be successful. Individual studies might incorporate more than one activity and transfer insights between them. Chains of studies might be conducted to adjust the alignment of insights across the corners, and will never really 'finish', even at product launch. Although this results in a rather anarchic flow diagram with

arrows in all directions, it should be read as a framework for mapping out the origin of an idea and its subsequent development over time.

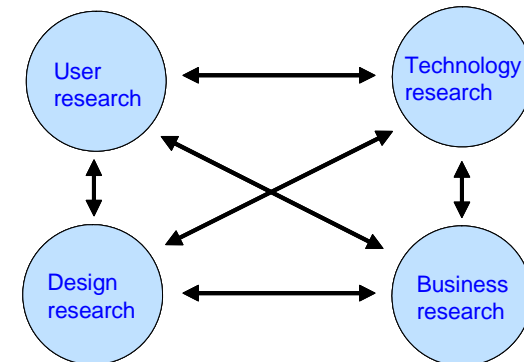


Figure 7. A model of the innovation process

Current HCI tends to deal with user, technology and design research, but does so in something of a commercial vacuum. Future HCI should address this by staying engaged with the innovation process longer, so as to consider business factors explicitly and follow-up on the fate of lab prototypes in the market. Many more historical case studies are needed in the field to uncover the kinds of factors that ought to be studied pro-actively in technical interventions and user trials. New methods should be developed to capture feedback from mass market product launches like the iPad, for scientific as well as commercial consideration and tracking. Business training and intellectual property protection should be incorporated into HCI courses so that graduating students are more aware of the commercial aspects of their field. This will connect with a rising trend in the other direction to incorporate HCI thinking into business education [31]. As a tool for

reflection, Figure 7 might be used by HCI practitioners to take stock of the coverage of research issues in each category for any innovation idea, and the type and flow of insights they personally create in any individual study. Finally, greater discourse should take place between HCI professionals, business practitioners and STS scholars.

We are well aware that HCI has already expanded its boundaries in recent years to encompass an impressive range of disciplines beyond its original starting point. However, we hope this article will be a stimulus to discussing a further expansion which appears to be critical to its application in the real world.

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