Using (near) real-time data to bring ergonomics into a collaborative design process

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Human factors and ergonomics professionals have new opportunities to collaborate in the design process by applying emerging technologies, however both the technologies and the design process are rapidly changing. Near real time data is available to connect the designer more or less directly with the user. Importantly, at the same time, the means exists to bypass explicit design input from the user entirely resulting in a potentially huge impact on the user’s health and satisfaction with the final design. Alternatively, the user can go straight to the manufacturer, bypassing other designers and HFE input. Where the impact on users is subtle or not well understood, the consequences on people might well be missed and critical flaws in designs go unchecked into the future. Three approaches to incorporating near real time data into the design process are explored and the suggestion made that by using a multi-methodology approach, HFE professionals can be more effective in collaborating with other stakeholders on input into designs.

Practitioner Summary: Dr Wendy Elford is a practical futurist and consultant in building and system design. She focusses on helping people to collaborate in the design process by showing them how they can collect and make sense of the data available to them. The goal is to make sustainable systems of work, systems that optimise productivity but fully account for the outcomes of people as they interact with their work and workplaces.

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1. Introduction

The argument for bringing human factors and ergonomics solidly into the design process is well established in HFE literature. The same material in a different format is restated in standards and guidelines, the results of projects are celebrated in case studies and award nights. The application of this advice in everyday design (here the emphasis is on the design of the built environment, systems of work and product design) is more difficult. Design processes are more complex than simple in nature, multiple stakeholders work in different ways in a changing environment, requirements are not always clear to everyone nor agreed on. In practical terms, HFE professionals are seldom the dominant players. At one end of the spectrum, HFE professionals are either not involved, provide input at last minute or provide input after the design is completed. At the other end of the spectrum, HFE professionals lead the design process or guide designers of a place, product or process. They push or pull the design towards the best outcome for humans, overcoming obstacles as best they can to provide early and effective input.

Over time, HFE professionals have aimed to become more effective by sharing the resources they use to support design. One important goal has been to have the ‘user’ advocate for themselves, trying out and commenting on designs and participating in making design decisions. The HFE professional has varying roles, to interpret, encourage, suggest and contribute to the design, sometimes directly, sometimes more indirectly. In summary, HFE professionals should be at least influencing design, but design processes are influenced from many directions at once.

Research into design processes – design research – is itself evolving. Design research methodology is context sensitive, existing in different forms in different disciplines. To add to the challenges of carrying out a formal process of design, all designers, including HFE professionals, are currently confronted with a massive number of opportunities to incorporate current data into the design processes that they influence. Not all of this data has equal value; its usefulness in the design process may be difficult to track retrospectively. Not all impacts on people are known for previous or related projects, so the relevance of HFE for a current project may be missed. Not every designer has HFE as the main priority. In this complex environment, being effective as an HFE professional is becoming hugely challenging, yet there are new opportunities which can...
quickly highlight the effect of designs on people during the design process. Using real time data in design has the potential to have a quick and positive impact on the designer process to optimise outcomes for people.

There is evidence that more formal design processes are being informed if not pushed by individuals who now have new opportunities to design for themselves. Design processes wherever they are centred are constantly evolving with technology. Computers support the handling of greater and greater volumes of data. That data is coming from sensors that are everywhere – embedded in or worn by people, attached to and embedded in materials and objects. Increasing processor speed and data storage, ubiquitous computing and the internet have helped professionals to do their design work more effectively and individuals to become more influential as designers. Add in social media, massive on-line courses, crowd sourcing and near real-time manufacturing with 3D printers and it’s easy to suggest that the design process is being redesigned itself. There is huge interest from designers in using the massive amount of data produced by these technologies, no matter who leads the design. There is certainly no shortage in interest from consumers to try out new products. This has lead to new opportunities and threats to the effective implementation of HFE in design.

2. Background

While the HFE professional aims to have some role in the design, good practice is known to incorporate user input into designs. The direct collaboration of designers with users is at least logical – cutting out the ‘middle man’ should improve knowledge of design outcomes. Direct user input not only has face validity; the user has an opinion ‘based in fact’ if they have actually tested out the proposed design. User participation has been found to improve design acceptance even when tradeoffs have resulted in a less than optimal design outcome. Indirect user input from data collected with the users’ permission, such as kinematic data and data from biosensors, RFID tags allowing geospatial data, are just some of the options which greatly extend the range of inputs into a design.

The number of ways in which designs can be conceptualised, calculated and communicated has also increased. With the use of computers in design, automation of some tasks, for example computer aided drafting or CAD, it is relatively easy to create 3D renders so a designer can show life like representations of a not-yet-built structure to future users.

The approach architects call generative design has been made possible by having faster and faster computers. These computers are capable of completing the calculations required to stretch the options for design by compressing more calculations into any given period. This design process can result in designs that are relatively unconventional, with potentially novel results for the people who use the resultant designs.

New means of manufacturing provides new options for generating, testing and communicating options for designs. Three-dimensional printing and this year, 3D drawing, give the possibility of rapid prototyping and just in time manufacturing to anyone who has the money for the equipment. In a commercial setting, time spent in design phase may be reduced, further compromising what may may already be a relatively short consultation across multiple stakeholders. The degree to which it is useful to have the artefact present in discussions has to be considered.

Time and location are also factors in design, with high quality data transmission being applied to communicate concepts and designs in new ways. Distributed design teams and 24 / 7 design schedules make design participation and collaboration more discontinuous and difficult to co-ordinate, yet perhaps more successful in the end as wider consultation is possible. Many teams can have access to the same data set, solving problems independently then coming together. Video conferencing, telepresenting and remote control technologies can make virtual work more effective. Virtual and augmented reality can be used to display and support interaction with designs which don’t as yet exist and to do this on location for both brown and green field sites. Of course other consultation tools such as surveys can be distributed and interpreted more quickly. Current options for collaboration in design appear almost limitless when social media is added to the mix.

Using social media allows designers to explore more of the nuances of the users needs and wants, and their interactions with earlier designs. In this way, a designer can make fast adjustments to the design real time. A vast amount of content is available on user demographics to inform designs. Participative and collaboratiave design can be extended to anyone who has access to the internet or a mobile phone. One of many risks here is that design is now done by committee; the tradeoffs made may not be fully investigated.
with the needs of some users remaining unmet. Being explicit about the design process and its supporting methodologies appears appropriate.

3. The design process is being re-designed

Design has often been spoken of as a sequential process with iterations, feedback loops where one step goes back to influence a previous step. This sounds quite orderly: a tangible result is produced at the end of an explicit process. Another view is that there are multiple streams occurring in parallel, not sequence, more or less interwoven in a way which the interactions shape the design; all this is more or less controlled by some master hand. These create a more and more definite design solution. The proposal here is that increasingly, the design product and process are blending further, so that the result of the design is only a temporary artefact of the process itself at any given time, present while the process constantly shifts to its next set of possibilities. This is the concept that the result of a design is ‘forever beta’, just one emergent element of a complex and constant dynamic system of design and re-design evolving over time. If improving design needs good feedback loops with data coming back to the designer, then real time data provides massive opportunity for design to be highly responsive and agile, responding to the new situation. Designers can now have the ultimate in ‘situational awareness’ through data that they produce through products which can be considered one long series of pilot projects. The beginning and the end, the research and outcomes phases of design work appear to be merging. Having HFE input constantly available during the design process and its execution appears to be important. Case studies can show the variety of ways in which this can be achieved.

Just how many of the scenarios taken above are really feasible in the day-to-day work of an HFE professional who is in a position to consult in a design project? This paper will set the scene for the presentation of three case studies which use different types of near real-time data. This is data that an HFE professional can, with some planning and resources, access to establish effective collaboration on complex designs. Three classes of input are presented: generating and testing design solutions, qualitative data such as narrative to shape designer’s decisions and biometrics to provide feedback on the state of the human in the system.

4. Some approaches to real time data

The challenge then is to be sure that the way in which design is incorporated into the design brings with it the best HFE input that designers can incorporate in the time available and with the degree of co-operation that is feasible. There is now almost limitless data which can be included, so care is needed so that the design process is not slowed down so much that it stops all together, or speeded up so much that important data gets missed. There has to be a clear pattern for making sense of the data to support a deliberate choice of what designers pay attention to now that there is so much possibility to put the impact on humans of a design back into the process. This paper proposes that, working back from the actual plans for a physical design, there are at least three broad opportunities can easily be identified from current practice. One is to let the user put ‘a hand on the designers pencil or the production line’ in generating the design. A second is to collect, interpret and make use of the users’ experience both before, during and after each pilot cleanly and quickly, and the third is to collect biometric data on the effect of the design on the humans who experience it and put this real-time into the actual design.

4.1 A generative design approach

Assisting users to get hands on whilst participating in the design process is not a new concept. To communicate, designers and users have always been able to illustrate ideas. Using traditional tools such as pencil and paper, ideas can be exchanged, though user input may not make it all the way through the design process so that contributed ideas are incorporated in the final design. Alternatives have been to show images of what users want, to mock up a product and to modify existing objects to show what is perceived to be a better version. Pencil and paper, photos and mockups act as what is called boundary objects in the design process, a tool for communicating what people cannot clearly describe, so that interaction between the designer and user can happen with fewer barriers and more effectively (Broberg 1997, Broberg, Andersen et al. 2011). The design can progress with inputs from both.

The challenge here is also that the designer has to clearly communicate the intended design to the user so that they can discuss options and opportunities easily and the object used for that communication is best
linked to design documentation. Computer aided drafting (CAD) has made it possible to cut out steps in the design process to quickly and accurately create a design ready for manufacturing, but this can leave the user behind in the process as the CAD drawings have to be interpreted. When rendering of designs in 3D made it feasible to gradually reveal a design; walk throughs quickly became more realistic than the 2D drawings. Now new technologies such as augmented and virtual reality can make revealing the design even more realistic. In addition to gradually revealing the design and creating an experience, virtual and augmented reality can also be extended to give the user some control over the projection and relative placement of elements of the design. This allows the user to not only experience the design before it exists, but to shape it at the time they experience it. In this way, the user generates new options for design with the designer, in real time.

What is missing from this data is a record the internal experience that the user has as they participate in the design. This has traditionally been captured using older technology of audio and video recordings or written notes. Capturing this qualitative data rapidly from as many participants as possible creates a new opportunity to pick up a wider range of weak signals and subtle feedback from users about the way they experience the evolving design.

4.2 An experience based approach

Every person has an experience of the systems they participate in, whether they can clearly describe this experience or not. In tightly controlled design processes, this experience data has been captured directly through multi-method approaches including talk through protocols, surveys, interviews, focus groups, diaries and other means. Design requirements can be collected from users to create a brief, as feedback during pilots and after the design has been produced to gain a deeper perspective of the outcome for the user. This can then be compared with the initial intent of the design. This is essentially a narrative approach to enquiring about the effect of the system on the user.

The challenge here is to gain as much valid input as feasible in a timely way and to present this to the design collaborators in a way which they can make sense of but which also respects their relative involvement and roles as stakeholders. Getting a greater volume of data should improve design – this is easily done by asking a broader range of questions of users and asking a wider range of users. When something appearing relevant to the design emerges, it seems reasonable to drill down deeper to explore this issue. It is relatively easy to see how the volume of data grows as the strategies of both breadth and depth play out. In complex, dynamic systems unexpected issues and opportunities can arise over time. Narrative and finding patterns in this narrative can provide essential and timely data - some of these will later provide critical to incorporate into the design.

Using experience data in a design is to use people as ‘human sensor networks’. Formal research tools such as Leximancer, Nvivo and Sensemaker are available to do both qualitative and in some cases, quantitative analysis of narrative data about people’s experience of a design. This provides the opportunity to improve design acceptance and satisfaction through looking at the design through the personal experience of the user. This also has the potential to pick up emerging issues which people are not yet expressing clearly by other means.

Not all issues will be identified in narrative data. Users may not be overtly aware of the status and impact of some aspects of the design such as stress and body posture. This data is important because it forms the basis of the biological and physical impact on users, an impact which might later become evident as the design is tested in greater depth.

4.3 A biometrics based approach

The ability to collect data on the impact of a design on a users physical, mental and emotional health is the foundation of HFE practice. An emphasis from some HFE professionals on capturing visible physical data such joint angles and forces has easily expanded to an interest in less obvious data such as muscle activity, brain waves, heart rates and hormone levels as the technology has evolved. Some technology has been prohibitively expensive, such as functional MRIs. Gradually the data generated from technology was previously only available to researchers, is becoming available to individuals. Some technologies such as telemetry, while they are not new, are being redesigned. For example smart phones can be paired with biosensors to make a system available to anyone with the will and the cash to buy the technology. The
accessibility of this technology now means that designers, for example of a warehouse, can take advantage of the data produced to shape the design in consultation with subject matter experts and users.

The challenge here is partly one of scope but more importantly, one of trust and ethics. The data gathered is personal and can be mis-used. This issue will only grow in importance as more and more options for measuring the biophysiological impacts of design on people real time become possible. The degree to which people can change their behaviour to lessen the impacts, vies with the degree to which designers can shape the system to force a better interaction will always be contentious. A second and very real challenge is the sheer volume of data that can be collected if multiple types biosensors are used. This is both a technical challenge for data collection and data management, but also a challenge for the manipulation and interpretation of the data by HFE professionals and other. The only real conclusion to draw at this stage is that uptake of this opportunity will be uneven with lack of trust in the system holding many people back from participating, while others will embrace the challenges and be in a position to rapidly innovate designs.

Gaining the agreement to participate in the use of this technology appears to be the key to the future success of this approach. It is possible that popular uptake in a non-work, non-design setting will make it more acceptable for use in actual design scenarios in work settings if appropriate guidelines for privacy and use of the data are in place. The ultimate application would be for this data to be fed back directly into process control of a system in operation. For example biosensors for cortisol to measure stress could give feedback to reduce the rate of production in a production line or automatically schedule time out for stressed upper level executives in their diaries. Clearly, the implications of combining multiple methods of acquiring and using (near) real-time data in design are enormous and must be thought through, applied with great care and re-evaluated over time.

5 Discussion and conclusion

This paper raises some interesting opportunities to discuss how HFE professionals might test and promote new ways of interacting in the design process. The fact that the user can now be connected so closely with the design professional holds enormous potential. The greater challenge in some ways is that the user is the designer, aware to a greater or lesser extent of the impact of the current iteration of the design on their own health, satisfaction and performance. An extension of real time data of course is that performance can now be more efficiently tracked as part of the system. This raises the possibility that the system can be designed for performance, but that measures of health and satisfaction – impacts on humans – are not valued and therefore not optimised in new versions of the system. The increasing pace of the design process from concept to execution is now potentially so fast that it is entirely possible that a group of stakeholders goes from design to design without ever knowing where they are independently or collectively winning or losing.

Other design processes are rapidly evolving. Artificial intelligence is present now in the design process. Generative design in architectural terms produced the buildings so admired at the Beijing Olympics. In this case, computer modelling allowed many more designs to be produced than would otherwise be possible. In the end, humans decided which designs would in fact be built. In the future, this may not be the case. When biometric data controls the rate of a production system, this can result in a worse, not a better outcome for the people working the production line. It all depends on the heuristics, the rules which are designed to control the system. These are built from big data and that data is shaped and interpreted through models which may or may not take into account the effect of the design on humans.

The potential to use a multi-method approach to triangulate, as it were, the results from hidden impacts (eg biometrics) to reported impact (eg experiential data) to direct participation in the design (data generated by collaborators in a generative design approach) should help steer designs in a generally more human centered direction. It’s not just desirable, but urgent that HFE professionals explore but act to influence how the potential for the use of real time data in design is applied in the real world.

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References