resus:station:
a redesign of the resuscitation trolley

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National Patient Safety Agency (NPSA)
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i–design case studies
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i–design partners
• The Royal College of Art Helen Hamlyn Centre, is a centre for inclusive design, with extensive contacts in industry and the design professions.
• The Engineering Design Centre at the University of Cambridge has a strong reputation in the improvement of design process and development of design methodologies to address specific issues.
• Applied Computing at the University of Dundee develops information technology systems to support older and disabled people.
• The HCI Group at the University of York has a long history of inter-disciplinary research in the area of user centred design arising from collaboration between the departments of Psychology and Computer Science.
• The Design Council inspires and enables the basic use of design by business, education and government to improve prosperity and well-being.
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Abstract
This case study details the redesign of a resuscitation trolley for in-hospital cardiac arrests by a multi-disciplinary team involving industrial designers, clinicians and clinical psychologists.

The complex system of resuscitation and the demands placed by a resuscitation team on the trolley were investigated through interviews and workshops with experienced users and continued input from the clinical side of the collaborative team. Using a modified ‘Failure Mode and Effects Analysis’ tool, the resuscitation process was mapped, the problems identified and design opportunities developed.

Using co-design methods and critical clinical refinement of a breadth of ideas, a first stage prototype was produced. Subsequent rigorous testing in a simulated environment provided a large amount of user feedback. This led to further improvements in the design, and five second stage prototypes have been produced for a more formal hospital trial in October 2007.

Keywords
medical error, patient safety, resuscitation process, co-design, task analysis

Project period
October 2005 – October 2007

Related Project
Safer by Design – Packaging for injectable medicines. Sally Halls, October 2006 – June 2007

Introduction
A resuscitation arrest is a high stress, time-restricted process, which often involves a large number of people. These factors combine to result in much scope for error, particularly regarding the use of equipment. The recently compiled National Reporting and Learning System (NRLS) data showed that ill-stocked resuscitation trolleys have led directly to a number of preventable deaths. This project is an opportunity to challenge the way in which resuscitation is carried out.

The aims of the design of a new resuscitation platform can be summarized as follows:

- To improve the patient outcome by reducing the risk of clinical error and adverse events; reducing the time to the initiation of resuscitation;
- Improving the proficiency of those carrying out Advanced Life Support (ALS), and ensuring that correct procedures are used.
- To improve communication and relieve anxiety amongst the resuscitation team.
- To have a new defined role in medical emergencies as well as arrests
- To assist in the collection of data and audit of arrests and thereby allow for continual improvement in our understanding of what effective resuscitation should mean.
- To develop a knowledge base and design approach transferable to other hospital scenarios.

Background
The research partner is the National Patient Safety Agency (NPSA), a government body set up within the NHS which aims to improve the quality and safety of care in the NHS. The project is sponsored under their Design for Patient Safety Programme which aims to improve the quality of design in products used in the NHS.

The project is being undertaken in collaboration with St. Mary’s Hospital, Paddington (a teaching hospital linked with Imperial College, London), giving a broad base of expertise covering industrial design, clinical and psychological perspectives.
The team comprises:

**Design perspective:**
Professor Roger Coleman (Professor of Inclusive Design and Co-director, HHC)
Colum Lowe (Head of Design, NPSA)
Jonathan West (Senior Research Associate, HHC)
Sally Halls (Research Associate, HHC)

**Clinical/Psychological perspective:**
Professor Sir Ara Darzi
Rajesh Aggarwal (Clinical Research Fellow, Imperial College, London (ICL))
James Kinross (Clinical Research Fellow, ICL)
Andrea Smith (Research Associate, Clinical Safety Research Unit, ICL)

There is much literature covering resuscitation, and previous attempts have been made to comprehensively redesign the trolley. This collaboration affords the breadth of skills necessary for this undertaking, with a non-commercial goal shared from the outset by all members of the team. This puts the project in a stronger position than its predecessors.

The Design for Patient Safety report (2004) identified the need for a systems-level approach to design within the NHS, in particular the need for collaborations between designers, researchers, healthcare practitioners, NHS agencies and other stakeholders.

This report pointed towards problems at a systems level which have huge implications for products used within the NHS. Any product to be used within a complicated system that is error-prone must recognize the demands and context of the system in which it will be placed. Understanding the system is crucial throughout the design process. The resuscitation trolley is a perfect illustration of this need; no design problem can be treated in isolation, as this may introduce further problems elsewhere. The entire system of use must be understood in order for the design to be effective.

**Methods**
The resuscitation procedures were initially researched through an extensive literature search (see bibliography). This was then expanded upon through input from practising resuscitation personnel. The clinicians in the collaborative team were important at this stage, as relevant knowledgeable input was being given from people who fully understood the intent of the project and eventual design work. An Advanced Life Support (ALS) course was attended and documented through video to observe how clinicians learn resuscitation, and videos of actual arrests were also observed. Animations of theoretical resuscitations were produced from close observation of real life arrests (Figure 2).
During this phase, the clinical side of the collaborative team taught, while the design side learned.

**Approach from a Design Perspective**

During the initial exploration of resuscitation, it became clear that a tool was needed to focus design attention on specific areas. A hybrid form of task analysis and a more detailed Failure Mode and Effect Analysis (FMEA) proved to be useful (sample in Figure 3). The tool involved breaking down the resuscitation process into smaller discrete tasks, each of which has potential errors, causes and effects. This focused input from the clinical side of the team to ensure the task list and errors were comprehensive, and helped to map the process as a cycle rather than a linear progression.

Each of the errors outlined using this tool provided a trigger for design work and concept generation. These triggers had previously been ignored by clinicians who are taught to deal with shortcomings in equipment design as ‘a fact of life’.

At this stage the design team was still learning from clinical teaching, but there was a gradual shift in roles. Designers started to act as ‘visualisers’ for mapping processes, and began to draw team thinking towards design opportunities.

The tool provided an expanded list of triggers to design. The usual process would be to then move directly toward the iterative method of successively revising the designs using critical input. However, the collaboration afforded a much greater opportunity of involving the users in the creative process, to give potentially further reaching results.

Thus, in order to expand upon the triggers derived from the logical, modified FMEA-based approach, the clinicians were involved in creative techniques to provide further design prompts.

These design prompts were more wide-ranging as they are not simply the result of observation of resuscitation processes, but involved the clinicians’ own thinking from experiencing resuscitation operations.

**Design Outcomes**

The result was a breadth of initial concepts. This approach gave a much wider range of ideas. As the designs underwent successive revisions through an iterative critical process, the initial range of ideas were kept as broad as possible. Many different concept areas were developed which treated the whole resuscitation process, and it was in selecting the best of these that critical input was required.

The members of the collaborative team, who...
Figure 4. Functions and use of Phase One prototype

Figure 5. Completed Phase One prototype
focused on the psychological elements of resuscitation and team interaction, completed work on a more detailed FMEA. The result of this was a tool which has been used to inform the design direction in a more objective manner (using weightings of importance for certain errors etc.).

The chosen design and features were detailed and ‘solid’ models were created on a computer. These were made into a full size, fully functioning prototype (Figures 4-5) which has been tested in numerous simulated resuscitation scenarios in different hospitals.

The eventual design has an open layout to make access easier and identification of equipment clearer. This saves time, and reduces the potential for errors in an emergency.

Different tasks necessary for resuscitation are carried out at different locations around the patient (e.g. airway management is done at the head). Also, a resuscitation team involves members with different skills and seniorities who may not have worked together before. The design therefore splits into three sub-sections, allowing the team to clearly identify individual roles, and configure the equipment around the patient as necessary.

It has been shown that the most efficient teams have a clear leader who does not have a hands-on role in the resuscitation. The design features a touch screen to guide the leader through the resuscitation process to aid team direction. It also logs the actions of the team for auditing purposes, as existing paper audits are seldom completed.

Stock control is also an important issue, as items tend to go missing from existing trolleys. The new design incorporates Radio Frequency Identification (RFID) technology. Each item is tagged with an RFID tag at the point of manufacture. If a tagged item is removed from the new design, the display will flash up a warning that the stock is incomplete, and list what has been removed. This also eases the restocking process.

From these features, it is clear that the new ‘trolley’ is actually more like a resuscitation ‘platform’. It is no longer just mobile storage, but is now an integrated platform from which to run a more streamlined process. This owes much to the inclusion of clinicians in the design process.

**Assessment**

The first stage prototype has been tested numerous times at different simulation suites, at the Chelsea and Westminster and St Mary’s hospitals in London. These facilities allow different scenarios of arrest situations to be simulated through a ‘Sim Man’ (a dummy which can replicate a heart trace, breathing and so on). The actions of different resuscitation teams and their performance with the new design was recorded extensively during these sessions.

User response to the design has been unanimously favourable. The open layout and splitting functions improved the efficiency of equipment selection, making the process more efficient. The RFID and touch screen technology were popular amongst the users. Suggestions for improvements to the design included providing more surface area on top of the trolley (used for drug preparation etc), improving the security of the...
trolley when idle, and improving the splitting.

Discussion
The main challenges of the project lay in gathering a consensus of opinion from such a broad and large user base. In addition to the collaborative clinical team members, Resuscitation Officers at other hospitals were also consulted (through bodies such as the Council for Professionals as Resuscitation Officers), and through attending and presenting the project at the International Congress of the European Resuscitation Council (see resources). Technological and manufacturing constraints were identified from the Medical Device Technology Show, and detailed consultations with British Telecom (BT) at their research facility.

Finding a design, which can satisfy all of these needs is difficult, but not impossible when the correct expertise is sought at each relevant stage. This process has been done iteratively to refine the ideas, and to ensure that the design remains relevant to the initial brief.

The project has already proved to be successful. At the prestigious Medical Futures Innovation
Awards held in London in June 2007, the redesigned resuscitation trolley beat 1200 entries and 30 finalists as overall winner in the category of Anaesthesia and Critical Care, as well as being awarded ‘Best Medical Device’ in this group. It was also short-listed for the Best National Health Innovation award.

Conclusions and future work
The shift in user research methods from treating users as test subjects alone to seeking their critical input directly in the creative process has been the most rewarding discovery from the designers’ and the users’ points of view.

Testing has established that the splitting function and the open layout are features which have definite benefit. These features have formed the basis for the next phase prototype, and a trolley manufacturer has been selected to fund and build five next-phase prototypes for extended trials in October 2007. This new design features more surface area for drug preparation, built-in tamper-proof blinds to improve security, and a more reliable splitting mechanism.

The board at St. Mary’s Hospital, Paddington have agreed to trials of these revised prototypes in October 2007. The nature and duration of these trials is currently being discussed with the relevant quality and safety, and ethics personnel at St. Mary’s.

Winning the prestigious Medical Futures Innovation Awards helps to validate the design approach, particularly in an area of design where the bottom line is usually cost. The more complicated and potentially expensive features such as the touch screen and the RFID or equivalent technology will take longer to implement. Discussions are currently being held with defibrillator manufacturers to enable the prospect of longer term development and convergence of these functions. This would pave the way for a more comprehensive platform for resuscitation in the future.
References

Resources
European Resuscitation Council (ERC)
The ERC is an interdisciplinary council for resuscitation medicine and emergency medical care.
http://www.erc.edu/new/

The Council for Professionals as Resuscitation Officers (CPRO): This is a UK professional body aiming to maintain, develop and promote the skills and expertise of Resuscitation Officers for the benefit of the public through education, research, audit and partnership. http://www.cpro.org.uk

MedTec UK is an annual trade show showcasing the latest in medical devices and technology.

Bibliography
Selected wider reading below:

Department of Health Expert Group An organisation with a report of an expert group on learning from adverse events in the NHS chaired by the Chief Medical Officer. 1-94. 13-6-2000

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About the research partners

National Patient Safety Agency: helps the NHS learn from things that go wrong and develops solutions to prevent harm in future. It does this by working with patients and staff to foster a culture where errors can be investigated and solutions developed, and by analysing information from staff and patients. From April 2005 the NPSA expanded and now includes safety aspects of hospital design, cleanliness and food.

www.npsa.nhs.uk

About the Research Associate

Jonathan West: has a first degree in Mechanical Engineering from Birmingham University and a Masters in Industrial Design Engineering from the Royal College of Art (2003). Jonathan's has worked in industry and at the Helen Hamlyn Centre where, as a Research Associate he has provided GlaxoSmithKline with design guidance on their pharmaceutical packs (directly influencing the European pack style), and is currently working on a new resuscitation trolley for the National Patient Safety Agency. Contact: +44(0)7812 173 812; jcdwest@yahoo.com

Sally Halls: studied Mechanical Engineering at Bristol University before coming to the Royal College of Art to study Industrial Design Engineering. After graduating, Sally took the opportunity to further this interest at the Helen Hamlyn Centre as a Research Associate, where she is helping to improve patient safety through the redesign of resuscitation trolleys. Contact: t: +44(0)7734 430164; Sally.Halls@rca.ac.uk

The Helen Hamlyn Centre was set up at the Royal College of Art in January 1999 to alert design and business to the far-reaching implications of a rapidly changing society. It works to advance a socially inclusive approach to design through practical research and projects with industry. Its Research Associates Programme teams new RCA graduates with industry partners. www.hhc.rca.ac.uk