

# Instrumental action: the timely exchange of implements during surgical operations

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**Abstract.** In this paper we analyse an apparently simple collaborative activity, that of passing an implement from one person to another. The particular case we consider is surgical operations where nurses and surgeons routinely pass instruments to one another. Through fine-grained analysis of specific instances we address, - the preparatory work engaged in prior to passing, the ways in which the layout of artefacts is organised with respect to the temporal ordering of the activity, and how this arrangement can be reconfigured in the light of problems and circumstances that arise in an operation. We examine how passing an implement is finely shaped within the course of its articulation with regard to emerging actions of the participants. We suggest that an analysis of fine details of seemingly simple activities with objects may have implications for our understanding of collaborative work, and a one or two key concepts that have informed the design of advanced solutions.

## Introduction

Despite the rich and varied ethnographic tradition within CSCW and the long-standing interest in the analysis of technologies in action, the ways in which physical objects and artefacts are arranged, grasped, manipulated, exchanged, and deployed remains surprisingly neglected. Many studies, including our own, have ascribed a certain analytic primacy to talk in collaboration and paid less attention to the ways in which seemingly simple objects and artefacts serve to underpin and enable the concerted accomplishment of complex activities. In this regard, the surgical operation is of particular interest, since despite its organisational complexity and the highly specialised knowledge and skills it demands, many of the tasks performed by surgeons rely upon relatively mundane objects and artefacts;

indeed artefacts that are not too dissimilar to tools that one might find in the kitchen or in a shed at bottom of the garden – scissors, knives, saws, pliers, tweezers and the like. The skilled and timely use of these tools, their availability, exchange and manipulation, is an integral feature of the accomplishment of this highly complex collaborative activity.

In this paper, we consider how personnel within the operating theatre, in particular the surgeon and the scrub nurse, systematically, yet unobtrusively, accomplish the timely exchange of implements; an exchange that preserves the smooth and largely unproblematic production of highly complex tasks and activities. In particular, we address the ways in which instruments are configured, displayed, held, handed and received, to enable the practical accomplishment of particular actions in specific, situatedly relevant ways. In surgery, the very passing of an instrument to another, rests upon a sensitivity to, an awareness, an understanding, and an anticipation of how and when the implement will be used at this moment on this occasion. The analysis of this subtle yet systematic and robust form of collaborative activity is used to reflect upon three areas of longstanding interest to research in CSCW – awareness, affordance and ubiquitous computing.

Despite the long-standing tradition of research on work and interaction in the delivery of health care, both in CSCW and more generally the social sciences, the operating theatre and surgery remains relatively neglected. This may come as some surprise when one considers the complex organisational structure of surgery, the array of tools and artefacts that are brought to bear in its accomplishment, and the various initiatives designed to enhance, even transform, current practice though the introduction of new technologies and digital resources. There are a number of important exceptions, carefully crafted studies that have begun to chart the complex interactional and communicative organisation that underpins practical accomplishment of the surgical operation including for example Nardi et al (1993), Mondada (2001), Moreira (2004), Goodwin et al (2005) and Koschman et al (2006). A number of these researchers have considered operations that use video-mediated ('key hole') techniques either to support the work of co-present colleagues (Nardi et al 1993 and Koschman et al 2006) or to also support distributed collaboration (Mondada, 2001). For example, in detailed studies Mondada and Koschman et al show how the surgeons coordinate their talk and delicate gestures with their hands and instruments when operating on a patient to create and configure a shared workplace and establish references to particular locations and features of the surgical field. Moreover, Hindmarsh and Pilnick (in press, 2007) describe how the passing of instruments by the nurses in the anaesthetic room is timed and designed to anticipate how and when an instrument will be used. These studies point to the distinctiveness of surgical operations and the ways in which their organisation differs from the sites that have more predominantly formed the focus of analytic interest in CSCW. Suchman (1993) has aptly characterised these other work sites as 'centres of coordination', and shown the ways in which they

encompass such seemingly diverse domains as air traffic control, station operation rooms, emergency dispatch, and airport operation centres. It is worth noting that such domains not infrequently involve a range of personnel with overlapping skills and knowledge that are primarily concerned with coordinating the activities of a range of physically dispersed individuals. In this regard surgical operations are rather different. They involve a complex division of labour that involves personnel from various occupations, with very different skills to collaboratively accomplish a single, principal activity that is performed by a particular individual namely the surgeon. The principal activity accomplished (and accountable) with respect to a prescribed set of specialised conventions and procedures relies upon the timely and organised contributions of others including the anaesthetist(s), registrar and nurses. The seemingly simple arrangement and exchange of instruments that enable the surgeon to undertake the various aspects of the procedure(s) provides the foundation to the collaborative accomplishment of the operation and in some cases the very survival of the patient.

Aside from providing an interesting and distinctive ethnographic opportunity, the analysis of the collaborative accomplishment of the surgical operation raises a number of interrelated issues that have been of some interest within CSCW. Firstly, as Schmidt (2002) points out the concept of ‘awareness’ has not only provided a vehicle to address the complex processes of organisational interaction that enable personnel subtly and unobtrusively to coordinate their actions and activities with each other, but also informed the design and development of a number of technical environments designed to support and enable, in many cases distributed, collaboration. Surgical operations and their reliance on instruments and implements, raise some interesting issues with regard to awareness, and point to the ways for example in which contingent assemblies and configurations of tools are designed, and can serve, to enable a number of participants to see and envisage, the structure of the procedure and ‘where we are now and about to be’. In our analysis we suggest that awareness does not simply rely on participants possessing the same information or knowledge about a particular activity but more on how they are able to contribute actively to the contingent organisation of awareness and interaction – in this case, the ways in which the participants in and through the grasping, handling, organisation and use of instruments can orientate prospectively to the upcoming actions and concerns of others.

Secondly, over the past decade or so we have witnessed a burgeoning interest in tangibility and the ways in which the physical manipulation of objects and artefacts can enable computational resources and capabilities. The contributions of Weiser (1991), Fitzmaurice et al. (1995), Ishii and Ulmer (1997) amongst others are critical in this regard, in particular for how they reveal the significance and enormous potential of creating interdependencies between the physical, the tangible and the digital. However, as Hornecker (2005) recently suggested, notwithstanding the growing commitment to tangibility and tangible user interfaces, de-

velopments have primarily focused on individual or single-user interfaces rather than collaborative aspects of tangible interaction and interactivity.

Thirdly, CSCW has understandably treated the concept of ‘affordances’ with some reservation and care and yet it is widely recognised that it does provide a rich resource with which to reflect upon the qualities and design of artefacts and technologies (e.g. Gaver, 1991; Norman, 1988). As we have suggested, many of the implements used during the surgical operation, are not unlike familiar tools and artefacts that one can purchase from a kitchen shop or home care store. There are, of course, subtle differences between many of the implements used in surgery and their more common counterparts. More importantly however, in the surgical operation we can see how the qualities of implements, their ‘affordances’, are oriented to, and constituted, collaboratively to enable the smooth and unproblematic exchange and deployment of particular tools and artefacts. It is also interesting to note, that notwithstanding the principal qualities and design for particular users, implements enable a broad variety of applications and uses not conventionally associated with the activities in question.

## An ecology of instruments

In the daily work of undertaking surgical operations surgeons are dependent on the availability of many specially designed surgical instruments – the tools of the trade. Every surgical case has its own requirements and demands a variety of different instruments for the performance of particular procedures involved. Instrument modification varies from the strength needed for bone work, to length required to reach depth, and to delicacy required to approach microscopic structures. The design of these surgical instruments has evolved over many years and has provided the surgeon with an array of different instruments suited to the specifics of particular interventions and procedures (Figure 1).

Given the range of different instruments used and the intricate demands of the actual surgical procedures, including the complex and frequent interaction and communication with other members of the surgical team, the surgeon is supported by one or several scrub nurses. The role of the scrub nurse, among other duties, is to provide assistance by passing the correct tools to the surgeon during the course of procedure. The key to the successful accomplishment of a surgical intervention is the timely availability and efficiency of tools. Surgical instruments not working properly or not immediately available may delay procedures, interrupt other activities or sometimes even jeopardise the safety of the patient.



Figure 1. A great variety of surgical instruments

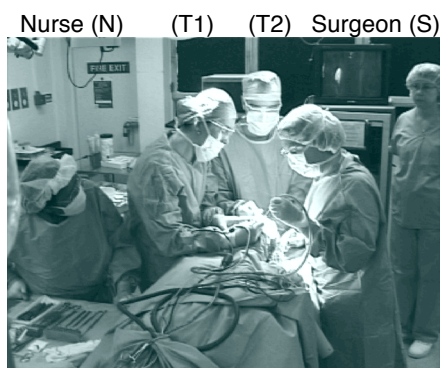
Let us join the action in the course of a surgical procedure when a surgeon gives a simple request for an instrument to a scrub nurse and the scrub nurse passes that instrument to the surgeon (fragment 1). At this moment the surgeon (S) is using a drill and a suction tool to gain access to an osteoma, or tumour, in the area above the patient's eyebrow. Two surgical trainees (T1 and T2) have joined the operation to function as skilled assistants to the surgeon and also to learn about this procedure. To the far left (in the images) is the scrub nurse (N), looking down on the instrument table. When we enter the scene, the surgeon is engaged in an elaborate discussion with the trainees about the case and procedures (image 1a). Within the discussion the surgeon intersperses a request for an instrument – “the (1.0) freer please”. Shortly following the instruction the scrub nurse fetches the instrument (an elevator tool) from the instrument table and passes the instrument to the surgeon (1b). The surgeon takes the instrument and continues to address her trainees by redirecting their attention to the surgical phenomenon by saying “you can just see there” and using the instrument just received to expose the osteoma for the trainees (1c).

#### Fragment 1

S: (...) septation becomes part of the intersinus septum which is integrated into the osteoma (0.1) that's the problem and that's what we are on here what I am doing is drilling around it (0.3) and you can just see::

(1.0)

S: the::  
(1.0)



1a

S: freer please

(Scrub nurse passes the instrument) →

(0.2)

S: you can just see there:::

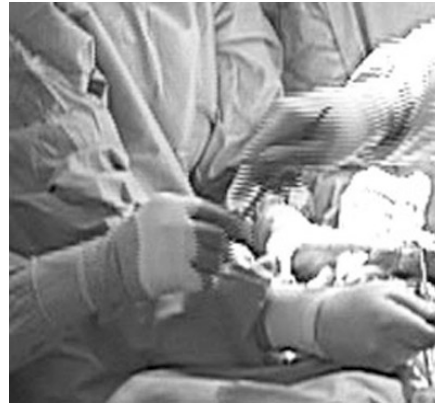
(1.0)

S: the::

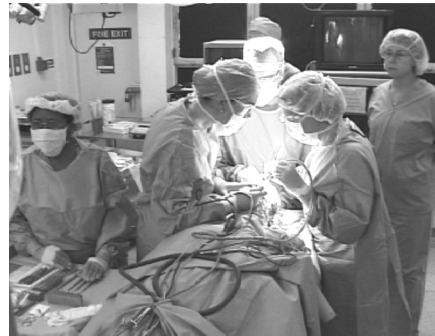
(1.5)

S: juncture (1.0) (just there) [ (0.5)  
between the osteoma →

T1: [ mmm



1b



1c

In this fragment we witness the smooth and seemingly unproblematic handling and passing of instruments. It involves the surgeon giving an instruction to which the scrub nurse immediately responds by fetching a tool and placing it in her hands. One of the challenging aspects of passing the correct tools to the surgeon is for the scrub nurse to know the names of all the range of different instruments. Learning the names can be difficult as there is no standardised nomenclature for the instruments. Sometimes the brand of the instrument is used and sometimes the inventor has given the instrument a name. Moreover, the same surgical instruments may have different names at different hospitals. Surgeons themselves do not always use the correct name and sometimes they use blanket terms or make up their own. However, the scrub nurse does not just respond to a request by quickly recognising its name and passing the correct instrument; the act of passing an object involves a complex series of actions and activities drawing on a range of important skills and resources. Even in this simple fragment we can see how the use and handling of instruments is embedded in a complex weave of multiple interrelated activities and responsibilities. For example, the passing is done in relation to other distinct and parallel activities. It is done in relation to the conduct of a delicate procedure involving the demands and use of a range of different surgical tools. It is also done in relation to other competing activities of the surgeon, in this case whilst she give elaborate characterisations and descriptions of the disease and to the trainees, or within the developing course of the surgery, the surgeon now and then may also have to direct particular attention towards the work of the anaesthesiologist and their joint concerns with the management of the

patient's condition. In this way it can be recognised how the passing of instruments are often secondary to other activities such as teaching and medical work. Given such circumstances, there may not be the opportunity to make an explicit request or instruction about what might be required at a particular moment. This will then place demands on others to prepare and communicate the timely availability and smooth transfer of instruments during the course of the operation. In such circumstances we find the smooth accomplishment of the use and handling of instruments relies upon a tacit body of skills, competencies and practice.

Before the operation begins the scrub nurse prepares the supplies and equipment needed for this particular surgical case. Different types of operations require specific tools and accessories. One of the most important aspects of selecting the instruments for the operation is to be familiar with the surgical approach and the anatomy involved - the instruments selected and prepared have to support the specific case and the ways in which the function of particular instruments can do the work. During the course of the operation, the surgeon uses a variety of tools that can be classified by their function: for cutting and dissecting, grasping and holding, clamping and occluding, exposing and retracting, and so on. Many of these categories include different types of instruments. For example, instruments for cutting and dissecting include a variety of scalpels, knives and scissors of different sizes and configurations.

The principal way of preparing for surgery is to assemble sets of instruments. Every set may include all the appropriate instruments needed for the case or a particular part of the procedure. There are standardised sets that may include all the instruments needed to open and close the incision, along with the ones needed to complete the surgical procedure. Commonly, the nurse also includes additional instruments based on information about the physiological status of the patient, proposed incision site, the character and conduct of a single procedure, and the surgeon's personal preferences. By obtaining information during the preoperative assessment and consulting particular preference cards, nurses know how to complement the selection. The instruments in these sets are carefully selected with regard to the procedure and the particular manoeuvres expected to be performed by the surgeon. For example, the type and the location of the tissues to be cut determines which scissor or knife the surgeon will use; the length may provide the means through which the surgeon can reach depths of body cavities; and the size and depth of incisions may determine the width and length for appropriate exposure of the surgical site. Also, as all surgeons have different ways of using their hands and fingers, the surgeon may want instruments that fit particularly well with their own way of grasping and manipulating instruments during particular manoeuvres.

Based on this competence and knowledge about the organisation and procedures of the particular case, the scrub nurse makes available the sets of instruments on tables next to the operating bed. For most cases, the nurses prepare two

tables: the instrument (back) table and the Mayo stand. The instrument table provides an area for all the instruments and the sterile supplies to be used during the procedure. The Mayo stand is used to hold instruments that will be used more frequently during the current stage of the surgical operation (see figure 2).

The preparation of sets of instruments laid out on the instrument table is one fundamental way of contributing to the smooth passing of instruments. So, for example, in our first fragment the scrub nurse responded quickly to the request for the “Freer” instrument simply because it was anticipated. The instrument was already made available on the instrument table in front of her, together with other currently relevant instruments, because the scrub nurse knew the case and the current stage of the procedure - a stage where particular instruments are needed to open and lift a flap of the skull in order to expose the tumour. Also, the scrub nurse knew about the particular instruments – in this case, the “Freer”, which is an instrument frequently used for separating and lifting bone structures when exposing a tumour.



Figure 2 – Instruments selected for the particular case

Scrub nurses then do not merely need to learn the names of specific instruments, their shapes, qualities and physical attributes or to develop the ability to identify and pass instruments quickly. Assisting the surgeon requires them to organise and make assemblies of what potentially could be the relevant tools used in the operation. They configure the ecology in order for them to provide an efficient and timely response to a request.

### Dynamic arrangements of instruments

It is not always possible to have all the instruments required for an operation laid out on one instrument table. We can see in previous examples how a Mayo stand is used to hold instruments that will be used more frequently. Even though each hospital normally has procedures for how tools should be laid out for particular operations, we frequently observe the scrub nurse are re-configuring and altering



the organisation of instruments laid out on the Mayo stand. Consider an example (Fragment 2).

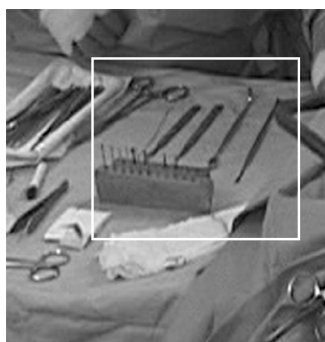
The surgeon is currently at a stage of a surgical intervention where she has exposed the area of the bone structure on the forehead (surgeon right; surgical assistant left). She is currently using a drill and other supplementary tools for exposing the cavity area (the frontal sinus) under the bone structure. On the instrument table (image 2a) the scrub nurse has placed the drill holder in the middle of the table next to the patient's bed (right); far to the left is a tray of additional instruments and behind the drill holder (for the nurse) is a pile of swabs. These are currently used by the surgical assistant (standing opposite the surgeon) holding the scalp and exposing the surgical area. The most relevant instruments are laid out in front of the drill holder.

When we enter the action the scrub nurse removes an instrument from the collection and then lays out the remaining ones on the table. The scrub nurse moves one instrument - (the "Freer") - to the first position in a collection of four instruments on the table (2b). A moment later, the surgeon asks for the "Freer". The scrub nurse looks down on the table and immediately finds it, first in the row of instruments next to the surgeon. She picks up the tool (2c) and hands it over.

#### Fragment 2



2a



2b



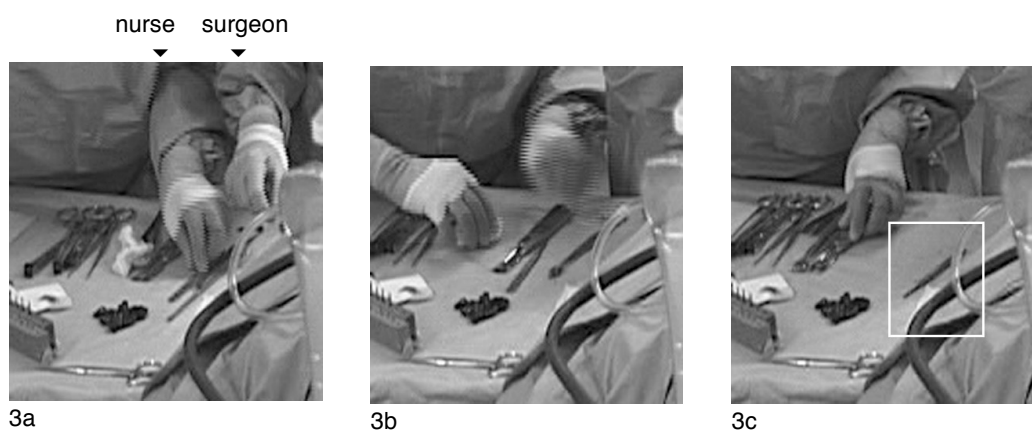
2c

In this fragment the scrub nurse orients to the relevance of a dynamic arrangement of instruments – that is, she organises the available instruments in a particu-

lar order with regard to the contingencies of the surgical activity. The scrub nurse has laid out those instruments and accessories that are going to be used during this procedure – for example the drills, the elevator instruments, the swabs (other instrument are kept on the instrument table behind her back). However, on this table the scrub nurse has also created a small area dedicated for the 4-5 most frequently and currently used tools (see frame in image 2b). These instruments are placed in a particular order. In this example the scrub nurse places the instrument anticipated to be used next, nearest to the surgeon. She creates an assembly of instruments where their spatial arrangement is related to their temporal relevance – the current assembly mirrors the temporal organisation of the activity it supports.

This dynamic arrangement of instruments may not only designed to support the nurse's own contribution so that she can pass the next instrument in a timely manner. There are many occasions – say when the surgeon is engaging in a procedure which only uses one or two instruments and is located a position next to the instrument table - when surgeons take instruments from the table directly. One way for the scrub nurse to support the surgeon to do this is to expose single instruments or organise the instruments into distinct groups. In the next fragment (3) the surgeon has just started to take and return a number of instruments laid out on the table. As a result of this, the layout of instruments has become disorganised making it increasingly difficult for the surgeon to find the next relevant tool. The scrub nurse notices the problem and helps the surgeon find the next one (3a). She removes the unused instruments (3b) and places another one further away from the rest (3c) – one of the two instruments the surgeon is currently using at this particular point.

### Fragment 3



By noticing the difficulties the surgeon is facing in finding the next instrument, the scrub nurse clears the area on the table and places a relevant one next to the surgeon. The scrub nurse knows that it is the knife that the surgeon needs after using the elevator instrument – because she has been able to observe that those two instruments are working as a pair at the moment. By doing this she re-

configures the assembly of tools on the table so that the surgeon can freely return and find the two instruments currently being used. The dynamic arrangement of instruments on the table supports the ways in which the scrub nurse and the surgeon can coordinate how instruments are made available, here and now. A working division of labour emerges that is made possible by the nurse not only remaining sensitive to the moment-to-moment demands of the activity, but anticipating what will be required next. The dynamic arrangement of surgical instruments is a spatial and material interface – an ecology – that makes possible very fine moments of co-ordination.

## A practical orientation to the passing and handling of instruments

In the examples provided so far, we have shown how the assembly and organisation of the instruments provides ways for the scrub nurse to make available a relevant set of instruments for the current surgical procedure. However, handling instruments can also be seen to be coordinated in other ways.

Consider the previous fragment once more (Fragment 4). We noticed that the scrub nurse creates gaps between the tools (4a). These not only support the visibility of the individual instrument for the surgeon but also support the practical task of grasping and taking the instrument from the table (4a-4b). Moreover, the orientation and direction of the instruments placed on the table also can facilitate how the scrub nurse transfers an object from the table directly into the hand of the surgeon (4c).

### Fragment 4



4a



4b



4c

In this fragment the scrub nurse takes the first instrument in a sequence of four (4a), where the spaces between the instruments allow her to easily grasp each individual instrument. The tools are positioned and orientated on the table, with the sharp end facing away from the scrub nurse. This facilitates how each is passed on to the surgeon (4b-4c), so knives and scissors can be passed without the risk of cutting herself or the surgeon. In this arrangement the instruments can also

be safely taken directly from the table by the surgeon. The instrument has been positioned and orientated for the purpose of being grasped or handed safely and appropriately to someone else. It is important to note that whilst performing procedures and collaborating with others on a complex procedure surgeons may have limited opportunities to look at the instrument made available to them or have little possibility to re-position the instrument in their hands before use. For the one passing the instrument then, they need to take, present and transfer the instrument in ways that are congruent with how the instrument is going to be used and handled by another participant in a particular activity. Let us consider another example.

We will consider a procedure in which the surgeon uses an instrument called a clip applier (Figure 3). Many operations involve skin incisions and one of difficulties when making an incision is that the skin can easily start to bleed. Sometimes when it is not possible to stop bleeding by conventional measures the surgeon uses small clips to prevent the loss of blood. When the surgeon has made the primary incision in the head scalp, the surgeon controls the bleeding from the wound by applying clips around the scalp edge. This procedure requires the clip applier. The clips are placed on the tip of this applier. Preparation of the clip applier involves the scrub nurse opening the applier, placing the clip on the point and closing the applier to make the clip open. Between the shanks of clip applier is a locking mechanism that keeps the instrument locked with the clip opened and ready for applying (as in Figure 3). When the surgeon wants to apply the clip he or she pushes the open clip against the scalp edge and attaches the clip by releasing the mechanism (by separating the shanks).



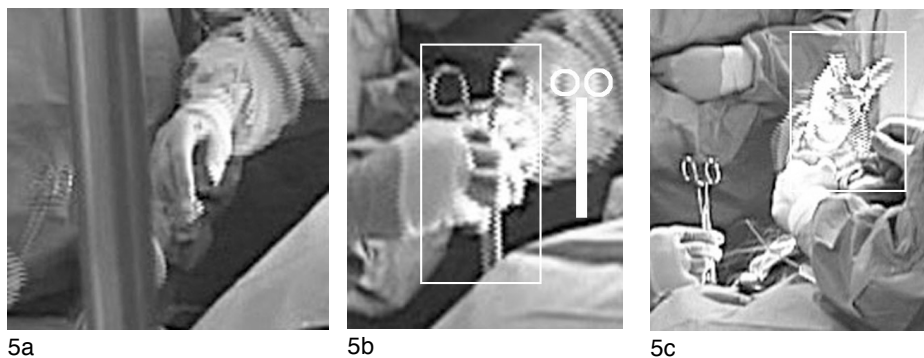
Figure 3. Clips and the Clip Applier

Clearly, the clip applier, like most instruments, has its own design and is made to accomplish a particular job and function in a particular fashion. When using the clip applier, for example, surgeons insert their fingers through the finger rings and orient the tip of the applier and the actual clip towards the scalp edge. They then separate the finger rings and the shanks to release and close the clip around the scalp edge. These practical actions are what the scrub nurse orientates to in the passing of the instrument.

As we enter fragment 5 the surgeon is asking for the next clip and returns the empty clip applier to the scrub nurse (5a). The surgeon keeps her hand in the air

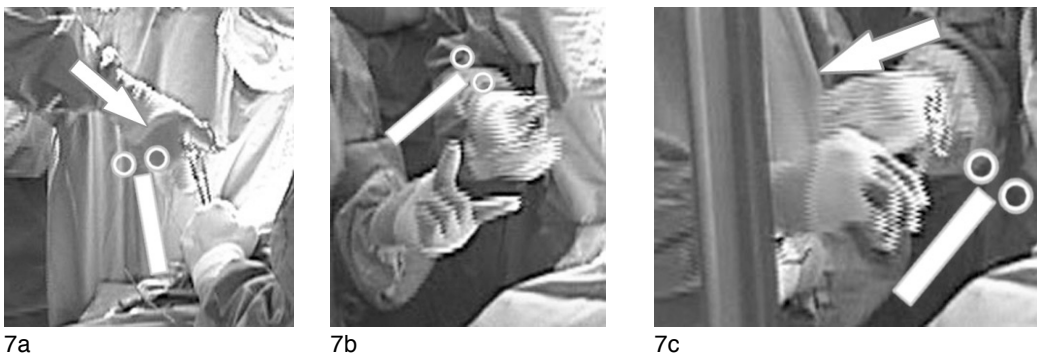
waiting for the next instrument; whilst waiting, the surgeon looks at the surgical field and uses a towel with her other hand to stop the bleeding. The scrub nurse fetches another clip and makes the instrument available for the surgeon (5b). The scrub nurse displays the instrument for the surgeon by placing it in her field of view. The scrub nurse presents the clip applicator in a position with the ring handles facing up and the clip facing down (see frame in 5b). The surgeon starts to move her hand towards the instrument and adjusts her hand so that her finger and thumb fit the position and orientation of the ring handles. Her gaze shifts briefly towards the instrument as she inserts her finger and thumb through the rings. The surgeon moves the instrument away from the scrub nurse and moves it directly into position at the edge of the scalp and releases the clip (5c). Already at this point, the scrub nurse has prepared and made available the next instrument (see 5c).

#### Fragment 5



This brief fragment points to the ways in which participants accomplish a smooth passing of the instrument. First, the scrub nurse displays the instrument and its availability (5b). Despite focusing on other matters, the surgeon can still notice that the next instrument is available. Second, the scrub nurse holds and configures the instrument in the air so that the surgeon can easily grasp and take it (5b). Third, the scrub nurse presents the instrument in a way (5b) that enables the surgeon to take the instrument, so it can be used directly (5c). Thus, the instrument is not only presented for easy grasping, but also passed on for immediate use so that this does not demand any reconfiguration of the instrument by the surgeon afterwards – enabling the surgeon to focus on the procedure and other necessary activities such as teaching work and communicating with the anaesthetic team.

One might expect that given the design of any particular instrument there would be little variation in the ways an instrument can be passed. However, if we consider a series of passings of similar instruments it becomes apparent that the ways in which it can be presented and transferred can be transformed within a given procedure. For example, in the two subsequent passings of clip applicators we see subtle differences in the ways the implements are positioned and orientated.

**Fragment 6****Fragment 7**

In the next passing (fragment 6) we can see how the surgeon is holding the clip applier in her hand when attaching a clip on the skin edge (6a), as in (5c). She has put her thumb and ring finger through the ring handles and rests the clip applier against the palm of her hand with her elbows pointing downwards (see image 6a). The surgeon returns the empty clip applier in the same way as she positioned the instrument when releasing the clip (6b). We can then see how the scrub nurse in the next passing presents a clip applier using the same orientation of the instrument just employed by the surgeon (6c). In this example (fragment 7), we see how the configuration of the passing is informed by the previous use and handled in a similar manner. The surgeon puts her thumb and long finger through the ring handles but now rather than resting it against the palm of the hand (as in 6a) she directs the shanks away from her hand with her elbows pointing upwards (7a). This is also how the instrument is handed back to the scrub nurse (7b) who then presents the next clip applier in a way that allows the surgeon to grasp it that way again (7c).

What we can see in these two instances is that the instrument is being passed rather differently: in the first instance it is held in a “up-position” with the ring handles facing upwards (6c); and in the second instance it is held in a “side-position” with the ring handles directed horizontally towards the surgeon, in line with the hand (7c). These different instrument configurations seem to be informed by the scrub nurse’s observation of how the surgeon is progressively holding and applying the clips.

In these fragments the scrub nurse seems to orientating to the changing practicalities of accomplishing this particular procedure at this particular moment. For example in this case the way the instrument is applied depends on the position of the surgeon relative to the patient or the area of the surgical site, or the instrument may be held in a slightly different way depending on the distance or orientation to the area on the scalp edge where the next clip is going to be attached. Again, we see how the passing and handling of an instrument is intimately connected with the character and progression of the surgical operation and the material and functional features of instruments being used. Indeed, both participants may be sensitive to quite fine details of the other's conduct when passing and grasping an instrument. Consider the following example where the scrub nurse has just prepared the next clip and the surgeon is about to hand back the instrument currently being used. The surgeon is now applying clips further around the scalp.

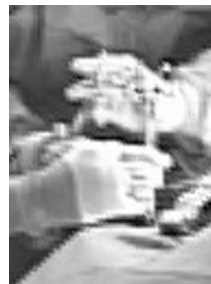
#### Fragment 8



8a



8b



8c



8d



8e



8f

The scrub nurse observing the surgical procedure begins to move the new clip applicator that is in her right hand slowly towards the surgeon. She holds the instrument in the field of view of the surgeon, keeping it still and waiting to be grasped (8a). A moment later, the surgeon releases the clip and removes the instrument from the surgical field. The scrub nurse opens her left hand displaying readiness to receive the used instrument (8b). As the surgeon places the used clip applicator in the nurse's left hand, the scrub nurse continues to move the new instrument with her right hand towards the surgeon's right hand (8c). The surgeon briefly turns her attention to the instrument now being passed on to her and moves her hand towards it (8d). As the surgeon is about to put her thumb and index finger through the ring handles, she makes a delicate adjustment of her hands and fingers: seem-

ingly rotating her hand to the right, bending and straightening her index and long fingers. The scrub nurse, who is looking at these reconfigurations, accordingly makes a slight shift of the instrument to the right whilst continuing to direct the ring handles in a motion towards the surgeon's pointing fingers (8e). The surgeon then thrusts her thumb and long finger through the ring handles and then upwards bringing the instrument towards her. The scrub nurse follows through the movement upwards for a brief moment before releasing it into the sole grasp of the surgeon (8f).

This fragment reveals a complex configuration and reconfiguration of hands and instruments by both participants as an implement is transferred from one hand to another. It is not simply that one person holds an instrument still for another then to grab, but, in passing the instruments is sensitive to how another is going to grasp, hold, orient and manipulate an instrument for a particular purpose in given circumstances. In this case as the surgeon moves around the scalp she has to change the way she applies the clips, in the ways she positions herself and use the clip applicator. The nurse is sensitive to this change and displays this in how she passes the next instrument. The participants engage in a complex micro-coordination of activities. The progressive performance of the passing embodies not only an orientation to an actual transfer but also a prospective orientation to an upcoming handling of the instrument in the practical matters of putting the instrument to effective use.

In this paper we have considered what is a seemingly simple activity that occurs in a complex collaborative setting – the arrangements that allow for one person to pass an object to someone else. In examining this in some detail we have seen the preparatory work that is involved in placing an object so that it can be passed in a timely fashion, particularly when this is one object amongst an assembly of objects. It is apparent that the spatial assembly of instruments is sensitive to their potential temporal organisation. In laying out instruments, nurses anticipate the order in which implements will be used. They also are sensitive to changing circumstances and problems that may emerge. They can dynamically reconfigure the scene, allowing for different orderings and different ways in which an instrument can be passed or not passed at all but picked up by another. We can also see how even the ways in which objects are passed can be transformed, either in the light of current circumstances, the activities of the recipient or prior actions, like in the way another person passes back an object or whether they needed to shift it in their own hand before use. A simple passing of an instrument is accomplished by a fine micro-coordination of activities involving activities by both the passer and the recipient.



## Discussion

For a number of years researchers in CSCW and cognate disciplines have suggested we look beyond conventional technologies and studies for ways to develop innovative systems to support everyday activities. Particular attention has focused on the possibilities of augmenting artefacts with digital capabilities so that individual appliances can provide novel kinds of information and computational support; support that can be embedded in, and resonate with, the local environment (Weiser, 1991). In order to develop ubiquitous technologies, it has been argued that we need to have a wide-ranging understanding of the ways in which ordinary artefacts are used within the accomplishment of everyday practical activities and in particular to explicate the characteristics and competences that enable such tools and appliances to be deployed to serve a range of practical purposes. The handling and exchange of instruments during the surgical operation raises issues that may bear upon the development of ubiquitous technologies; issues that resonate with long-standing concerns within CSCW.

Awareness remains a pervasive resource in reflecting upon the design and deployment of ubiquitous technologies to support collaboration and yet, as Schmidt (2002) notes, further analytic attention is required to unpack its organisational characteristics and significance. In this regard, there are a number of aspects of the instrument handling in the operating theatre that raise some interesting and perhaps relevant issues with respect to our understanding of awareness. In the first place, we can see, for example, how the arrangement, or configuration of an assembly of instruments, objects and artefacts, provide resources to enable the structure or trajectory of action to be seen, anticipated and accomplished. The arrangement is organisationally, interactionally and contingently implicative: its reconfiguration transforms the field of expected possibilities. Secondly, awareness, is not an abstract, nor simply a general competence, but rather depends upon, and is inseparable from, highly specialised skills and competencies that are part and parcel of the accountable accomplishment of the tasks at hand. In other words it is by virtue of practiced familiarity with, and engagement in, the activities at hand, that participants can be 'sensibly' aware of each others conduct, its implications and the matters at hand. Thirdly, the simple passing of an instrument in a timely and appropriate manner, directs attention to the ways in which 'awareness' relies upon the participants' abilities to prospectively anticipate particular actions and to recognise, and orient to the emerging and contingent, trajectories of action. In turn, particular events, activities, happenings and like, inevitably require that participants retrospectively reshape and reconfigure a sense of what's next, and what's after that. To treat 'awareness' as a 'state' or a general competence, or render it a 'fat moment', to corrupt Garfinkel's (1967) expression, rather than as ongoingly accomplished within the specialised demands and arrangements

of particular environments might prove a misnomer when reflecting upon the design and development of ubiquitous and collaborative systems.

Our observations of the arrangement, handling and use of instruments during the surgical operation might also have some bearing on the concept of 'affordance'; a concept that has been roughly treated within CSCW and HCI. Despite the important debates concerning the criteria and characteristics of affordance (e.g. Gaver, 1991; Norman, 1988), we can begin to see how particular properties of an artefact are situationally and contingently constituted by participants themselves, in and through interaction and collaboration. Notwithstanding the characteristics of implements and the 'constraints' that they may place on, or engender from, action, we can see the very different ways in which the same instrument is handled and used by different participants within the same setting. These ways of approaching and handling instruments are of course inextricably embedded within the practicalities and practices that inform an activity's accomplishment. They may also be sensitive, as we have seen, to a co-participant's anticipated use, here and now, of the implement. In other words, we might need to readdress the analytic horizon of affordances and begin to take seriously the highly variable and contingent ways in which the 'same' object might inform and be informed by action and interaction.

These observations also bear upon the growing interest in CSCW and cognate fields of enquiry on, 'tangibility' (e.g. Ishii and Ullmer 1997) and allowing people to communicate through 'touch and feel' (e.g. Strong and Gaver, 1996). It has been suggested that the design of systems to support collaboration might fruitfully benefit from novel developments in haptic technologies (e.g. Adcock et al 2004). These recommendations have largely focussed on providing individuals with haptic feedback including a sense of the object's size, position or movement. Moreover, research into tangible and haptic interaction has not focused much attention on the relationship between form (appearance), function and action, and its relevance to interaction and collaboration, as pointed out by Sitorus et al (2007). With requirements for training surgeons so they can learn the 'feel of an operation' and the introduction of robotic and other sophisticated technologies to support medical interventions, it is not surprising that there has been considerable interest in haptic technologies in the surgical setting (e.g. Gerovich et al 2004). The simple exchange of implements during a surgical operation raises, we believe, some interesting issues concerning tangibility. The smooth exchange of instruments, for example, relies upon the participant's ability to sense the shifting weight and balance of particular implement, to enable the passing hand to withdraw and the recipient to grasp and remove the object (in the situationally appropriate manner). The shifting tactile qualities of the implements, and the activities of exchange, are critical to collaboration and the performance of accomplishing the highly complex task of surgery. In this, and one suspects many other circumstances, we need to begin to consider how tactile properties of 'objects' can be re-

produced to support distinctive, collaborative, in some cases simultaneous use of the same artefact. In other words, in rendering the digital, tangible, to support for example the performance of remote tasks, we may well need to prioritise the differential, yet collaborative aspects of an instrument's practical application or deployment. In turn, we suspect this will demand more detailed empirical studies that begin to delineate the ways in which touch and feel inform the concerted accomplishment of many workplace activities.

We believe that one of the most important contributions of CSCW since its inception has been the emergence of a burgeoning body of naturalistic research concerned with the social organisation of everyday activities and in particular cooperation and collaboration in the workplace. For many of these studies, it has proved a challenge to draw out their specific implications for the design and development of advanced technologies, and some cynicism, perhaps rightly, has accompanied these attempts. It may however be inappropriate to assess the contribution of such studies with regard to their short term implications for the design of particular technologies; indeed as we are all aware, given the institutional constraints that frequently bear upon system development, it is unlikely that ethnography will meet with much more success than other methods used within the field of CSCW and, more generally, in HCI. As others have suggested, it might be more worthwhile to begin to delineate more systematically the ways in which our findings concerning collaboration, communication and the situated use of tools and technologies, ranging from the banal to the highly complex, may provide resources for developing a re-specification, a more profound realignment of the ways in which we conceptualise technology and action and the ideas and theories that currently pervade both academic and applied research. In the longer term, one suspects that the judgement of CSCW will not lie its small scale contributions to particular systems, but in the ways in which it encourages designers, developers, managers and the like, to take the mundane seriously, as inspiration, and to prioritise technology in ordinary action.

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