Sound sight: Seeing with ultrasound

Monika Büscher, Lancaster University, UK. Email: m.buscher@lancaster.ac.uk
Gloria Jensen, Skejby Hospital, Aarhus, Denmark. Email: gloria@stofanet.dk

Recent advances in medical imaging, information and communication technology promise to support medical visual practice as well as everyday healthcare experience. However, this potential is not easy to realise. A better understanding of existing practices can inform socio-technical innovation, and we draw on ethnographic observations and our involvement in the design of 'palpable computing' to examine the use of ultrasound imaging technologies in consultations with pregnant women with a view to ideas and implications for socio-technical innovation.

Keywords

Ethnomethodology, palpable computing, ultrasound

Introduction

Since their first use as diagnostic tools in the 1940s, ultrasound technologies have interacted deeply with diagnostic practice [1], cultural experiences, practices of pregnancy and parenthood. They have the power to engage and reassure parents-to-be, but at the same time render women transparent, developing historic socio-technical trends to play down their embodied experience in favour of visual evidence and expert diagnosis [2].

Ultrasound technologies continue to be shaped by, and shape, cultural practices. Three interconnected areas of socio-technical change are particularly interesting. First, the increasingly realistic representations of 3D/4D ultrasound are easily recruited to formulate the foetus as a person with emotions, traits and rights. While this facilitates parental bonding [3], it further eclipses embodied clues of foetal development for which the woman is the gatekeeper, and allows the foetus to emerge publicly as a social being ever earlier, complicating debates about moral choices [4, 5]. Second, innovations in telemedicine can make maternity care available to more women (e.g. in remote areas), help target referrals more effectively, improve the quality of care [6], and support tele-diagnosis and telesurgery [7]. Experience in other healthcare fields suggests that, as these technologies are appropriated, institutional structures, bio-medical models of the body, moral and practical care responsibilities and relations change [8]. Third, pervasive and palpable computing [9, 10] promise to make computing, including new imaging and telemedicine technologies, more available, easier to understand, use and control. Scenarios envisage ubiquitous technologies whose affordances are clearly available to the senses, or 'palpable', and therefore more easily appropriated. Ultrasound

transducers, computation that translates sound into images and measurements into diagnostic figures, displays, and interaction devices, might be assembled in diverse locations – the hospital, the GP's practice, the home – and combined with other technologies and services (mobile phones, TVs, databases, image recognition) [11]. Ubiquitous computing, combined with connectivity, interoperability and palpability promises to augment practices of understanding, treating, and experiencing pregnancy. However, it is difficult to translate such ideas into concrete, desirable socio-technical change. Detailed analysis can inform design and, below, we discuss ethnographic observations of ultrasound scanning with a view to socio-technical innovation around pervasive and palpable computing.

Background

The observations presented here are part of a long-term participatory technology design project (PalCom) with midwives, pregnant women and staff at the Skejby Hospital obstetrics department in Aarhus, Denmark. As a member of a team of healthcare professionals, computer scientists, interaction designers, and ethnographers, the first author has accompanied staff and patients as a participant observer, carried out interviews and participated in PalCom workshops, where collaborative analysis, data sessions and 'fieldstorms' based on the ethnographic studies are used to inform technology design. In the analysis below we combine an ethnomethodological perspective, that is a sociological interest in 'ethnomethods' or the practical achievement of socio-technical order [12] with a professional perspective of lived practice. As part of our ethnographic observations we carried out, observed and video-recorded 18 ultrasound examinations over two days.

Seeing with ultrasound

In 2005, a staff of six nurses and three doctors at the Skejby hospital ultrasound department carried out over 14,500 examinations [13]. Currently, roughly half are twelve to fourteen week scans, designed to screen for the risk of Down's Syndrome and to ascertain the well-being of mother and child. Most examinations, like the one described here, indicate that everything is normal and the risk for Down's Syndrome is low. Our example is also typical with regard to the talk and activities that constitute it and has been chosen for this reason. We invite the reader into the detail of this particular but typical consultation to examine key moments of the cultural and material production of pregnancy and parenthood.

Gloria is one of the ultrasound scanning nurses at the Skejby hospital ultrasound department. She is seeing fourteen women today. One has just left, and from the online appointment system Gloria sees that her next patient is already in the waiting room. Gloria briefly studies her paper medical record, enters the patient number into the scanning machine to index measurements during the examination, and glances at the record to note the patient's name: Hanna. To make a first assessment of Hanna's well-being and to establish a rapport, Gloria picks her and her partner Carl up from the waiting room.

Before Hanna has even entered the scanning room, a contradiction raises its head. Ultrasound examinations are a routine element of Western maternity care. They are designed, and often succeed, to reduce anxiety, yet at the same time provoke it. The twelve to fourteen week examination, for example, can reveal physiological problems, or suggest a high risk of Down's syndrome. Such diagnoses can necessitate difficult decisions, and require complex interactional work before, during and after the examination [14]. Ultrasound technologies play an important role in the management of anxiety.

One window, many views

Hanna and Carl are looking at a screen mounted on the ceiling opposite the bed (Figure 1), where they see the same as Gloria.

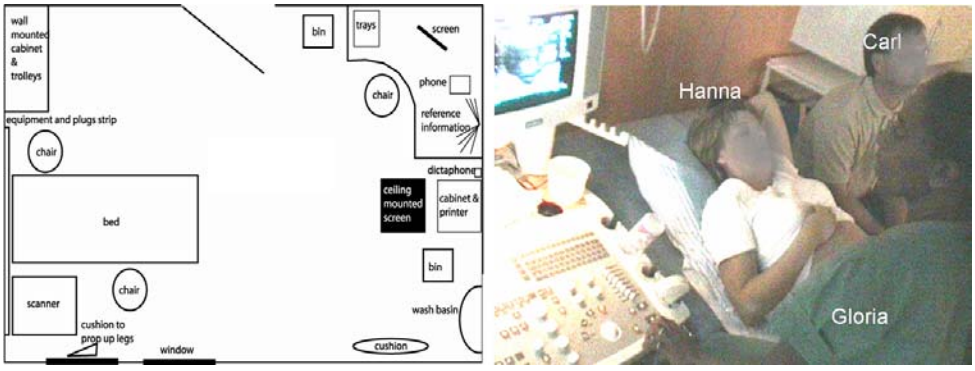
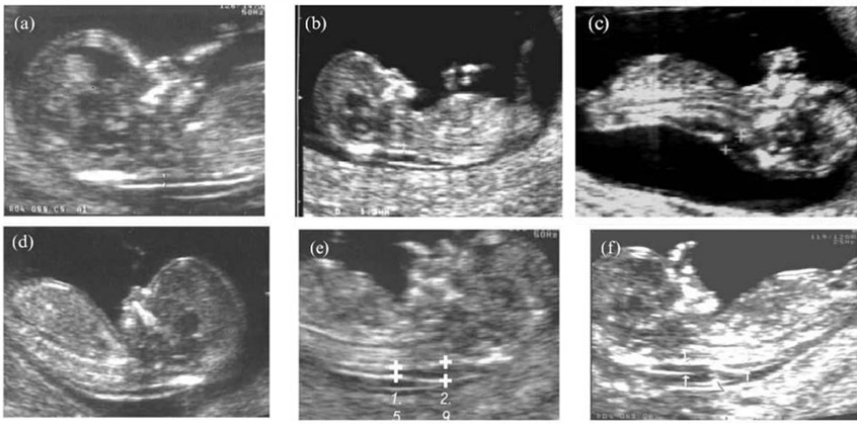


Figure 1 Layout of the Scanning room, Hanna, Carl and Gloria[1]

[1] Patient names and details have been changed, and their faces obscured to safeguard anonymity.

She explains that, if the foetus is between twelve and fourteen weeks old, it will have a typical 'neckfold', whose thickness, or nuchal translucency (Figure 2), can correlate with the occurrence of Down's Syndrome and yield reliable risk figures.



Ultrasound pictures of 12-weeks fetus. In all six images there is a good sagittal section of the fetus. Image (a) is appropriate for measurement of the nuchal translucency (NT) because only the fetal head and upper thorax are included and the nuchal membrane, which is thin, can be seen separate from the amniotic membrane. In (b) the magnification is too small for accurate measurement of NT. In (c) the fetal neck is hyperextended and in (d) the neck is too flexed. In (e) the maximum measurement of NT should be taken. In (f) the umbilical cord is round the neck. In this case the NT should be measured both above and below the cord and the average of the two measurements should be used in the calculation of risk.

Figure 2 Textbook instructions for measuring nuchal translucency [15].

Trained to look for a view like the one shown in Figure 2(a), Gloria reaches for the scanner[2]:

118	G:	okay. Then we just have a look and see
119		who is at home there
120	H:	mhm
121	G:	your birthday when is that
122	H:	twentyninth September nineteen seventy-four
123		( )
124		(0.9)
125	G:	wo:w!
126		you need to pee
127		(.)
128		(It's) actually so much here
129		( ) y(hh)ou know(h)=
130	H:	does [it matter=
131	G:	[.hhh
132		hh. hh. hnah ((laughter))

[2] Basic transcript and translation by Jesper Asp Sørensen (with Jakob Steensig, Margit Kristensen, Tony Gjerlufson). Subsequently refined with help from Gloria. The translation follows a simplified version of conversation analytical conventions (Sacks, H.; Schegloff, E. A.; and Jefferson, G. (1974) 'A simplest systematics of turn-taking in conversation', *Language* 50, pp. 696-735).

(doubtful)	hard-to-hear utterances	wo::w	extended sound
( )	inaudible utterance	*italics*	emphasis
[words]	utterance in overlap	you ((PL))	Danish makes a difference between you singular and plural.
((comment))	comment		
(0.3)	timed pause	144	Line numbers reflect gaps and the position of the excerpt in the complete transcript.
(.)	untimed short pause		
.hh/hh.	inbreath/outbreath		

133		.hh well: it might be I send you out to
134		(.)
135		to empty the bladder
136		but that I don't think is necessary
137		(it's more what) is lying up here
138		and [swimmi]ng round
139	H:	[Yea:h]
140		(1.8)

Most immediately striking in this excerpt is the power of language. As Gloria initiates the scan, and tries to 'see who's at home', 'lying up here and swimming round', she slips into personification, a typical and contradictory feature of talk in ultrasound consultations with parents. The 'personifying' talk coincides with activities that construct the foetus as the object of a clinical examination, activities which could undermine its claims to personhood. This contrast is symptomatic of the fact that 'although ultrasound is perceived to be a "window," it is a "window" through which different groups see different things' ([16], p. 7). Moreover, the ultrasound 'window' does not only enable different perceptions, but also practices of social control over 'proper' parental responses (ibid.). For the purpose of designing technologies that afford the production as well as the contestation of such perceptions and practices, it pays to examine the in-situ production of transparency and social control more closely.

The production of transparency

Gloria asks for Hanna's birthday to check that the patient number is correct, while moving the probe on Hanna's belly, eyes on the screen. Her looking demands silence (line 124) until preliminary completion is marked by her exclamation: 'wo:w! you need to pee' (line 125). Gloria's surprise does make it sound as if the ultrasound had suddenly opened a window that reveals all. However, Gloria is surprised about how full the bladder is – not the fact that it is full. Because a full bladder creates an acoustic window, patients are advised not to urinate half an hour prior to the scan. Gloria is giving Hanna an opportunity to say if she is uncomfortable.

What is interesting is that the talk masks interaction with non-human 'actants' which is actually crucial to perception with ultrasound. The term 'actant' [17], used in actor network theory to describe entities that 'act' and that are sensitive to the actions of others – human or non-human – is useful here. Actants act without consciousness or intentions, but with important consequences.The bladder, for example, lifts the uterus and contains echo-free urine that al-

lows sound to pass undhindered. Other actants are the sound waves, foetal and maternal soft tissues and bone that differentially reflect them, and the computation that translates sound into black, grey or white. The dual role of the bladder as an object made visible and an important player reveals that transparency is not a technological effect, but a process that requires interaction with matter, delicately coordinated with talk, silence and embodied action, raising the stakes for the design of telemedicine technologies that 'stretch' collaborative action. It also provides important insight for the design of palpable computing.

Most importantly, the observations show that software designers are not the only ones interested in making 'system' states and processes that are usually not accessible to people perceivable. During ultrasound examinations, medical staff and parents-to-be routinely make complex 'system' states and processes palpable. Palpability is not a property of the states and processes under scrutiny, it arises in interaction. This means that designers can not design palpability 'into' technologies, they can only design for its production. By studying how Gloria, Hanna and Carl make aspects of the foetus, including the risk of chromosomal defects, palpable, we can identify important aspects of the practices involved in making things palpable. This can inform design in two ways. Pervasive and palpable computing technologies are, first, meant to support communication and the work of making sense of information in many different contexts. Maternity care is one such context. But to fulfill this aspiration, people must be able to perceive, understand and control the possibilities these technologies provide. They should be able to improvise, combine technologies and make them work together, and they must be able to notice and address malfunctions. Palpable technologies, therefore, and secondly, are designed to support people in making sense of what the technologies are doing (and *could* do). A close examination of Gloria, Hanna and Carl's efforts can inform and inspire both, designing for palpability, and the design of palpable applications [10]. In this paper, we focus on the former.

Human – matter interaction

The halting speed of Gloria's next utterances (line 133-135) documents her effort to attune herself to the interaction with the actors and actants in this situation, which seems to yield results. In line 136, Gloria indicates that the scan can proceed with the bladder as full as it is.

She is familiar with the ultrasound, and the computation of the machine. Skilfully probing the interactive conventions between people and matter in this particular configuration (line 133-139), she assesses ‘visibility conditions’, notes first clues of the health of the foetus and looks for ‘a good view’. While her words depict the foetus as ‘swimming round’, it is actually her exploratory and diagnostic movement of the probe that makes the image swim. Yet, her words describe – accurately – what Hanna, Carl and the ethnographer see: a ‘chase’ for a mobile foetus. Note that this is true also for Hanna, who not only sees, but also feels Gloria looking and who owns the body whose tissues and fluids are used to visualise its contents. The excerpt above draws to our attention how the levels of palpability, or people’s awareness of, and control over, interactions with actants differ.

Like coded representations of computational states and processes (e.g. in task managers and debuggers), traditional ultrasound images are often not meaningful for the lay-person. Even though in a physical sense, Gloria, Hanna and Carl see the same, Gloria – the expert – sees more. The reasons for this are complex, but one of the key differences is that Gloria has learnt to interpret the translations of ultrasound echoes. This makes actants’ actions that are imperceptible or ‘noise’ for Hanna and Carl palpable and intelligible to Gloria. Training one’s sensitivity to the translations of ultrasound does not require a perfect understanding of the fine detail of acoustic physics. Gloria recounts strategies like seeking instruction through courses, books and colleagues, repeating the same procedures to produce the same view, identifying ‘landmarks’ and patterns, comparing different views and different patients, and producing a sense of the foetus’ body by imitating its position with her own body in her imagination. These strategies help sharpen her understanding of, and control over, maternal and foetal physiology through ultrasound. Software developers describe similar strategies – including attempts to ‘follow packets’ (units of data) through the circuits of networked computational devices in their imagination. Research has long suggested ways of smoothing the learning curve for non-expert software users and support the development of tailoring cultures [18]. However, there is an important difference between the translations of ultrasound and those used to account for computational processes. While ultrasound scanners translate natural and consistent actant responses based on the laws of physics, current representations of computational behaviour rely on manmade ‘reflections’ of physical processes [19].

Instruction

The probe in her right hand, the controls under her left, Gloria freezes, zooms, selects, and points (Figure 3). An interactional pattern of ostensive gesture plus description followed by a confirmation from Hanna emerges: 'here's the head – yeah' (line 144-145), 'here's the body – yes' (line 148-149), 'heartbeat – yes' (line 150-151). Gloria's utterances contain features of 'online commentary', where medical personnel formulate sensory evidence, often in order to prepare patients for 'no problem' diagnostic evaluations [20]. However, 'online commentary' does not usually elicit a response, not least because the evidence is typically only available to the medical professional – e.g. through a stethoscope. Gloria's utterances, in contrast, are made in full view of evidence that may not be intelligible for the parents-to-be. They are instructive and demand a response.

Figure 3 Patterned interaction. Framed line numbers indicate that it is Hanna speaking.

Instruction does, however, not always resolve difficulties in seeing something meaningful. Indeed, Figure 3 shows that in line 160 Gloria says 'leg', while her cursor points at black, empty space. Without words she follows the then faintly visible leg up to point out the feet. Hanna and Carl remain silent. What is seen on the screen does not look like a leg. At first, it seems as if this breach of the pattern and the lack of understanding it documents is acceptable. Glo-

ria measures the length of the foetal body, considering again that ‘maybe we’ll have to send you out to urinate’, which sparks discussion of the written instructions Hanna received. But as they talk, Gloria continues to move the probe. She finds another view and zooms in. They resume the pattern, and now Hanna confirms seeing the leg (line 219-220):

212	G:	(a little) hand	
213	H:	yes, there is	[in deed]
214	G:		[with fingers]=
215		[right]	
216	H:	[the fingers]	
217	G:	.hhyes	
218		(0.3)	
219		leg here	
220	H:	.hhyes	
221	G:	feet [here]	
222	H:	[mhm]	

Through talk, the images on the screen, and embodied actions (including pointing and gesturing with the cursor) Gloria, Hanna and Carl give healthy human form to the personhood Gloria evoked earlier. Moreover, they show how people make something as intangible as understanding – or lack of it – palpable. Hanna’s ‘yes’s’, ‘mhm’s’ or their absence allow Gloria to tailor her way of making the baby visible for Hanna and Carl.

This example highlights an age-old dilemma of computing technology design. It is impossible to build human-like sensitivity to documentary evidence like Hanna’s ‘yes’s’ and ‘mhm’s’, and the sequential organisation of its production into technologies. Yet, people are often tempted to treat ‘interactive’ computing technologies as capable of sequentially organised interaction [12]. In seeking to support the strategies people use to make things palpable, palpable computing faces the same problem. In human-human interaction, instruction is occasioned and collaboratively negotiated. There is no scope for such collaborative production of appropriate instructions in human-matter or human-technology interaction. However, by allowing people to gauge the ‘sensing’ and ‘reasoning’ that underpins the production of a particular state [21, 22, 23] it would be possible to make the ‘powerful-but-dumbness’ of computing technologies available to people’s senses.

Negotiating palpability

Gloria marks the start of the 'main business' through a switch to medical vocabulary (Figure 4), highlighting the membrane that lines the uterus (line 242, 248). She finds it difficult to see what she needs to see (line 262 -267) and asks Hanna to assist by coughing (line 268), in an attempt to make the foetus change position.

Figure 4 Measuring nuchal translucency. The black arrows mark the position of the cursor.

This excerpt highlights that Gloria is not doing 'medical seeing' while Hanna and Carl are doing 'social seeing', a first 'bonding' with their child [16] as they wait for a medical diagnosis. Hanna (through embodied action and talk) and Carl (through embodied action and silence) actively, materially and semiotically, participate in diagnostic perception. However, the translated nature of ultrasound makes it difficult to sense, let alone help control material actants without ongoing instruction. For Gloria the difficulty is that she needs Hanna and Carl's collaboration, but must keep her instructions to a minimum. The whole examination should take no more than 25 minutes, placing a limit on how much she can explain, but Gloria also acts in

the interest of good care: as she examines the foetus with her eyes and both her hands, she makes some of her seeing publicly available as she does it. This could be delicate: At any point, she may notice irregularities and want to look more closely. Such diagnostic scrutiny should not be visible to the parents, so as to avoid worrying them unnecessarily.

What happens next is a common way of managing (and perpetuating) this conflict. Gloria starts to highlight features in the foetus' profile, while continuing to move the probe to get a better view. This makes Hanna think that the coughing was successful – she says 'mh a lot has happenend' (line 282 in Figure 4), a misconception Gloria does not correct. The foetus has moved, but the new view still does not afford accurate measurements. Gloria embarks on a different endeavour without telling Hanna or Carl:

376	G:	((mumbles)) look
377		(3.5)
378		and his bladder there (0.5) two legs
379	H:	[two legs]
380	C:	[(two legs)]
381	G:	[two feet]
382	H:	[that's nice] .hhh
383	C:	[(.mmmja)]
384	G:	can you(PL) see that
385	H:	[ye:s]
386	C:	[myeah]
387	G:	((laughs quietly))
388		it's a bit bow-legged, huh?
389	H:	[aaaa]
390	C:	[mmmm] ha ha .hh
391	G:	[hmpf]
392		that's what they all say [(mumbles))]

Not only do Hanna and Carl actively (albeit often somewhat blindly) participate in 'medical seeing', but Gloria, in turn, also participates in their more 'social' seeing of the foetus. The public announcement of normal physiology: 'two legs, two feet' is acknowledged twice (line 382-383 and 385-386) and followed by a light-hearted tease: 'it's a bit bow legged, huh?' (line 388), which predictably provokes protest. This is a staged opportunity for bonding. Gloria knows that 'going down the body' is likely to show a foetus comfortably floating in the amniotic fluid. This makes for a bow-legged look, and experience tells her that most parents will protect their child from ridicule. She even intimates the staged nature of her performance: 'that's what they all say' (line 392). Such devices may be used to find out whether parents exhibit 'proper'

behaviour towards their prospective child. However, it also shows that social control is not wielded bluntly. Parents certainly are subjected to social control [16], but the example shows how far from being passive recipients, they are deeply implicated in this process.

After reducing the amount of urine in Hanna's bladder, Gloria, Hanna and Carl eventually succeed to obtain the measurements needed. Calculations based on standard formulae [24] indicate that the risk of Down's Syndrome is well below the threshold for concern.

Discussion

Having considered concretely and in some detail important aspects of how ultrasound technologies are dovetailed into the management of anxiety and the cultural and material production of pregnancy and parenthood, it is clear that advanced technologies must support collaboration to stand a chance of successful appropriation. Collaboration, as the examples in this paper show has two aspects:

- Human – human
- Human – non-human

With regard to the former, our study – in line with work within human-computer interaction research [25] – shows that success relies on the ability to stretch the resources that allow people to collaborate – for example, dynamically changing discursive and embodied orientations to issues of concern – without fragmenting them. But this is not enough. In order to be able to creatively combine and exploit the potential of advanced medical imaging, telemedicine and pervasive technologies, and to be able to notice and address malfunction, people must also be able to make computational states and processes, limitations and affordances palpable – for themselves and others. The study at hand highlights a number of opportunities and challenges:

- Translations of states and processes may be complex and hard to understand. People require support for practical strategies such as comparison, pattern recognition, repetition to train their sensitivity and understanding, and make things palpable.
- The levels of understanding, the perspectives on what should be made palpable and how differ between people and situations.

- There are currently no means of amplifying or translating actant moves based on the laws of physics in computation.
- In human-human interaction instruction is occasioned and collaboratively negotiated. There is no scope for such collaboration in human-technology interaction.
- People make things palpable (or not!) not only for themselves, but also for others.

Current socio-technical innovation, like traditional ultrasound technology, inescapably shapes and is shaped by cultural practice. Designing for collaboration and for palpability can enhance human practices of perception and reasoning. This is particularly important with regard to ultrasound examinations, where findings can occasion sometimes difficult negotiations about how personhood, pregnancy and parenthood is experienced, understood and treated [5].

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