A participatory approach to helicopter user interface design

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ABSTRACT

The importance of involving users during user interface (UI) design activities is widely recognised however the nature of this involvement may vary significantly. This study investigated the benefits and challenges of applying Participatory Design (PD) during the development of helicopter UI. During the first phase, four helicopter design professionals were interviewed in order to understand their views on user involvement and current approaches. The second phase involved three helicopter test pilots and three human factors specialists participating in a PD workshop (based on design thinking) focussed on a helicopter UI design case study (the Automatic Flight Control System within a Royal Navy Merlin Mark 2). There was strong agreement from all the participants that user involvement is important and current approaches were described as mainly consultative. Benefits identified included a better understanding of the problem and context of use and therefore closer alignment of the design with user needs. The approach encouraged divergent thinking and benefitted from being multidisciplinary. Minor changes to the workshop format should be considered in order to minimise the risk of bias and make the best use of the participants' time. This study developed a valuable approach to PD which is likely to be generalizable to other domains.

KEYWORDS

Participatory design, user involvement, design thinking

Introduction

Background:

Automatic Flight Control Systems (AFCS) are regarded as a potential solution to the hazards associated with flying military helicopters in Degraded Visual Environments (DVE) (NATO RTO HFM-162, 2012). However automated systems are not without their risks and have been the focus of extensive Human Factors (HF) research for several decades (Norman, 1990, Bainbridge, 1983, Parasuraman, 2000). Many of these problems are related to the interaction between the pilot and the automated system hence the importance of Human-Centred Design (HCD).

HCD is a process by which humans are considered within the design of both military and civil systems and usually includes some form of user involvement (UK Ministry of Defence, 2017, British Standards Institute, 2010). Both Noyes, Starr and Frankish (1996) and Kujala (2003) highlight the value of involving users early in the design process particularly during the development of user requirements. The benefits of doing so include user acceptance and user satisfaction; however the impact on cost-effectiveness is more difficult to prove empirically (Kujala, 2003). Approaches to user involvement vary and can be described as sitting within one of three distinct categories based on the level of involvement as illustrated in Figure 1.

Design ***for*** users (informative)	Design ***with*** users (consultative)	Design ***by*** users (participative)

Figure 1. Levels of user involvement based on Damodaran (1996), François et al. (2017), and Eason (1995).

Examples of all three of these approaches being applied to the design of aircraft cockpit UI were found in the literature. For example, cockpit interface designers surveyed by Ohlander et al. (2017) expressed their desire to observe pilots in order to inform design activities, whereas Noyes, Starr and Frankish (1996) describe an example of both an informative and consultative approach. A study by Alppay and Bayazit (2015), which included users directly involved in paper prototyping activities, could potentially be described as a participative approach to designing helicopter flight instrument panels. Overall, published research relating to direct user participation in the design of aircraft cockpit UI is sparse.

Participatory design

Participatory Design (PD) is a term used to describe the participative involvement of users during the design lifecycle. PD has its roots in Scandanavia in the 1970s and was focussed on enabling workers to influence new technologies being introduced into the workplace (Spinuzzi, 2005). Sanders (2002) and Spinuzzi (2005) argue that one of the strengths of PD is its ability to access tacit knowledge which is more difficult to explore using conventional informative or consultative approaches. This consists of peoples' experiences and the knowledge they cannot express using words. Figure 2 illustrates how PD attempts to explore tacit user needs by investigating not just what people say and do, but also what they make.

Levels of user need	Ways people express these needs	Ways of accessing this knowledge
Explicit	Say Think	Say
Observable	Do Use	Do
Tacit Latent	Know Feel Dream	Make

Figure 2. Levels, expression and exploration of user needs based on Sanders (2002).

Methodology

This study aimed to explore the potential benefits and challenges of applying PD during the development of the UI for an AFCS within a military helicopter and was conducted in two phases.

The first phase consisted of questionnaires and semi-structured interviews with four experienced helicopter design professionals focussed on understanding their views on user involvement and current approaches to involving users during design. The second phase focussed on applying a PD approach to a helicopter user interface case study using a single day workshop format and six participants. Questionnaires and a semi-structured group interview were used to collect data in order to assess the benefits and challenges of the chosen methods and overall approach. The questionnaires focussed primarily on the ease of use and usefulness of each method whilst the interview addressed the wider benefits and challenges of the approach.

The overall research paradigm was case study and action research with the investigator directly involved in facilitating the PD workshop. This primarily qualitative approach was selected in order to explore insights from multiple perspectives. The approach to data analysis was based on grounded theory and consisted of concurrent triangulation of data sources including multiple perspectives and data collection methods. Qualitative data was theme coded and analysed using the NVivo software package. This qualitative action research approach was loosely based on the methodologies used by Jun et al. (2018) and Muller (1992).

The case study chosen as the focus of the workshop was a hypothetical redesign of the AFCS user interface within the Merlin Mark 2 (Mk2) helicopter operated by the Royal Navy. This focussed specifically on the Active Dipping Sonar (ADS) task which includes an automated transition manoeuvre to and from the hover. The rationale for choosing this case study was that it provided an example of an automated task conducted using a military helicopter which is regularly flown in DVE conditions.

A purposive sampling strategy was applied and consisted of two distinct participant groups. Phase one included four helicopter UI design professionals from two separate defence companies (each having worked on multiple types of helicopter) who completed individual semi-structured interviews and questionnaires. Phase two included three test pilots working alongside three HF specialists during the PD workshop. The scope of phase two was restricted to a single workshop due to limited access to sufficient numbers of pilots and HF specialists.

Building on PD approaches described in the literature (Spinuzzi, 2005, Muller, 1991) the workshop applied a number of interactive knowledge elicitation and design techniques. The structure of the workshop was based on the design thinking process (Dam and Siang, 2018b, Gibbons, 2016) and is illustrated in Figure 3.

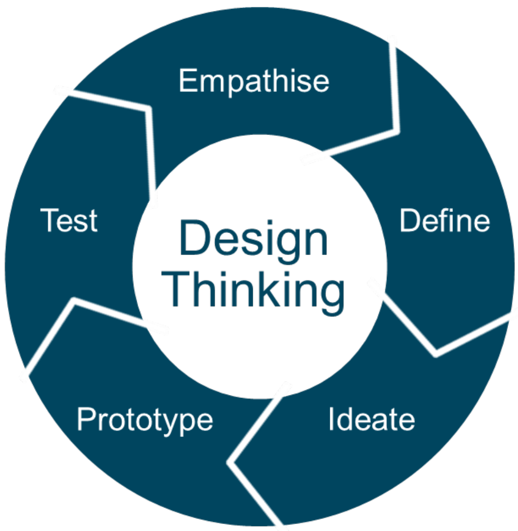

Figure 3. Stages of design thinking process based on Dam and Siang (2018a).

The process is intended to be iterative however in this case the one day workshop focussed on performing only one cycle of the process due to time constraints. The specific techniques used during the workshop were based on the design thinking process (Dam and Siang, 2018a, Gibbons, 2016), the design sprint process (Google, 2017), as well as other human-centred design methods (IDEO, 2014) and are summarised in Table 1 (more detail on each of these methods can be found in the references provided).

Table 1. Methods used during Participatory Design workshop.

Stage	Method	References
Empathise	Description of task using storyboard	(Krause, 2018) (IDEO, 2014)
	Brainstorm	(IDEO, 2014)
Define	How-might-we (HMW) statements	(Google, 2017) (IDEO, 2014)
	Sticky dot voting	(Google, 2017)
Ideate	Crazy 8's	(Kaplan, 2017) (Google, 2017)
	Heat map voting	(Google, 2017)
Prototype	Paper prototyping	(Nielsen, 2003) (Snyder, 2003)
	Storyboarding	(Google, 2017) (IDEO, 2014)
Test	Demonstration and verbal feedback	(Google, 2017) (IDEO, 2014)

A design thinking approach was chosen as it is a human-centred approach to innovative problem solving which allows people who aren't trained design professionals to be involved within the creative process (IDEO U, 2018). It is a widely used approach (Dam and Siang, 2018b) which focusses on identifying user needs and collaboratively creating and testing design artefacts in order to reach innovative solutions (Gibbons, 2016) within constrained timescales (Google, 2017).

Results

All participants across both study phases strongly agreed that user involvement during helicopter UI design is important whilst highlighting some potential challenges.

Phase one

Based on the questionnaire and interview results, current approaches to involving users within helicopter UI design cover all three levels illustrated in Figure **1** but are mainly consultative, with user involvement at various stages throughout the design process. The types of users involved are primarily highly experienced individuals often including test pilots. Users with less experience are also involved in order to ensure that the final UI is not optimised for expert users alone.

According to the helicopter design professionals the main benefits of involving users is their ability to help designers understand the problem and the context of use and align design activities with the user needs. This reduces the risk of having to make costly changes later in the design process. However, users can also be constrained by their experience with legacy systems and a limited knowledge of the latest technology developments which may make it harder for them to think about new or novel ways of achieving the same goal. Differences in opinion between users can make it harder to converge on a single acceptable design solution particularly if the specific individuals who are involved change throughout the project lifecycle.

Phase two

The PD workshop during phase two resulted in numerous design artefacts such as crazy 8's ideation sketches, voting heat maps, and low fidelity UI prototypes like those shown in Figure **4**.

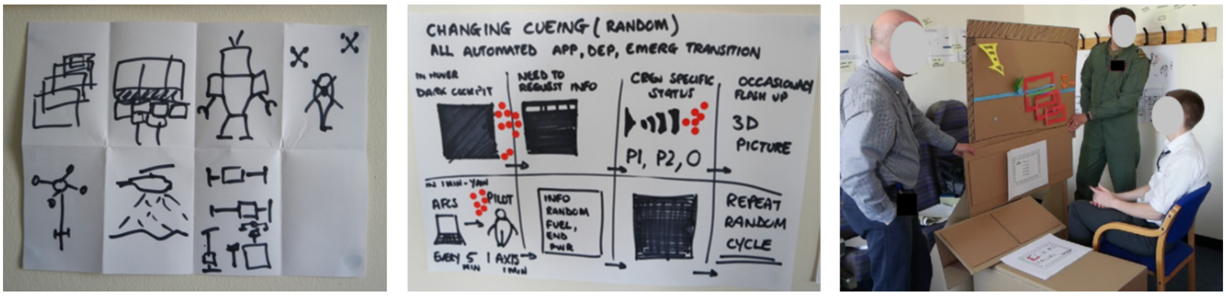

Figure 4. An example of a crazy 8's sketch, heat map voting, and paper prototype produced by workshop participants.

The stacked bar charts in Figure 5 **and**

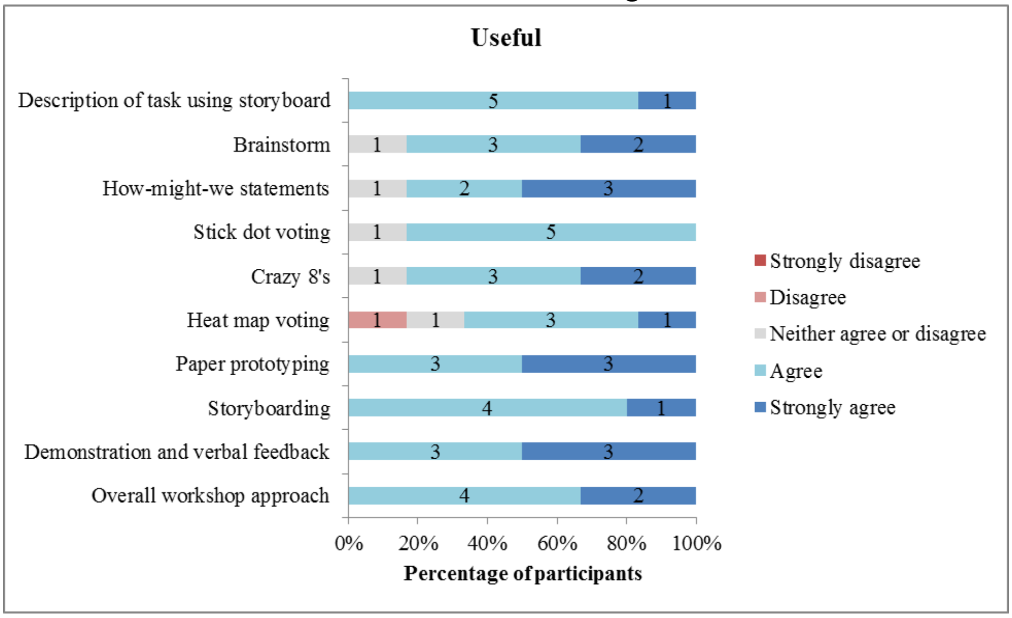

Figure **6** present the responses to the questionnaire rating scales regarding ease of use and usefulness. Overall, participant feedback on the methods was positive. There was some divergence in responses relating to the ease of use of the how-might-we statements and the usefulness of the heat map voting. The presence of a few 'neither agree or disagree' responses may indicate that there was some neutral sentiment or uncertainty from individual participants regarding the ease of use of the sticky dot voting, crazy 8's and heat map voting, and regarding the usefulness of the brainstorming, how-might-we statements, sticky dot voting and crazy 8's. However, in general the overall approach and its constituent methods were considered both easy to use and useful.

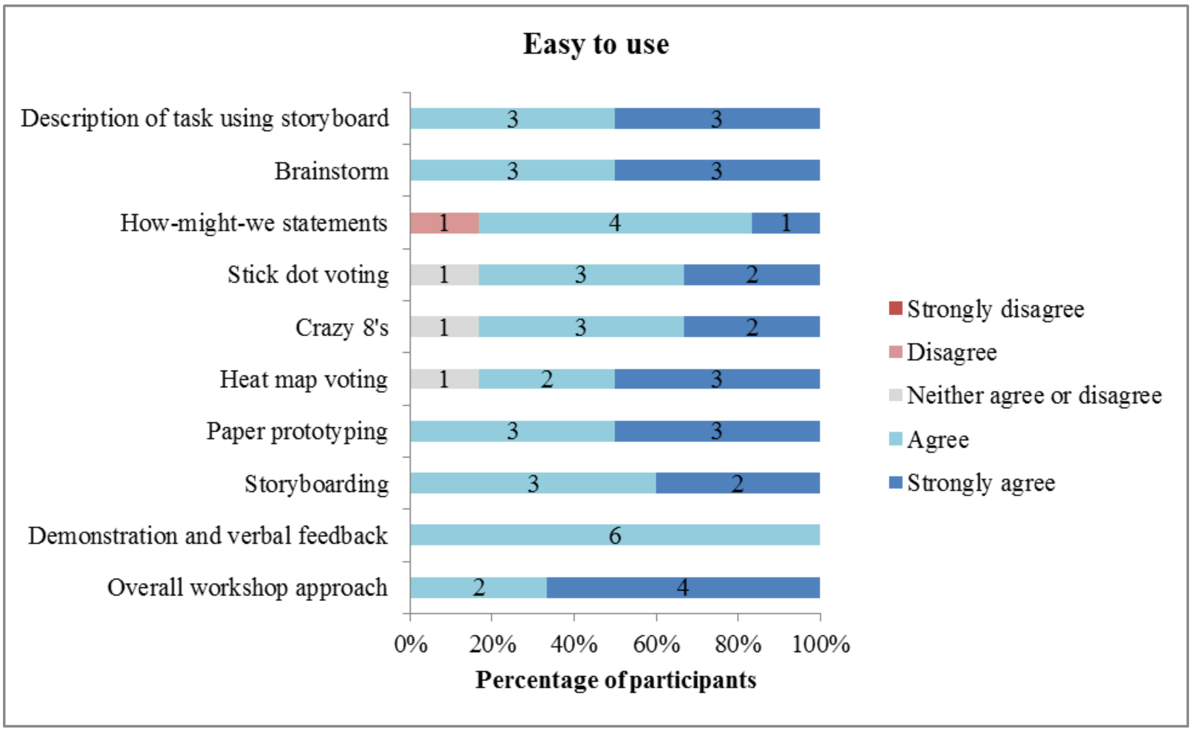

Figure 5. Distribution of participant ratings of ease of use.

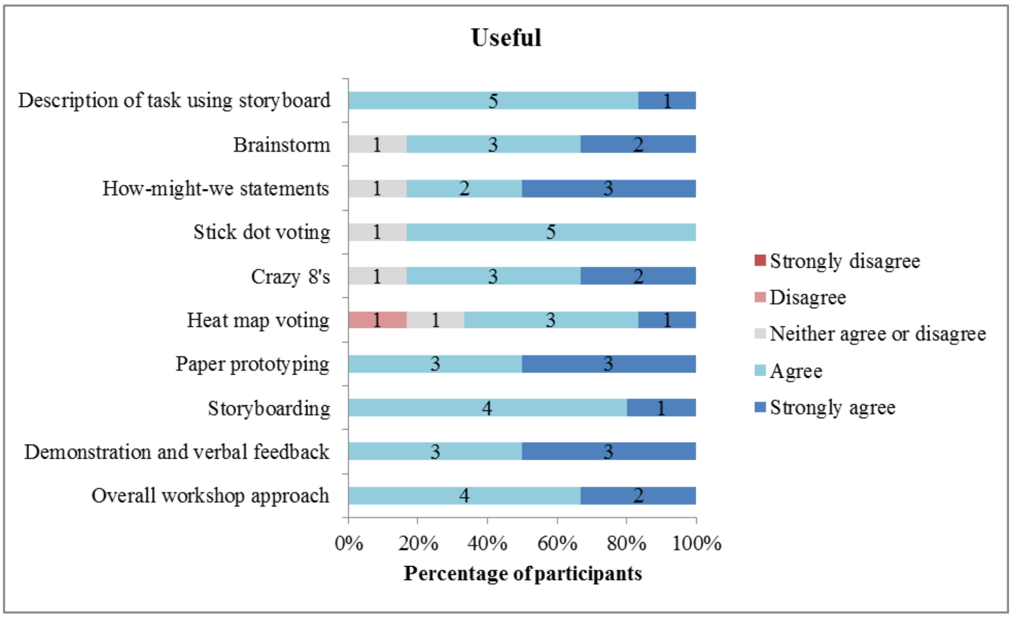

Figure 6. Distribution of participant ratings of usefulness.

A number of key themes relating to benefits and challenges emerged from the questionnaire responses and from the group interview. These are discussed in the following section.

Discussion

The overall PD workshop approach and its constituent methods were both easy to use and useful. The approach avoided focussing on specific technical solutions or allowing other limitations such as certification requirements to constrain the early development of risky or novel ideas. Therefore, this type of workshop would be most applicable during requirements definition and within early research and development activities where it could provide a rich source of information for understanding the problem and informing and prioritising requirements.

A major benefit of this approach was the opportunity to work collaboratively across professional disciplines, which supported findings from previous research (Ohlander et al., 2017, Olsson, 2004). This enabled a large number of diverse design ideas to be generated and then combined and developed further by taking advantage of the broad range of knowledge and experience in the group. The crazy 8's method was particularly powerful for quickly generating a large number of diverse ideas which the group could then build upon.

A challenge associated with this type of approach which encourages divergent thinking is whether it is compatible with a highly regulated industry like aviation. This provides further evidence to suggest that the approach should be applied early in the design process with regulatory and other constraints being considered afterwards. This would allow the design concepts to be refined throughout the rest of the design process to ensure their feasibility without constraining the potential for innovative ideas early on.

The interactive nature of the workshop led to a potential risk of bias during the voting and prototyping activities where the participants may have unintentionally influenced each other's decisions. In future this might be mitigated by ensuring that the voting activities are conducted anonymously and with a restricted number of 'votes' (as opposed to the heat map voting techniques) and by separating the groups into different rooms during the prototyping stage.

Two other areas that could be improved were the description of the intended outputs of the workshop as well as the participants' understanding of the context of use. Although the initial storyboard was well received, additional ways of immersing the participants in the context of use during the empathise stage (for example familiarisation activities using cockpit simulators or virtual reality) and clearly communicating the intended workshop outcome during the define stage should be considered within future work.

The strict time constraints for each of the activities and the single day format of the workshop were beneficial as they allowed the participants to see the design progress throughout the day and maximised the likelihood of attendance from busy personnel. However more time should be devoted to the prototyping stage as this activity provides a significant contribution to the main output of the workshop.

On reflection, the multi-phased action research approach focussing on a specific design case study worked well as it allowed the investigator to triangulate findings from across multiple stakeholder perspectives and data collection activities to identify emerging themes. One limitation of the study was the use of only one workshop session. This was mainly due to the limited availability of participants; however additional workshops may have increased the reliability of the findings and added richness to the data.

This study has therefore provided insights into current approaches for involving users within helicopter UI design, the benefits and challenges of doing so. It developed and assessed an approach for applying PD to the design of helicopter UI. Although the study was specifically focussed on helicopter UI design, the findings will be directly relevant to the design of other aircraft including within the civilian aviation industry. The main findings are likely to be generalizable to UI design outside of the aviation domain.

It is therefore recommended that this PD approach be applied within early research activities including those informing future military helicopter UI requirements. During any future application of this approach, the proposed modifications to mitigate the risk of bias should be implemented and the duration of the empathise and prototype stages extended. Future research areas might include investigation of using digital prototyping techniques during PD activities and the involvement of a broader range of stakeholders within PD workshops.

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