



USING THE HUMAN CENTRED DESIGN METHOD TO DEVELOP TOOLS FOR NON-TECHNICAL SKILLS IN EMERGENCY MANAGEMENT

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ABSTRACT

Human Centred Design (HCD) is a widely used design process that seeks to ensure that products are designed to efficiently and effectively support the needs of the human user. At the heart of the HCD process is an iterative cycle of development and testing in conjunction with end-users. This places the humans who play such a central role in emergency management at the centre of the design activity. The BNHCRC project: team monitoring, decision making and organisational learning has used the human centred design approach to develop a number of tools that support human decision making and team management during emergencies. This report introduces the human centred design process and shows how it was used to develop the decision making and team management tools.



BACKGROUND

The decision making, team monitoring and organisational learning project has developed a number of tools that can help people at state and regional levels to enhance decision making and to better manage their teams. These tools were developed in response to a growing awareness by emergency management agencies in Australia and New Zealand of the importance of non-technical or 'people' aspects of emergency management.

The tools were developed in close conjunction with a small group of end-user partners (the New South Wales State Emergency Service, the South Australian Country Fire Service, and the Tasmanian Fire Service) using a human-centered design method. Rather than making the user adapt to tools that have already been developed the human centered design method constructs tools around the needs of the people who will be using them. This report describes the human-centered design method and presents some case studies of how it was used to develop and evaluate the tools in the project.



HUMAN CENTRED DESIGN

Human Centred Design (HCD) is a widely used process that informs the development and testing of an extensive array of products that humans are required to interact with. In fire and emergency management HCD has been used in the development of various tools to enhance the communication and situation awareness of emergency responders (Humayoun et al., 2009; Lanfranchi & Ireson, 2009; May, Mitchell & Piper, 2014; Yang et al., 2009) and to develop things like service platforms for risk and emergency management (Chavez et al., 2015).

Beyond the design of tools and artifacts in emergency management, concepts from HCD have been applied to develop practical solutions for both service providers and members of the community to mitigate the negative health effects caused by smoke clouds (or haze) in Indonesia (Anggakara, Andrian & Kuwalty, 2016), to try to increase diversity in the fire management workforce (Spradlin, 2017) and to understand the practices and principles that underpinned the 2010 Chilean Miners Rescue (Junginger, 2015).

The basic premise of Human Centred Design (HCD) is that systems are designed to suit the characteristics of intended users and the tasks they perform, rather than requiring users to adapt to a system. It seems like common sense to assert that in order for the tools developed through the project to be utilised, they must be usable. However given the myriad of difficult to use technologies and tools in the world, the 'sense' required to produce a usable product is not necessarily that common. Fortunately this concept is well defined in international standards and associated literature.

Usability Testing (UT) is a key component of HCD and uses methods that rely on including users, or user-based design principles, to test the ability of systems to support user needs. UT helps to identify potential problems and solutions during design and development stages by using an iterative approach to testing. Establishing such a design process can help ensure the usability of systems by addressing human and other technical issues. The process can be simply described as an iteration around four key stages, and is described in Figure 1.

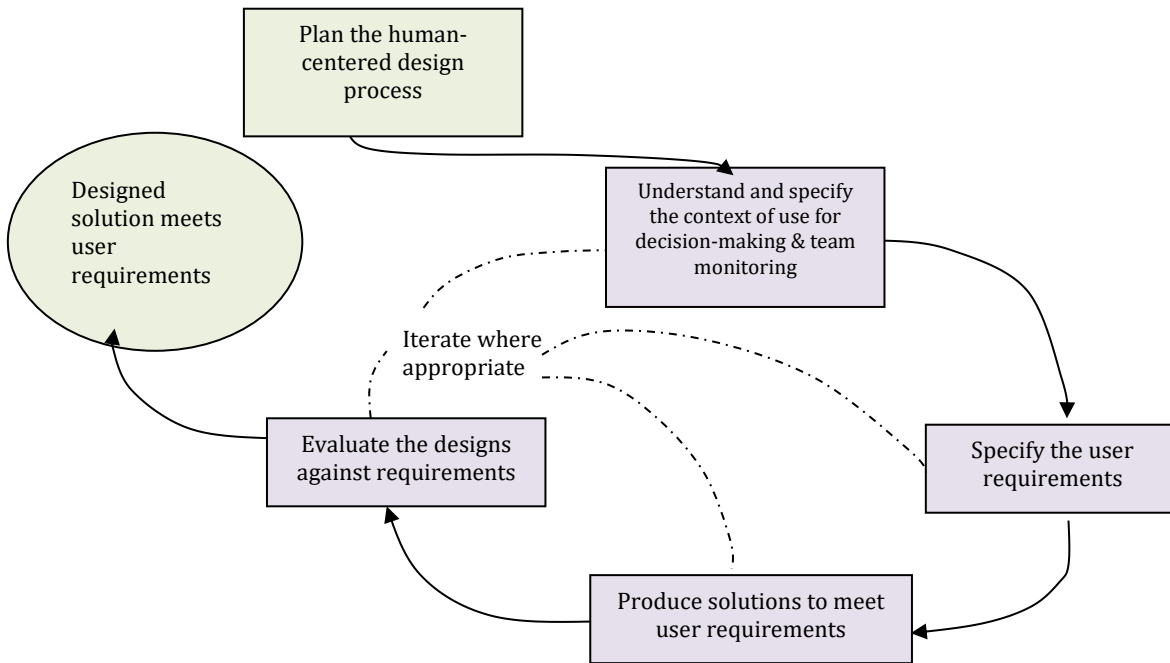


FIGURE 1 – INTERDEPENDENCE OF HUMAN CENTRED DESIGN ACTIVITIES (ADAPTED FROM ISO 9241-210:2010(E) P.11)

Previous documents in the project have identified who the user is and the context in which they might make decisions or assess teams. This current document is therefore more focused on the evaluation of those designs/tools.

As specified in the HCD standards a central pillar within any HCD framework is the consideration of so called design usability principles which consider human cognitive limitations and provide a first step in establishing a base for an understanding of good human centred design practice.

It is important to ensure the appropriate design usability principles are used prior to selecting the Testing, Evaluation and Assessment (TEA) method. The method of measurement is critical as this will be the basis on which effective user performance is assessed. The TEA concept forms part of each phase of the system lifecycle and HCD activities. TEA may cover a number of potential methods (i.e. heuristic evaluation, questionnaires, link analysis, walkthroughs and user tests) that could be used to evaluate system usability within each phase of the HCD process.

The ISO set of standards for usability includes ISO (2006) 9421-110. This standard identifies seven design usability principles as being important for the design and evaluation of interactive systems – and can reasonably be applied to the design of the sorts of tools proposed in this project. These principles help users to avoid experiencing usability problems, such as: misleading information, poor information on the user interface and navigational limitations during use (ISO, 2006).

These principles (as highlighted in the ISO [2006] 9421-110 standard) are:

- Suitability for the task: Supports the user in the completion of the task



- Self-descriptiveness: At any time, it is obvious to the users which mode they are in, where they are within the mode, which actions can be taken and how they can be performed.
- Conformity with user expectations: Conforms with user expectations if it corresponds to predictable contextual needs of the user and to commonly accepted conventions
- Suitability for learning: Suitable for learning when it supports and guides the user in learning to use the system.
- Controllability: System is controllable when the user is able to initiate and control the direction and pace of the interaction until the point at which the goal has been met.
- Error Tolerance: A system is error-tolerant if, despite evident errors in input, the intended result may be achieved with either no, or minimal, corrective action by the user.
- Suitability for individualisation: A dialogue is capable of individualisation when users can modify interaction and presentation of information to suit their individual capabilities and needs.

The principles serve as a set of general subject areas for the design and evaluation of tools forming part of the usability evaluation activity. The relevance and importance of each of the principles will vary depending on the specific context to which they are applied (ISO, 2006). Therefore, it is important to consider the relevance and balance required of the various design usability principles to achieve the goals of usability. In the BNHCRC project, each of the principles was considered in relation to the tools that we developed although some principles were more important in defining useability than others.



END-USER ENGAGEMENT

Our approach in this project has been to embed TEA within the practices of the end-user organisations. The typical form of the TEA has therefore been to include the team monitoring and decision-making tools in Exercises or, where this was not possible, in dedicated workshops that focused directly on evaluating their usability using an expert group of likely users. Where possible we have also sought to embed end-users into the research process so that they become a central part of the TEA. Working closely with end users and bringing them into the design process is a key part of human-centred design (ISO, 2010; Jackson, 1980).

Bringing end-users into the research process creates a partnership where the researchers contribute their knowledge of literature, theory and the research process and the end-users contribute their requirements, operational knowledge and understanding of the barriers to utilisation and adoption. This partnership is designed to develop tools that are better tailored to the operational environment, and people within agencies who better understand the tools and can champion their adoption within the agency (Leonard-Barton and Karus, 1985). When end users are not involved in the design process this can lead people to resist using the tools that are developed (Prasad & Prasad, 2000; Rose and Bearman, 2013).

Embedding end-users into the research and design process therefore has two goals, 1) to produce tools that can help people to make better decisions and manage their teams more effectively, and 2) to create the right context for the adoption of the tools by emergency management agencies. In this way we have brought utilisation to the centre of the project, embedding it within the research process so that utilisation informs and is informed by the research from the beginning of the project. For us utilisation is not a separate activity but an integral part of the research process.



CASE STUDIES

THE TEAM PROCESS CHECKLIST

The team process checklist (TPC) (one of the team monitoring tools) was iteratively developed and evaluated across five regional coordination centre (RCC) exercises conducted by one of our partner agencies.

The exercise began at 5pm with an initial briefing to the regional duty officer about high fire danger weather expected for the following day. This led to full activation of the Regional Coordination Centre from 8am the next day where the main part of the exercise was run. During the day one or more significant fires were reported and needed to be managed. Actors simulated radio traffic on the fire-ground and adopted the roles of key stakeholders (such as police).

An initial version of the TPC was developed based on research by Wilson et al. (2007) and Bearman et al. (2015). At each exercise the checklist was given to either three and four state level end users who were observing and evaluating the exercise. The TPC was designed around user requirements for a team monitoring checklist that was simple, straight-forward and able to be used in the time constrained environments typical of regional and state level emergency management. The TPC helped the observers to evaluate the teamwork of the RCC identifying issues that needed to be addressed.

After each exercise the observers met for about 1 hour to discuss their observations. This meeting was led by the lead researcher. The lead researcher read out each question and facilitated a discussion about how the observers thought the team had performed. This discussion was based on specific behaviours that had been observed rather than general impressions. This discussion also included a consideration of the extent to which observers had a common understanding of concepts in the questions. Any differences in understanding were discussed and changes to questions were suggested. As would be expected discussions about differences in understanding were much less common in the last few exercises. The observers also discussed whether each question was clear and whether it needed to be amended or removed. Finally, the observers discussed whether the checklist as a whole provided useful information and whether it captured all of the information that was deemed to be important. Any changes were made before the next exercise, where the process was repeated. The observers' evaluation of the team's performance was discussed with all staff at the end of each exercise and in a separate meeting with the regional commander of each region.

After the Exercises the checklist was evaluated in a separate study. Nineteen emergency management participants (mean age = 48.93, years of experience in EM = 18.63) watched a short video of a team carrying out a task and evaluated the team's performance using the TPC. The participants rated the checklist out of 5 on: how *useful* the checklist was in helping them think about how the team performed, how *clear* the questions were and how *comprehensive* the checklist was (ie the extent to which it identified all of the problems and good aspects of teamwork). The checklist was rated as 4.37 on usefulness, 4.58 on clarity and 4.389 on comprehensiveness.



The HCD process then has embedded end-users into the development and testing of the TPC, producing a checklist which is optimally designed around the needs of the user. According to the seven design principles presented earlier:

- **Suitability.** The checklist is simple, straight-forward and easy to use by an observer and can be used effectively during emergency management operations. Only that information which is absolutely necessary is included.
- **Self-descriptiveness.** It is clear to end users which of the three components of teamwork each item on the checklist relates to.
- **Conformity with user expectations:** The format is checklist based and uses consistent terminology which is familiar to the user.
- **Suitability for learning:** The checklist is fairly simple and straight-forward to use which aids learning. Information on the intended use of the checklist is included. However, appropriate training on the checklist should be provided separately by agencies intending to use it.
- **Controllability:** The checklist format allows the user to initiate and control the direction and pace of use according to their needs.
- **Error Tolerance:** The checklist is subjective and designed to provoke discussions with team members so any errors can be considered and rectified through these discussions.
- **Suitability for individualisation:** There are different versions of the checklist based on different applications (performance monitoring, after action review) but the checklist itself cannot be modified by individual users.

The Real Time Performance (Short Form) version of the TPC is presented below:



Team Process Checklist (TPC)

Purpose

This tool is designed to assist people to think through three aspects of teamwork: Communication, Coordination and Cooperation. If a 'No' response is recorded for any of the items this should be used as the starting point for a discussion with members of the team. Please note that while this tool is as comprehensive as possible it will not detect all of the ways teams can become impaired.

Coordination

- Are the roles and responsibilities of team members clear?
- Are actions always carried out as expected?
- Does everyone have a common understanding of mission information?
- Is there a clear and common purpose?
- Is everyone adjusting to meet the demands of the situation?
- Are team members requesting assistance from others, where necessary?
- Are team members correcting any mistakes made by others?

Communication

- Is information being passed on in a timely manner?
- Is information being passed on accurately?
- Are team members ensuring that information has been received and understood by others?
- Are appropriate communication procedures being used?
- Are situation updates being provided?

Cooperation

- Does everyone show a willingness to work as a team?
- Do team members exhibit confidence and trust in each other?
- Is everyone following team objectives without opting for independence?
- Are any differences of opinion being resolved effectively?
- Is anyone creating unnecessary conflict?

Decision-Making Aides Memoir

The research team for this stream (Brooks and Curnin) identified early in the research project that use of the aide memoir required a certain level of familiarity with the decision-making concepts. Therefore, in order to facilitate the testing and evaluation of the checklists a training course was designed.

Structure, Function and Participant Assessment of Training Course

The learning objectives for the course were:

- Improve decision-making skills associated with the management of bias, psychological safety, maintaining situational awareness, managing pressure & anticipatory thinking.



- Recognise the overlap between the concepts that underpin these skills.
- Assess associated checklists/tools in simulated environment for usability.

As indicated in the third learning outcome, the aides memoir developed within the research project were embedded in the training course and assessed during agency designed exercises. The tool used to evaluate the usability (and therefore the degree of 'human-centredness' was the Quality In-Use Scoring Scale (QIUSS) v1.0 used under a creative commons license from Brian Sherwood-Jones. This asks users how effective, efficient, safe and satisfying the aide memoir is to use.

The key modules within the course are identified in the figure below.



FIGURE 2: STRUCTURE OF THE TRAINING COURSE IN DECISION-MAKING

A modified version of this course was delivered as a masterclass to a mixed group of responding agencies in Hobart. The masterclass formed part of a broader workshop facilitated by an independent contractor. The independent contractor conducted an evaluation of the workshop following its delivery. The following results are noteworthy:

"The Masterclass was nominated by nearly every single delegate as one of the most effective sessions offered at the Workshop. Some respondents even broke up the Masterclass into its different modules and nominated them in dot point."

Five propositions were put to delegates in the quantitative component of the Evaluation Sheet. An analysis of the response to those propositions revealed

- 92% of delegates either strongly agreed (57%) or agreed (35%) that the workshop was relevant to their needs.
- 87% of delegates either strongly agreed (30%) or agreed (57%) that 'they had a better understanding of the role they would be expected to play in an incident response situation.'
- 81% of delegates either strongly agreed (22%) or agreed (59%) that 'they had a better understanding of the resources available to support them during an incident response situation.'



- 81% of delegates either strongly agreed (30%) or agreed (59%) that 'they had a better understanding of what they need to do in order to be better equipped to play an effective role in an emergency response situation.

The facilitator's report noted that *"overall this feedback indicates that the Workshop was extremely successful in achieving all its objectives of developing the capacity of the individuals within the network and their understanding of where they fit if called upon to play a part in a significant national response"*. (GEMS Pty. Ltd, 2017, p.1)

User Centred Design of the Aide Memoire

The design process for the associated aide memoir has, as suggested in Figure 1, an iterative process. This might be best explained by looking at the iterations for a particular section of the checklist – cognitive bias.

Cognitive bias is a phenomenon that occurs in all human thinking and occurs for a range of reasons – because there is too much information, because of our strong desire to make sense of things and so on.

Initially the research team identified key biases that had been identified in the peer reviewed and grey literature. Interviews of expert decision-makers (Level 3 incident controllers) were used to supplement that list. The results identified six key biases that influence decision-making in emergency management at strategic levels:

1. **ANCHORING BIAS:** Our decisions can be anchored by early intelligence. Have we assessed credibility of the intelligence to the same standard throughout?
2. **COMMISSION BIAS:** Are we committing to a decision because we feel like we have to 'do something' when the available intelligence at that point in time would actually suggest we wait?
3. **OVERCONFIDENCE BIAS:** Are we being overconfident?
4. **AVOID BANDWAGON EFFECT:** Have we thoroughly assessed the credibility of intelligence that contradicts the current understanding/option?
5. **USING HEURISTICS:** How did we decide? Did we take the first option, the best option? The only viable option? Did we use a different approach?
6. **AVAILABILITY BIAS:** Are we making decisions based on our previous experience of similar incidents and if so, are these incidents really the same?



An expert group (n=10) from the Tasmanian Fire Service conducted a desk-top review this aide memoir, and initially assessed the checklist using QIUSS. The results are identified in Table One.

Table One: QIUSS Results for Bias Aide Memoir – Expert Group (n=10)

<i>Item</i>	<i>Average</i>	<i>Descriptor</i>
Effectiveness	1.9	Does the job - achieves adequate performance
Safety	2.1	Neutral - no impact on safety or security
Efficiency	1.9	Workmanlike - can perform the task without hindrance
Satisfying	2.3	Bland - using it is something you do when necessary

The training course and aide memoir was also embedded within a national exercise which involved an oil spill from a ship. 25 people completed QIUSS following the exercise. The results are identified in Table Two.

Table Two: QIUSS Results for Bias Aide Memoir – National Exercise (n=25)

<i>Item</i>	<i>Average</i>	<i>Closest Descriptor</i>
Effective	2.9	Functional - you get a good outcome
Safe	2.7	Dependable - it provides good protection
Efficient	2.8	Helpful - it is efficient and tuned to your needs
Satisfying	3.0	User Friendly - you are happy to use it and use it out of choice

Although the biases aide memoir was identical, the results were higher for the group that used the aide memoir in the exercise. This tends to support the argument that 'use-in-context' is an important aspect of human-centred design. Regardless, the results from the expert group at TFS suggested there was more work to do to bring the aide memoir to an acceptable standard. The expert group made a series of recommendations for changes to the aide, and the modified aide is reproduced below:

1. **INTEL:** Our decisions can be anchored by early intelligence. Have we assessed credibility of the intelligence to the same standard throughout? Have we only looked for intelligence that supports our decisions or



preferred options?

2. **ACTION OR INACTION:** Are we committing to a decision because we feel like we have to 'do something' when the available intelligence at that point in time would actually suggest we wait?
3. **OVERCONFIDENCE:** Are we being overconfident? How confident are we?
4. **AVOID BANDWAGON EFFECT:** Have we thoroughly assessed the credibility of intelligence that contradicts the current understanding/option?
5. **DECISION STYLE:** How did we decide? Did we take the first option, the best option? The only viable option? Did we use a different approach?
6. **EXPERIENCE:** Are we making decisions based on our previous experience of similar incidents and if so, are these incidents really the same?
7. **AUTHORITY:** Are we accepting decisions or options based on rank rather than good decision-making practice?

The changes made include simplifying the language, adding 2 biases that the group agreed had been excluded from the original aide memoir, but were important (confirmation bias and authority bias), and recommendations about when the aide memoir might be used – during options analysis and/or as a critical decision checklist.



DISCUSSION

A regular response to the call for more human-centered design of products is 'of course.' It goes without saying that tools made for people should be developed using this design process so that these tools are safe and easy to use. Anyone who has battled a computer, a TV or a microwave can attest to the fact that this doesn't always happen. In emergency management, where consequences can be catastrophic, it is even more important that the tools we provide our people (be they for physical or mental work) meet these requirements.

The two case studies show how the HCD process can be used to design tools for use in emergency management. The team process checklist was iteratively developed by end-users who used the checklist to evaluate real time performance in 5 separate exercises. This was followed by a separate evaluation study that ensured that a different group of participants would also find the checklist to be useful, clear and comprehensive. The decision making aide memoire similarly was embedded into exercises and iteratively evaluated by end-users during exercises and expert groups. We recognised that in order to effectively use these aides memoir, training was necessary. A training course was constructed and also iteratively tested to improve it.

Embedded in these steps are the key components of user-centred design – understanding the user and the context in which use occurs; evaluation of initial designs using quantitative and qualitative methods; and iteration of the design based on user feedback. Following these steps increases the likelihood that tools that are developed will be effective, efficient, safe and satisfying to use.



APPENDIX 1: QUALITY IN USE SCORING SCALE

Effective

0	Useless	No useful functionality at all. Might as well not have it.
1	Inadequate performance	It provides very little help with performing a task. Even if you use all the features, you still get a very poor result.
2	Does the job	You can achieve adequate performance but nothing more than that.
3	Functional	You can get a good outcome. It enables you to perform your tasks.
4	High performance	You can achieve your goals completely. You get very good outcomes under all circumstances.
5	Transforms the task	You get outstanding results and can achieve exceptional performance. Even a regular user will award this score very rarely.

Safe

0	Dangerous	It puts people in harm's way, or provides no protection whatsoever.
1	Risky	Using it puts you or someone else at risk, and it can only be used with considerable care.
2	Neutral	It has no impact on safety or security.
3	Dependable	It provides good protection and you would feel safe if you used it again.
4	Trusted	It provides very good protection against all threats.
5	A real protector	It provides completely assured protection. Even a regular user will award this score very rarely.

Efficient

0	Impossible	It takes so much time and effort that it prevents you from doing the task. Dysfunctional, and prevents you achieving any outcome.
1	Tedious	So long-winded that you can hardly get the task done. You waste a lot of time and effort with it.
2	Workmanlike	You can perform the tasks without hindrance but it does not provide any real assistance.
3	Helpful	It is efficient, and tuned to your needs.
4	Slick	It really helps you achieve your goal with no effort at all.
5	Almost psychic	Anticipates what you want to do next. Even a regular user will award this score very rarely.

Satisfying

0	Horrible	You refuse to use it unless it is absolutely necessary.
1	Unpleasant	Unpleasant to use, and is only used with considerable resentment. A pain in the neck.
2	Bland	Using it is just something you do when necessary.. You are not involved or interested.
3	User friendly	You are happy to use it and you use it out of choice.
4	Joy to use	You get a kick out of using it. Using it provides real enjoyment.
5	A miracle of rare delight	Possibly the most enjoyable system you are ever likely to find. Even a regular user will award this score very rarely.



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