Collaboration and Awareness Amongst Flight Attendants

by

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Abstract

Collaboration is a core component of work activities amongst flight attendants as they work to promote onboard safety and deliver a high level of customer service. Yet we know little of how flight attendants collaborate and how we can best design technology to support this collaboration. Through an interview study with flight attendants, we explored their collaborative practices and processes and how technology aided such practices. While technologies like interphones and flight attendant call buttons acted as collaboration tools, we identified instances where the usability and functionality of these devices were the main barriers for maintaining efficient communication, situation awareness, and information exchange. Our findings inform the design of future technologies for enhancing communication and collaboration in an aircraft setting. As a proof of concept, we developed "SmartCrew", a smartwatch application allows flight attendants to maintain an awareness of each other and communicate through messaging with haptic feedback. It is designed with an emphasis on real time information access and direct communication between flight attendants regardless of their location.

Keywords: Flight attendants; situation awareness; workspace awareness; collaboration; pursers; cabin crew; Crew Resource Management (CRM)

Dedication

This thesis is dedicated to my two best friends: my sister Sharon Wong and my crazy flight attendant friend Kenny Chung. Without whom, this journey would not have been possible. Thank you for the laughs, the incredible support and constant patience.

And to my parents, and brothers who have been my angels and the best gift life has to offer. You mean the world to me!

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List of Acronyms

ACM	Association for Computing Machinery
AQP	Advanced Qualification Program
CSCW	Computer Supported Cooperative Work
CRM	Crew Resource Management
FA	Flight Attendant
FD	Flight Deck
FAA	Federal Aviation Administration
FAM	Flight Attendant Manual
HCI	Human Computer Interaction
FAM	Flight Attendant Manuals
LOFT	Line Oriented Flight Training
SOPs	Standard Operating Procedures
SPOT	Specific Operational Training
UBICOMP	Ubiquitous Computing
UI	User Interface
UX	User Experience

Chapter 1. Introduction

Collaboration amongst flight attendants is important as they are responsible for the delivery of both customer service and on-board safety. Miscommunication or error has the potential to be embarrassing and highly publicized (Skogstad et al., 1995; Salas et al., 2001). The need to optimize the communication process between pilots and cabin crew is emphasized, but there is little research that focuses solely on collaboration amongst flight attendants during flight operation (Skogstad et al., 1995; Salas et al., 2001; Krivonos, 2007; Zhu & Ma, 2015). The collaboration process applied by flight attendants is extensive; but there exists a gap in understanding how collaboration occurs and what is required (Endsley et al., 2003). My research studies this collaboration process from a Human Computer Interaction (HCI) perspective, which pertains to the examination of the design and use of technologies (Hewett et al., 2009).

In this chapter, I provide an overview of the steps I took to understand the collaboration process, and the current use of collaboration tools by flight attendants. Further, I define the research questions and goals that my research aims to address. In conclusion, I explain the methodological approach to address the research problems and provide an outline of the chapters to follow in this thesis.

1.1. Background

1.1.1 The Importance of Collaboration in Aviation industry

In the 1950s, as flight operations expanded from single to multi-operator, the significance of synchronized teamwork in the aviation industry was initially overlooked and underestimated (Helmreich & Foushee, 2010). This posed a challenge to improve aviation safety (Helmreich & Foushee, 2010). Consequently, rigorous operator training and improvements were made to the cockpit interface but it did not reduce the number of accidents with US commercial and charter flights. Such fatal discrepancies claimed an average of 240 lives per year in the US (Ligda et al., 2015). However, in the early 1970s, insight from interviews conducted with pilots led to an understanding that flight accidents may be due to a lack of crew coordination and communication rather than individual skills (Helmreich et al., 1999). Thus, in 1981, United Airlines (an American air carrier) was the first airline to provide training for its cockpit crews (Helmreich et al., 1999). By the 1990s, it had become a standard practice globally and training was extended from the cockpit to the entire flight crew (Helmreich et al., 1999). This training was titled: Crew Resource Management (CRM) (Helmreich et al., 1999; Salas et al., 2001; Midkif et al., 2004). While some airlines gradually adopted similar practices, some faced challenges in integrating such training into their organizational culture and operational setting. Consequently in 1999, the Federal Aviation Administration (FAA) of the United States permitted aircraft carriers to tailor training to meet their specific needs whereby, under the Advanced Qualification Program (AQP), both CRM and Line Oriented Flight Training (LOFT) were made compulsory for the entire crew (Helmreich & Foushee, 2010; Ligda et al., 2015). Since then, CRM training has evolved into five generations with a history of two decades (Salas et al., 2001). The generations focused on different issues beginning from psychological testing, to cockpit group dynamics, to the inclusion of other crews (e.g. Cabin crews, maintenance personnel), and to the integration and proceduralization of crew training (Salas et al., 2001). In the last generation, the CRM training acknowledged that human error is inevitable and to prepare for such error, the training must aim to build the crew’s capacity in managing errors proactively and without punishment (Helmreich et al., 1999).

The CRM training helps flight attendants develop skill in team building, information sharing, problem solving, decision-making, situational awareness, and dealing with automated systems (Helmreich et al., 1999; Salas et al., 2001; Midkif et al., 2004). These skills are meant to help flight attendants to: (a) avoid error made by humans or machines (b) detect errors (c) mitigate the results of any error (Salas et al., 2001). Studies show that while the CRM training is beneficial, it focuses on critical situations and emergency evacuation and not on non-emergency communication (Helmreich et al., 1999; Salas et al., 2001; Ligda et al., 2015), such as social support (Tang, 1991; Helmreich, 1984), feedback, supervision, and leadership (Algera, 1990). As part of the training to maintain an awareness of the entire cabin, flight attendants are also trained to learn how to use inflight tools for collaborating amongst each other.

The collaboration tools found in today's aircraft are the interphone, the flight attendant call button, visual indicators (no-smoking sign, seat belt sign), and audio alerts (Crets, 2013; "Cabin Chimes," 2016; "Cockpit/Flight Attendant Communication Question," 2016). These collaboration tools are important as their availability reflects a high degree of awareness and coordination as analyzed by pilots in a simulated aircraft (Ligda et al., 2015). It is highly likely that in the near future, flight decks will become increasingly automated and communication systems will become more advanced (Travelmail Reporter, 2014; Kollau, 2015; Future Travel Experience, 2015). Therefore, it is important to understand how technology supports flight crew collaboration in a distributed setting. This will also improve a flight attendant's adaptability to the crew in each flight, as well as reduce conflicts among the crewmembers during high workload, time pressure and air-space constraints (Mosier et al., 2013; Bearman et al., 2015).

1.1.2 Situation Awareness, Workspace Awareness and Distributed Cognition

People need to constantly maintain an awareness of their surroundings and coordinate with team members in highly dynamic, complex, uncertain, and risky environments. This involves several components. First, team members need to have a ***shared mental model*** which is the mutual understanding or description of the tasks, goals, strategies and team members (Mathieu et al., 2000; He et al., 2007). This knowledge structure will serve as their common ground to communicate with all team members (Carroll et al., 2006; He et al., 2007). Second, team members need to have the "up-to-the-moment understanding of another person's interaction with the shared workspace" called ***workspace awareness*** (Gutwin & Greenberg, 1996). By keeping track of other's current activities, team members are aware of the appropriate moments to effectively collaborate (Gutwin & Greenberg, 1996). Third, team members need to have ***situation awareness*** which is being alert and knowledgeable about the activities taking place in the environment (Adams et al., 1995; Endsley et al., 2003). Most teams fare well in monitoring the environment, but they struggle to perceive the critical components that are relevant for predicting the next steps and responses in a timely and appropriate manner (Endsley et al., 2003). This can further create communication breakdowns, increase the teams workload and deteriorate the overall teams performance (Ligda et al., 2015). Thence to maintain a high degree of situation awareness, team members also need to be have prior knowledge to fill the gap in their perception and implications of the given situation (Adams et al., 1995).

To design systems for awareness, one needs to understand cognitive theories focused on understanding how people achieve team cognition and successfuly collaborate synchronously and asynchronously. One such theory is ***activity awareness***. Activity awareness is a CSCW framework to understand how knowledge of people, projects and places can be shared via interactions over extended time periods (Carroll et al., 2006). It contains four main parts: ***common ground*** involving full or partially shared knowledge beliefs (Carroll et al., 2006), ***communities of practice*** (tacit knowledge of expected behaviors and roles) (Wenger et al., 2002), ***social capital*** (creating social good through trust) (Coleman, 1988), and ***human development*** (capability to react to new changes in tasks) (Vygotsky, 1980).

Flight attendants work in a distributed setting, which means that ***distributed cognition*** is built using shared mental models, as well knowledge of the social, cultural, and physical context (Hollan et al., 2000b). This includes knowledge sharing through the shared use of physical artifacts in the environment, e.g., boundary objects (Star & Griesemer, 1989), as well as expertise sharing that occurs through interactions and communication (Hollan et al., 2000b). ***Ubiquitous computing*** looks into how these interactions are supported by the tools and physical artifacts in a distributed setting, so that complex workflows can become seamless, pleasant and have less cognitive load.

My research explores and examines the gap in knowledge around how flight attendants collaborate and use collaborative technologies. Very little research has focused on how flight attendants use technology to maintain and support awareness and collaboration and how technology should be designed to meet any challenges in usage. Therefore, I am interested in understanding the experience flight attendants have when collaborating and learn how future collaborative technologies should be designed to improve workplace practices.

1.2. Research Problems

The overarching problem addressed by this thesis is that: *we do not know how flight attendants collaborate and how we can best design technology to support this collaboration.* This is divided into several sub-problems listed below:

1. **We do not know how flight attendants maintain situation and workspace awareness.** In general, there has been studies on how flight crew (Sarter & Woods, 1995; Ligda et al., 2015), anesthesiology (Gaba et al., 1995) and firefighting (Jiang et al., 2004) are able to maintain their situation and workspace awareness, however we do not know how this applies to flight attendants specifically in domestic and international flights.

   The Crew Resource Management Training provides a basic level of training around creating shared mental models, but there is little research that details the kinds of information that flight attendants in different roles/positions need to keep track of in their shared workspace, the way information is gathered to create situation and workspace awareness and how flight attendants use this awareness to predict behaviours and ensure effective crew and workload management.

2. **We do not know what challenges flight attendants face when using existing collaborative technologies in normal and emergency situations.** The physical space, number of passengers/crew members and collaboration tools vary based on the aircraft that is flying for a domestic or an international flight. Collaborating in these different aircrafts can be evaluated to some extent based on the simulations (Dowd, 2010). However, there is little research that details the problems from the flight attendant's perspective in using these tools to collaborate for the different activities and uncertain situations inflight. We do not know if flight attendants face challenges when collaborating either to communicate procedures, coordinate activities or for task assistance in a real-time distributed setting.

3. **We do not know how to design new technologies such as smartwatches that will support flight attendants' awareness and collaboration needs.** Inflight collaboration tools have been updated in different airlines (domestic and international), and introduced to crewmembers (Travelmail Reporter, 2014; Kollau, 2015; Future Travel Experience, 2015). However, there is a lack of research that informs the design of new technologies for flight attendants practices and needs. We do not know what design recommendations should new technologies include to support flight attendants' awareness and collaboration needs.

1.3. Research Goals

To address the research problems, the overarching goal of this thesis is to *understand the collaborative practices of flight attendants and inform the design of future technologies that will help them maintain awareness and collaborate effectively*. The research problems helped us to define the following research sub-goals:

1. **Describe how flight attendants maintain situation and workspace awareness (RP.1):** I will conduct a user study with eleven flight attendants from domestic and international airlines to understand what awareness information is pertinent in each work role/position/responsibilities. Using a qualitative research methodology, I will study flight attendants' experiences and investigate how they gather awareness using direct communication and visual cues, body language, gestures, and other forms of non-verbal communication.
2. **Describe the challenges flight attendants face when using existing collaborative technologies in normal and emergency situations (RP.2).** Based on the user study, I investigate the activities flight attendants perform with collaborative technologies. I explore the present technological constraints, lack of shared resources and the affordances of the setting (such as a physical workspace) when there are changing requirements in the different phases of the flight, need for real time information, and immediate assistance in normal and emergency situations.

3. **Investigate how to design a smartwatch application as a proposed solution that will support flight attendants' awareness and collaboration needs (RP.3):** To design solutions for enhancing communication, one needs to know in which context the communication takes place and how it should be interpreted (Kanki, 2010). As a HCI researcher and designer, it allows for identifying an appropriate and effective solution for new technologies. For this purpose, the first two research goals determined who the communicators are (which are the social/organizational context), where the communication takes place (the physical context), during what flight phase and under what operational conditions (task/operational context) does the communication breakdown occurs. In the third research goal, I ascertain the user-centered requirements that are essential for flight attendants in a distributed setting and suggest potential design implications and a smartwatch application as a proposed solution for supporting the awareness and collaboration needs of flight attendants.

1.4. Methodological Approach

The Association for Computing Machinery (ACM) defines Human Computer Interaction (HCI) as "a discipline concerned with the design evaluation and implementation of interactive computing systems for human user and with the study of major phenomena surrounding them" (Hewett et al., 2009). The field of Computer Supported Cooperative Work (CSCW) studies the interdependencies of activities and their coordination between collaborating human actors and computer systems, i.e. how does the design of computer tools support group work (Schuler & Namioka, 1993; Carstensen & Schmidt, 1999). As my research questions focus on how interactions take place between flight attendants and technology in a distributed setting, this research falls under the umbrellas of HCI and CSCW. In addition, as the airline industry is moving towards innovative technologies where computing is pervasive, and the benefits are available from anywhere and at anytime, my thesis falls in the field of Ubiquitous Computing (Ubicomp) (Weiser, 1999). Under these umbrellas, I explored the interactions between flight attendants that are shaped by their practical needs to collaborate effectively.

A qualitative research methodology was appropriate as it allowed me to investigate the meanings behind flight attendants' social and culture experiences, ideas, beliefs and values and to ascertain and theorize prominent issues (HCI and CSCW) (Corbin & Strauss, 2008; Creswell, 2012). Among the different methods for qualitative research, interviews is the most common and observations act as an confirmatory evidence for the interviews (Schuler & Namioka, 1993). I conducted semi-structured interviews with a sample size of three pursers and eight lead/cabin crewmembers from domestic and international airlines. I targeted different airlines to understand how collaboration occurs in both small and large aircraft. Semi-structured interview questions aid researchers by allowing them to have in-depth discussions with participants (Corbin & Strauss, 2008). Participants were asked to answer open-ended questions and cite examples from their daily routine as well as from occasional incidents to explain their work practices (Corbin & Strauss, 2008).

This thesis represents work that has been done in collaboration with Samsung (Canada) as our grant partner. The length of the research grant was for six months, which was extended to additional four months (covering a total of ten months). The process with Samsung involved collaborating with a team of User Experience and Marketing managers to discuss three milestones: a brainstorming session for selecting an idea for using smartwatches, a feedback session for the user studies and design tools (persona, purser experience map, design scenarios) and a demonstration session for showing the final design of SmartCrew. These collaborative sessions included visits to Samsung's Vancouver office and exchanging emails. Samsung also supported us with additional devices (Android phones and smartwatches) for testing the right medium for the smartwatch design.

1.5. Thesis Overview by Chapter

This section provides an overview of the research presented over the following eight chapters. In Chapter 2, I present a literature review of past research that defines the nature of teams, and how team cognition and distributed cognition are developed for supporting awareness and collaboration. In addition, I investigate how these theories are applied presently in the aviation industry. In Chapter 3, I describe the research methods used in my study. In Chapter 4, I present the findings and insights derived from the study. In Chapter 5, I discuss the findings and compare the insights to other teams who also work in highly dynamic, complex, uncertain, and risky environments. The discussion touches on challenges and trade-offs around providing real-time feedback in a team environment. I conclude with design implications for future technologies to foster a high level of situation awareness and workplace collaboration amongst flight attendants. In Chapter 6 and 7, I describe the design process and steps to accomplish the design and implementation of a prototype system to support flight attendants' collaborative needs. In Chapter 8, I conclude the thesis by summarizing how I achieved my research goals. I also list my research contributions and suggest areas for future work in designing tools to support awareness and collaboration amongst flight attendants.

Chapter 2. Related Work

In this chapter, I review the literature related to my research. First, I explore ***team cognition,*** which is a building block for effective team performance. Then, I describe the theory of ***distributed cognition*** to understand the interactions between individuals, physical artefacts, and tools in the environment. Second, I review how teams' distributed cognition is attributed through shared mental models, situation awareness, and workspace awareness. Third, I describe the related work around standard practices and systems that have been developed to support ***team cognition in the aviation industry.*** Lastly, I review the literature review on ***smartwatches*** to ground it as my proposed solution for flight attendants.

2.1. Team Cognition

According to Salas et al. (1992), a team can be defined as "a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership" (Tullo, 2010). In a fully functional system, the coordination of actions in a collaborative activity is "seamless." That is, actions are executed in the right time, right order, right place, and meet a task's constraints (Gutwin & Greenberg, 2002a; Salas & Fiore, 2004). This execution of coordinated behaviors amongst team members is called ***team cognition*** (Hollan et al., 2000; Salas & Fiore, 2004). Team cognition then becomes crucial in complex real world tasks and safety critical domains that require a high level of coordination for effective decision making. For example, air traffic management, which comprises of pilots and air traffic controllers (Ligda et al., 2015) and fire rescue squads, are required to work together to make effective decisions under high pressure during cognitively demanding tasks (Bearman et al., 2010). Achieving successful team cognition is not easy though. Workers must develop a shared mental model and situation awareness to work effectively in a distributed setting. I describe these concepts next.

2.1.1. Distributed Cognition

Distributed cognition is known to be about ***mental structures (cognitive process),*** such as shared mental models, as well as knowledge of the ***social, cultural, and physical*** contexts (Carroll et al., 2006). It is a theory commonly studied in the design of technologies to explain the interactions between individuals, physical artefacts (boundary objects), and tools in the environment (Hollan et el,. 2000b). It emphasizes the active participation of individuals and states that "individuals working together on a collaborative task are likely to possess different kinds of knowledge and so will engage in interactions that will allow them to pool the various resources to accomplish their tasks" (Hollan et al., 2000a). Thence, having computers at different locations does not enable a collaborative or ubiquitous system; instead collaboration is enabled by how the ***cognitive process*** is ***socially*** distributed across team members, and how team members interact and ***culturally*** solve a problem using the ***physical*** devices to exchange information offered in different locations and times (Weiser, 1999). The interplay of interactions is what will bring communities closer together and form connections between team members (Weiser, 1999). This is also supported by Cooke et al. (2007) who believe that team cognition emerges through the interactions of team members, and the transfer of interactions across different tasks done with the support of technological tools. This implies that when team interactions are not present, team members can rely on a shared mental model or team situation awareness to effectively coordinate (Cooke et al., 2007). However, all three need to be collectively and effectively applied, else it will influence team cognition and impact a team's overall performance leading to different shared mental models. Thus, distributed cognition is a useful theory for informing the design of collaborative technologies as it takes into account how new technologies might *"fit into or disrupt current working practices"* (Rogers & Ellis, 1994).

Early theories promote the idea of team members producing a ***shared mental model*** or representation of a situation to aid team cognition (Mathieu et al., 2000; Mohammed et al., 2000; Sawer, 2015). Research shows that teams with a shared mental model are likely to work better together as they interpret cues and prioritize information in a similar manner (Mathieu et al., 2000; Endsley et al., 2003; He et al., 2007). They take coordinated actions and make compatible decisions to manage situations in their environment (Mathieu et al., 2000; Endsley et al., 2003; He et al., 2007). Such as Cooke et al. (2007) compared experienced teams to inexperienced teams in an uninhabited aerial vehicle (commonly known as a drone) simulation; they found that experienced teams had fewer errors on process related-training knowledge and scored higher on areas of communication and coordination, team decision making, team situation awareness, and the overall process. Thence, sharing the same mental model can improve team synchronization and team cognition and reduce the need to explicitly communicate, as noted by studies on firefighter training (Jiang et al., 2004; Toups & Kerne, 2007). This also suggests that team members who are familiar with each other and have been trained together tend to develop faster team cognition (Cooke et al., 2007; He et al., 2007; Toups & Kerne, 2007). They can perform their tasks better in a group setting as they share the workload, monitor the work behaviors of other members, and develop and contribute expertise on subtasks (Smith & Hancock, 1995; Mathieu et al., 2000). Cross training in multiple roles has also shown to be an effective way to help team members create a shared mental model and be easily assigned to different roles as the situation warrants (Toups & Kerne, 2007).

However, studies of flight attendants have shown that they prefer to be scheduled together for successive shifts and long periods of time for high team performance; however, this is challenging to achieve in practice and crew members must frequently work with new team members (Skogstad et al., 1995). Even within a highly coordinated and equipped training system, as is the case in the aviation industry, individuals may still experience difficulty in accessing shared knowledge or may encounter a mismatch in shared expectations (Perrow, 1985; Rogers & Ellis, 1994). This can lead to major breakdowns and a failure to act in the right manner at the right time (Rogers & Ellis, 1994).

CSCW researchers have reflected on the concept of shared mental models to describe its limitations as a static theory for understanding distributed cognition, as it does not help team members to refactor/transform information to solve these breakdowns and ill-structured problems of high uncertainty (Vygotsky, 1980; Carroll et al., 2006). Teams then have to tap into a diverse and boarder network of information, where interactions are with team members who have complementary knowledge and can supplement the expertise to solve the ill-structure problems (Holland et al., 2000b).

To understand this dynamic nature of team's interactions, ***activity awareness*** identifies four facets of awareness that teams can maintain while team members are collaborating with one another (Carroll et al., 2006). The first facet is ***common ground,*** which is the availability of shared information/knowledge such as having a shared mental mode and situation and workspace awareness, as explained earlier (Carroll et al., 2006). The second facet is ***communities of practice,*** which builds on the idea of integrating team members' roles, behavior or decisions into best practices or patterns (Wenger et al., 2002). These include learning from one another, sharing, and refining core goals, values, and practices. Team members perform their work activities by planning, coordinating efforts, and providing and receiving advise from one another to improve the team's overall performance. The third facet is ***social capital***, which is the creation of social goods (Coleman, 1988). Team members who share a strong network of trust (i.e. built from mutually beneficial or satisfying interactions) are motivated to personally contribute and share a collective achievement. Such as in times of divisive and stressful moments, team members share the social good of assisting one another in each other's work. They know that by being cooperative, others will also help them when they require assistance (Coleman, 1988). The fourth facet is ***human development,*** which is the articulation of behavioral patterns that are drawn by members and teams working together to solve ill-defined, complex problems (Vygotsky, 1980). This facet focuses on grooming an individual to become more capable over time and assume new roles and perform better in new and complex tasks (Vygotsky, 1980). In my research, I focus on the first facet of awareness, i.e. common ground for flight attendants, and provide an overview on the other facets that may have an impact on a flight crew's performance as a team. Following this, I discuss the remaining first facet of awareness: situation and workspace awareness.

2.1.2. Shared Situation Awareness

For effective team cognition, collaborators need to be aware of the conditions around them and communicate efficiently amongst team members (Cooke et al., 2007; He et al., 2007; Belkadi et al., 2013). This involves ***situation awareness***: "being aware of what is happening around you and understanding what that information means to you now and in the future" (Adams et al., 1995; Endsley et al., 2003). Situation awareness equips people with an understanding of what information is required to accomplish a particular task and the formation of knowledge through interactions with team members (Heath & Luff, 1992; Gutwin & Greenberg, 1996; Endsley et al., 2003). In highly dynamic, complex, uncertain, and risky environments, the role of situation awareness becomes pivotal. This has been seen in studies of commercial aviation (Sarter & Woods, 1992), anesthesiology (Gaba et al., 1995) and firefighting (Jiang et al., 2004), where collaborators are able to see or hear the same information, but they understand it differently (Heath & Luff, 1992; Dourish & Bellotti, 1992; Endsley et al., 2003; Salmon et al., 2010). For instance, Sarter & Woods (1992) explored the interactions between pilots and the Flight Management System (comprised of electronic flight instrument displays). Compared to traditional analog dials and gauges, the electronic flight instrument displays can help pilots to manage pertinent information and control the mode (altitude) best suited to a flight situation (Sarter & Woods, 1992). However, even though both pilots share the same information displayed in the Flight Management System, they still lacked the mental model in understanding the functionality of each mode and tracking and predicting the modes' behaviours. This led to an increased cognitive load and mode-related errors during the different phases of the flight (Sarter & Woods, 1992).

To maintain situation awareness, Endsley et al. (2003) explains that there are three main levels: 1) the perception of the elements in the environment, 2) comprehension of an element's meaning, and, 3) the prediction of consequences in the near future. Many teams face challenges in the third level when they attempt to apply what they know from their current situation to predict future actions and outcomes in a dynamic environment (Endsley et al., 2003). Failure to reason independently and collectively as a team (in situation awareness) is likely to lead to inappropriate decision making and to negative consequences for the team (Belkadi et al,. 2013). In the case of anesthesiologists, they must make decisions based on rapid events in surgery and share the same mental model with other professionals (anesthesiologists, surgeons and nurses) in the operating room. Such as in the real case example of a lung operation, where the surgeons lacerated the right atrium of the heart, causing massive blood loss and very low blood pressure (Gaba et al.,1995). The surgeons placed a large clamp across the laceration site and instructed the anaesthesiologists to administer two liters of fluid into the patient's intravenous (IV) lines to improve the blood pressure. One anaesthesiologist was adding an additional (IV) line, but the other anaesthesiologist understood the situation and predicted that the additional (IV) line would not improve the blood pressure, therefore this anaesthesiologist suggested to the surgeons to place it directly in the heart beyond the obstructing clamp. This resulted in a successful repair of the lung and avoidance of any risk to the patient that may lead to permanent injury such as death or brain damage (Gaba et al.,1992; Gaba et al.,1995).

To help anaesthesiologists make dynamic decision making, Gaba et al. (1992) proposed five levels for maintaining awareness: the ***sensorimotor level,*** i.e. learning to perceive the world using senses, the ***procedural level,*** i.e. where one follows a set of rules to make decisions, and a level of ***abstract reasoning,*** i.e. referring to the basic knowledge base to make inferences. The fourth level is the ***supervisory control level,*** i.e. the allocation of attention, prioritization of tasks, and the fifth level involves the scheduling of actions and ***resource management,*** i.e. the mobilization and utilization of available resources, the distribution of workload, and communication with other personnel. Similar to Endsley et al. (2003), the ***supervisory control level*** includes the process of Observation, Decision, Action, and an additional component of Re-evaluation (Gaba et al., 1992; Gaba et al.,1995). Re-evaluation is the continuous reassessment of the situation to successfully solve problems in a dynamic situation (Gaba et al., 1992; Gaba et al.,1995). In the case of firefighters, shared situation awareness includes making quick decisions in high stress environments, but also constantly reassessing dynamic situations, revising plans and reshuffling priorities to alert people of the potential danger to themselves and to their fellow firefighters (Jiang et al., 2004). Jiang et al. (2004) developed a context-aware messaging application that allows firefighters to exchange information about their situation and their surrounding environment in a spontaneous and opportunistic manner. Through this constant interaction, firefighters are able to achieve a high degree of situation awareness and are able to respond and adapt to situations effectively (Jiang et al., 2004).

We have seen studies of situation awareness in several areas of work practices including the cockpit, but it has not been studied in detail in terms of how flight attendants maintain situation awareness amongst themselves.

2.1.3. Workspace Awareness and Coupling

Workspace awareness is part of situational awareness; it is the "up-to-the-moment understanding of another person's interaction in a shared workspace" (Gutwin & Greenberg, 1996). This means that workspace awareness occurs within the temporal and physical bounds of the task that a group is carrying out over a visual workspace. To gain awareness of one's workspace, the knowledge of 'Who' (team member's role: presence, identity and authorship), 'What' (actions, intentions and artifacts) and 'Where' (location, gaze, view and reach) are important questions that needs to be addressed for coordinating seamlessly with others (Gutwin & Greenberg, 1996). To achieve an awareness of the workspace, team members use a combination of verbal and visual communication as their primary source of information (Brinck & Gomez, 1992; Gutwin & Greenberg, 2002b). Verbal communication can include either explicitly talking about one's work activity and the position held or by overhearing others' conversation. For example, the study by Hutchins (1990) illustrates how team members on a ship perform navigation tasks while talking aloud over a phone circuit. The open conversations allow other team members to be updated and stay vigilant about the changing environment. Visual communication is important for workspace awareness. Visual communication is gained by observing and monitoring team members' gestures, bodily actions, activities, and whereabouts, and the presentation and manipulation of artefacts (Gutwin & Greenberg, 2002a; Gutwin & Greenberg, 2002b). Gestures can be performed with one's body motion, face, mouth and eyes to control devices or to enhance communication (Bieber et al., 2012). Gestures and bodily actions are visual cues of the movements of a person's head, arms, eyes or hands. The difference is gestures are explicitly communicated by the sender, while bodily actions are not intentional and merely picked up by the perceiver (Gutwin & Greenberg, 2002b). While artefacts are 'conversational props' or boundary objects that, by their positions, orientations, and movement, can show the state of people's interaction with them (Brinck & Gomez, 1992). For example, during a study of pilots, researchers found that pilots spent approximately 60% of their time observing their partner's display, while it was being used. Besides the information transferred by the display, the pilots were also specifically observing the dynamic interaction between their team member and the display (Segal, 1995). The visual evidence of looking at what their partner was gazing at and what information on the display (the artefact) helped to provide the pilot with an understanding of what their partners were working on. In such dynamic interactions, team members also make use of deictic reference, which is the practice of pointing or gesturing at a noun (in this case, a display) to confirm if they understood their partner's actions correctly (Tang, 1991; Segal, 1995).

Collaborators use knowledge of workspace awareness to obtain a mutual understanding about the coordinated tasks and resources, to anticipate the actions of others, interpret deictic references to objects, and find opportunities to effortlessly and seamlessly assist one another with individual and shared tasks (Dourish & Bellotti, 1992; Segal, 1995; Gutwin & Greenberg, 1996; Gutwin & Greenberg, 2002a; Carroll et al., 2006). The degree to which collaborators work together between individual and shared work is called "coupling" (Tang, 1991; Tang et al., 2006). When a collaborator needs to wait for a team member to finish their work before beginning his/her own task, it is called "tightly-coupled" work. When both collaborators can continue working with their own tasks without any interaction with other group members for long periods of time, the work is called "loosely-coupled" (Mohammed et al., 2000). Collaborators come together for various reasons such as to discuss/decide/plan the next activity or current task that would require another team member's involvement (Gutwin & Greenberg, 1996).

We have seen study of workspace awareness being applied in several areas of work practices, but it has not been studied in detail for flight attendants.

2.2. Team Cognition in Aviation

The significance of team cognition in training crewmembers cannot be emphasized enough. Given its importance, airline operators have made training around team cognition a requirement as part of CRM training before flight attendants can take a position in-flight (Ballard et al., 2004; Midkif et al., 2004; Transport Canada, 2016). Ideally, training conducted inflight would be most effective to test the CRM skills; however, due to the limitations of operational costs, increasingly congested airspace, and safety, airline operators use class lectures and computer assisted simulations (Dowd, 2010).

2.2.1. Class Lectures and Simulations

Class lectures include the introduction to each crew member's roles responsibilities and position (such as who is doing what and when) and the general state of the aircraft (i.e. location, course, altitude, flaps configuration, etc.). These work roles also known as the Standard Operating Procedures (SOPs), along with the aircraft details, are documented in the Flight Attendant Manual (FAM) (Orlady, 2010; Transport Canada, 2016). The objective of inserting SOPs in the flight attendant manual (FAM) is to replace the time and effort spent by the senior crewmembers in explaining routine related information and making it accessible to new crewmembers at all times (Orlady, 2010). As per Dowd (2010), the aim of the classes is to equip new crewmembers with knowledge of how to build a shared mental model or common ground to understand and coordinate tasks effectively in flight attendants' workspace, while the simulations are training facilities designed to look like a real aircraft. Without being in the aircraft in person, the trainings assess team performance based on team members' skills to manage the operational environment and process information that is made available. Flight crews are assessed on their ability to make a series of low-risk, safe decisions on scenarios that are based on typical daily operation with reasonable and realistic difficulties and emergencies (Dowd, 2010). Both classes and simulation trainings are required to be qualified as a flight attendant, however, which one is appropriate and mandatory is discussed next (Dowd, 2010).

2.2.2. Standard Evaluation Trainings/Programs

The goal of the standard evaluation training/program is to provide the platform for practicing both technical and CRM skills in observable event sets. One of the several training and evaluation programs, regulated under the Federal Aviation Administration (FAA) and Advanced Qualification Program (AQP), is the Line Operational Simulations (LOS). The LOS is designed for pilots and flight attendants (Dowd, 2010). The LOS is sub-divided into three categories: 1. Line Oriented Flight Training (LOFT), 2. Specific Operational Training (SPOT), and 3. Line Operation Evaluation (LOE) (Dowd, 2010). LOE is used to assess a pilot's expertise and proficiency in particular skills, which are deemed significant to the overall flight safety (Dowd, 2010). While both LOFT and SPOT are used to train the entire flight crew and heavily rely on scenarios that simulate and resemble inflight experiences, there is a slight difference between LOFT and SPOT. LOFT is a thorough program that simulates the entire inflight experience including pre-flight, inflight and post-flight events (Dowd, 2010). LOFT is used both for qualification and recurrent training purposes and includes details on the completion of prep-work, paperwork, communication with air traffic control and company facilities, and performing routine procedures for a normal flight (Dowd, 2010). In contrast, SPOT is designed with specific training objectives. SPOT is partially made up of segments based on a trainee's need, such as remediation on CRM skills in a specific phase of the flight. Also, SPOT allows instructors to intervene in a scenario and provide feedback. These programs are considered to be effective as they help to evaluate the communities of practice, i.e. how crewmembers employ their skills individually and collectively as a team (Carroll et al., 2006; Dowd, 2010). In my thesis, I show the breakdowns that occur in flight attendant work practices, despite the aforementioned training.

2.3. Smartwatch Design

In later chapters of my thesis, I describe the design and development of a smartwatch application as a potential prototype to address flight attendants' needs. Therefore, I now describe the past literature on interacting with smartwatches. A smartwatch is a wrist-based device that has miniaturized computing powers with a capable processor, graphical display, sensors, and wireless communication capabilities

(Motti & Caine, 2016). Their small display makes them unobtrusive and provides discreet access to phone notifications, applications and incoming calls (Motti & Caine, 2016). With minimal user input and micro interactions, such as touching on-screen targets using gestures (directional swipes, pinch, tap), users can attain their required information in seconds (Xiao et al., 2014; Akkil et al., 2015; Shimon et al., 2016). Besides gestures, there are also physical inputs to interact with the smartwatch, for instance Apple Watch (Flaherty, 2014; "Watch," 2016) uses pressure sensitive input and a side-mounted dial to perform zooming and scrolling, while Samsung Gear S2 ("Learn How to Use Your Samsung Gear S2 Smart Watch," 2015) uses a similar spinning front bevel. Due to the small display, past studies have tried to optimize the touch input and solve the 'fat finger' and 'occlusion problem' on smartwatches in a diverse way. The fat finger problem refers to the relatively large size of a user's finger in comparison to the target size on the touch screen (Shimon et al., 2016). The occlusion problem refers to the blocking of the viewable screen due to the relatively wide finger surface (Shimon et al., 2016). There have been a vast number of studies that look into improving smartwatch input and assisting in daily tasks (e.g. sending short messages or searching for directions).

In the area of optimizing text entry, Oney et al. (2013) and Chen et al. (2014) used a QWERTY keyboard. Oney et al. (2013) prototype Zoomboard, was evaluated with six participants in a text entry experiment (Figure 2.1a). They used taps to enlarge target sizes via iterative zooming. Users can first tap the surface to zoom-in and then tap to choose the letter they want. Users continue to tap until the preferred word is complete. Their results revealed that Zoomboard is as accurate as a full-sized physical keyboard and participants found the zooming keyboard was more satisfactory than the non-zooming keyboard. Chen et al. (2014) developed Swipeboard to enter characters with two swipes; the first swipe indicates the region of the preferred character, and the second swipe specifies the character within that region (Figure 2.1b). Their user study with 16 participants, and with Zoomboard as a baseline technique, revealed that the prototype supports novice to expert behaviors and improves a users' performance to achieving a high entry speed (19.58 words per minute (WPM), 15% faster than the existing baseline technique) (Chen et al., 2014). Similarly, Komninos & Dunlop (2014) prototype is similar to a QWERTY keyboard and divides the keyboard into six large keys and next-word predictions to enable faster text entry (Figure 2.1c). Their user study with

20 participants revealed that users liked the interaction technique of prediction and next-word completion, but they found user interface and correcting a misspelled word challenging (Komninos & Dunlop, 2014).

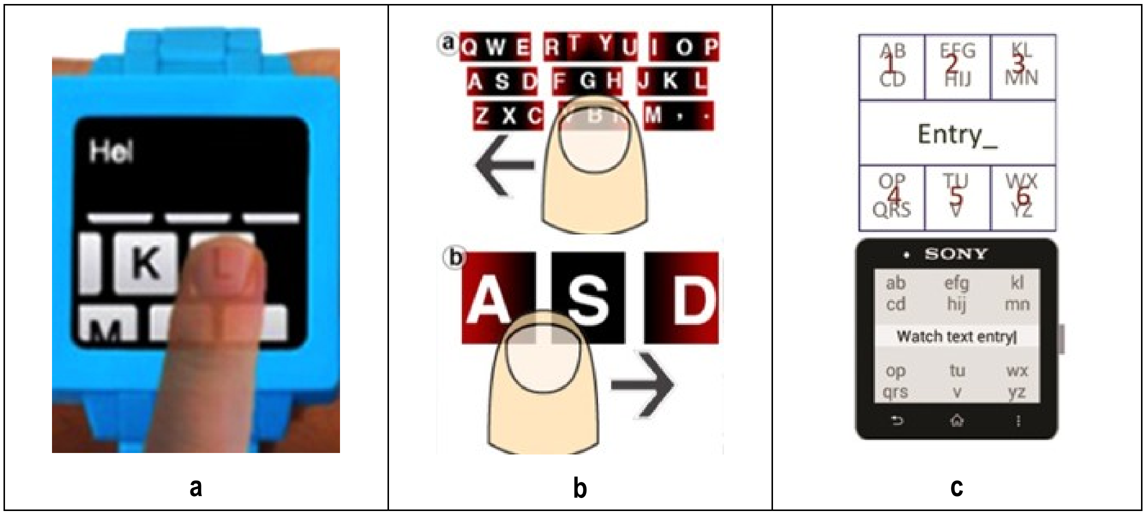


Figure 2.1 Text entry touch input on smartwatches
(a) ZoomBoard (b) Swipeboard (c) Sony SmartWatch 2
Source*: Publications* (Oney et al., 2013; Chen et al., 2014; Komninos & Dunlop, 2014)

Other researchers explored how smartwatches can assist in gaining awareness of team members, coordinating their activities, and displaying contextual information. However, they did not perform a usability study with users to test their prototype. For example, Bernaerts et al. (2014) used digitally augmented gestures and developed a smartwatch application to assist office workers to help them gain access to rooms, room schedules and an awareness of workers who entered the office (Figure 2.2a). Their smartwatch application was built on Samsung Galaxy Gear and provided three kinds of feedback to the user: visual, audio (e.g., a knocking sound when performing a virtual knock) and vibration for notifications (Bernaerts et al., 2014). Bieber et al. (2012) assisted workers performing construction and maintenance work using digital services and repair manuals on their smartwatch prototype (Figure 2.2b). Using gestures, they allowed workers to receive new instructions without having to stop their current tasks or read the next chapter of the manual without having to touch the display of the smartwatch (Bieber et al., 2012). Their prototype was built on Meta Watch and monitored the work progress and situation of the workers using logged data. The log data was then sent to a server, where the user's activity was assessed. The prototype would then display the information that was personalized to the user’s activity. As per Bieber et al. (2012), when smartwatches are coupled with the Internet or other devices, they can provide feedback in the form of tactile, acoustic or visual indicators. Migicovsky et al. (2014) Contest, a Pebble smartwatch prototype coupled with a cloud-based service, a smartphone, and a client application, demonstrated how dishonest students can collaboratively and unobtrusively cheat in real time on MCQs (Figure 2.2c). From afar, the smartwatch application looks like a normal digital watch with date and time, but the answers are encoded in groups of missing pixels. Without much interaction, students can also vote for a particular answer by double-clicking the watch buttons (Migicovsky et al., 2014).

Figure 2.2 Smartwatches for Awareness and Colllaboration
(a) Samsung Galaxy Gear (b) Meta Watch (c) Pebble Smartwatch
Source*: Publications* (Bernaerts et al., 2014; Bieber et al., 2012; Migicovsky et al., 2014)

Akkil et al. (2015) takes interacting unobtrusively with the smartwatches one step further by focusing on glance awareness and gaze gestures (looking LEFT, RIGHT and UP for selection of items on the smartwatch) (Figure 2.3a). Their experiment included wearing gaze-tracking smart glasses (head mounted Ergoneer Dikablis gaze tracker) that were wirelessly connected to the smartwatch prototype (built on the Microsoft .NET Gadgeteer 4.2 platform) (Figure 2.3b). To simulate gaze tracking, the smartwatch camera was also set to face the users. Their experiment, conducted with twelve participants, revealed that the gaze-based interaction was practical for simple tasks and haptics was the preferred glance feedback modality (Akkil et al., 2015). Interestingly their suggestions for future work such as “auto-scrolling of text or display different notifications one after the other” without user input and “automatic deletion” of already seen notifications is implemented with a few variations in a commercial watch called 24kupi as shown in Figure 2.3c (Akkil et al., 2015; 24kupi, 2017). 24kupi allows for auto-scrolling for student’s notes and, to avoid being caught, the user can press the side button and erase all the materials on the smartwatch (24kupi, 2017).

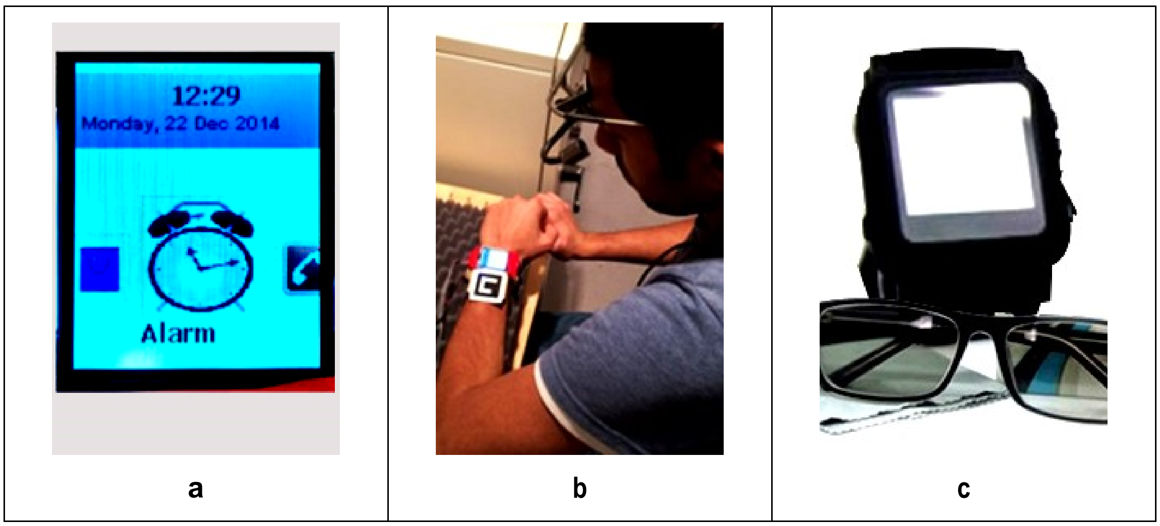


Figure 2.3 Smartwatches for gazed-based interaction
(a) Microsoft .NET Gadgeteer 4.2 (b) Ergoneer Dikablis gaze tracker (c) 24kupi
Source*: Publication* (Akkil et al., 2015) *Commercial website* (24kupi, 2017).

Collectively, these past studies have shown that smartwatches are a good device for mobile and ubiquitous interactions, such as being able to easily customize display information (e.g. meeting room schedules), making previously inert objects animated (e.g. service and repair manual) and making workflow more faster and efficient by gaining awareness of the user’s activity (Weiser, 1999). Yet there has been a lack of research on how smartwatches can help flight attendants collaborate and coordinate effectively with one another. In this research, I explore how smartwatches can be designed as a potential solution for supporting flight attendants’ collaborative activities in a distributed setting and how interactions can be enhanced for collaboration.

2.4. Summary

In this chapter, I reviewed the literature on what constitutes a team and what makes the needs of teams that are in highly dynamic, complex, uncertain, and risky environments different. I developed my understanding upon the cognitive theories that influence the study of collaboration and communication. These cognitive theories include: Team Cognition (which is embedded in shared mental models, situation awareness and workspace awareness) and Distributed Cognition. To understand how these teams collaborate and communicate in distributed settings, we broaden our knowledge by looking at how shared mental models could be dynamic through the lens of distributed cognition. Distribution Cognition is shown to be about mental structures (cognitive process), such as shared mental models, as well as knowledge of the social, cultural, and physical contexts (Carroll et al., 2006). This framework emphasizes the interactions and inputs of team members to have effective team cognition.

The review of the literatures gives us a background on understanding what makes effective team cognition, which would consequentially impact team performance. For instance, teams like the flight crew, anesthesiologists and firefighters are required to be aware of their changing environment. By not maintaining situation and workspace awareness, the static mental model of an individual team member could risk the safety and security of the entire team. In other words, awareness amongst team members impacts team performance and the overarching collaboration process. Based on these underlying theories, I will evaluate the current collaborative practices and needs of flight attendants in my study (detailed in the Chapters 3 and 4). I concluded this chapter by explaining the interactions provided by smartwatches as an ubiquitous technology. These interactions are later integrated and used in the prototype design and implementation of the smartwatch application that was created in collaboration with Samsung Canada as a grant partner and as part of this thesis (Chapters 6 and 7).

Chapter 3. Methodology

In this chapter, I provide a detailed description of the research methods I adopted for this study. These include the recruitment and background of the participants, as well as the method used to collect and analyze the data. Based on my research questions and goals identified in Chapter 1, my research follows a qualitative approach which uses techniques like in-depth interviews to collect data of flight attendants from domestic and international airlines. Through these interviews, I aim to derive answers that are user-centered in nature (i.e. what is relevant and meaningful for them) from a Human Computer interaction (HCI) perspective. This includes exploring how flight attendants' specific roles, position and technology in various aircraft activities and phases impacts their collaboration and understanding their current needs and practices in normal and emergency situations.

3.1. Participants' Demographics and Recruitment

I interviewed flight attendants from domestic as well as international airlines to get a broader understanding of their work practices. I recruited eleven participants through snowball sampling (word-of-mouth) (Given, 2008), social media (posts on Twitter and Facebook), and by requesting locally-based airlines to distribute our advertisement to their employees. Each participant was compensated for their time and was given a $30 CAD gift card/cash. Table 3.1 illustrates the number of participants included in the study: four males and seven females who were employed in different roles. The median age of participants was 40 years old with a range of (26 to 56) years old. The median numbers of years worked in the aviation industry was 8 years with a range of (2 to 25) years.

Participants roles included three pursers and seven lead/cabin crewmembers. Cabin crewmembers are flight attendants whose role is to ensure a comfortable and safe flight for passengers, while pursers/leads are chief flight attendants whose role is to manage and oversee the team of flight attendants and complete detailed reports and verify all safety procedures. Pursers were from three different international airlines and leads/cabin crewmembers were from a mix of domestic and international airlines (some had worked in both). These airlines were based in Canada, the United States, Germany, China, and Dubai. Most participants used technologies like smartphones, tablet, and laptops, however it was observed that only two participants owned and used wearables such as smartwatches (Table 3.1).

Table 3.1. Participants' demographics

No#	Gender	Age	Years Worked	Position Title	Airline Location	Smartphone	Tablet	Laptop	SmartWatch
P1	F	56	4.5	Cabin Crew	Canada	x	x		
P2	M	45	14	Cabin Crew	Canada	x	x	x	
P3	F	40	8.5	Cabin Crew	Canada	x	x	x	
P4	F	46	8	Cabin Crew	Germany	x		x	
P5	M	31	25	Purser	Dubai	x			x
P6	F	30	6	Cabin Crew/lead	Canada	x		x	x
P7	F	40	7	Purser	China	x	x	x	
P8	F	26	2	Cabin Crew/lead	Germany	x	x		
P9	F	44	15	Cabin Crew/lead	United States	x	x	x	
P10	M	42	18	Purser	Hong Kong	x	x	x	
P11	M	25	2	Cabin Crew	Dubai	x	x		

3.2. Study Procedure

To participate in the study, participants were asked to complete and submit an Office of Research Ethics informed consent form. This form was available online on the Connections Lab website (Appendix C).

3.2.1. Semi - structured Interviews

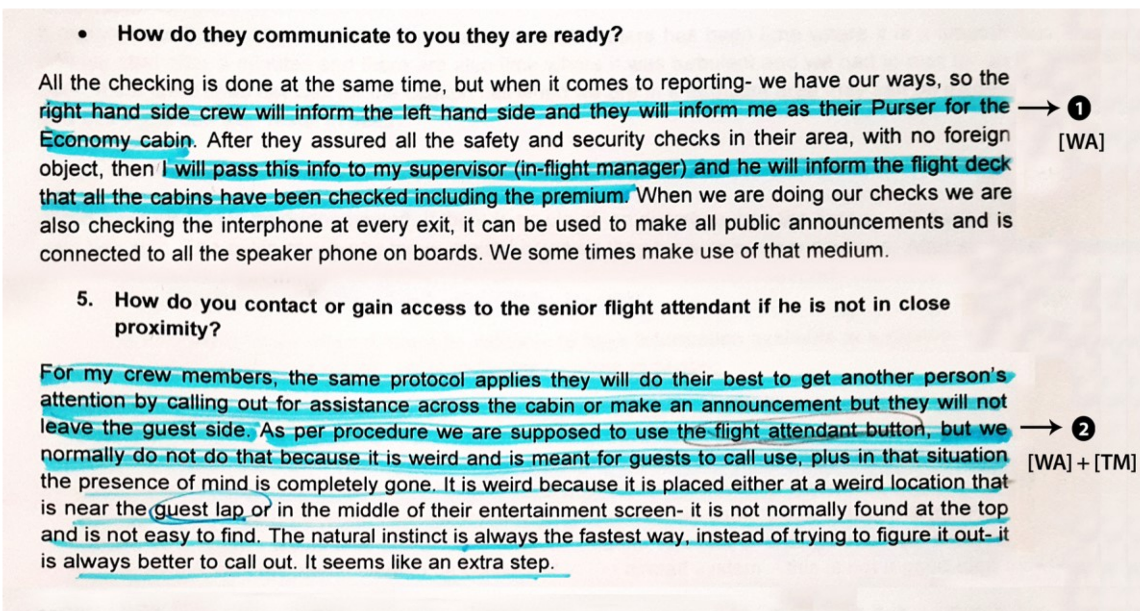
I used semi-structured interviews as the data gathering method. As they are conducted only once with an individual or with a group, they follow a schematic presentation of questions (Corbin & Strauss, 2008). These questions include the core question and many associated questions/themes related to the central question (DiCicco-Bloom & Crabtree, 2006). I arranged the interview questions from general to specific phases to give the participants more time to think about and reflect on their practices. In the general phase, I explored the participants' demographics, e.g., job positions, time in positions, and their familiarity with technology. In the specific phase, I investigated the what, when and how questions, i.e. what do flight attendants do in their daily routines, why they do they perform certain actions, who do they collaborate with, what is the most important information and procedures for them and what are the areas they face difficulty in, how often do flight attendants collaborate with one another, and what type of technology was used during that communication and which phase of the flight was it used.

These questions were designed to elicit the participants to provide details of their view-point and share their experience of unusual and memorable past events, such as: "How do you communicate with your crewmembers and when?", "What positions are you located too?", "What works well about this activity?", "What does not work well?", "Do you use technology to support this activity?", "If so, how?", and "Are there any drawbacks or obstacles to using technology as part of this activity?" I had flight attendants describe a range of specific stories of their on-board flight experiences, e.g., "Tell me about a time when communication with other flight attendants worked well" and "Tell me about a time when there were communication breakdowns." This technique of elicitation is known as "Critical Incident Technique" and it allowed me to understand the particular demands that were placed on the system, and the motivations of why participants decided to select alternative mediums of communication (Flanagan, 1954). These interview questions can be found in Appendix E.

3.2.2. Data Collection and Analysis

The semi-structured interviews were conducted over the telephone or via an online communication system (e.g., FaceTime, Skype) and lasted 45 to 90 minutes. Data was collected in the form of researcher's notes and audio-recording of all interviews. Interviews were transcribed and analyzed using inductive thematic analysis and triangulation (Braun & Clarke, 2006; Harper & Thompson, 2011). Triangulation is a process to check the integrity and validity of the different assumptions/inferences drawn from different stories of the participants (Harper & Thompson, 2011). I analyzed the data collected in three stages: the open coding of the study notes and the transcripts; the organisation of these ‘codes’ into related areas to construct ‘descriptive’ themes and the development of ‘analytical’ themes.

Stages one (Open Coding): In this stage, I iteratively read each interview and study notes to interpret the text line-by-line for meaning and content. This process is known as open coding and it is a first step to interpret the study results to uncover, and create concepts based on participant’s ideas (Holtzblatt et al., 2004; Corbin & Strauss, 2008). As shown in (Figure 3.1), the text taken from the interview is on the left and codes are handwritten on the right. These were generated inductively to capture the meaning and highlight the key content of each sentence.


- **How do they communicate to you they are ready?**

All the checking is done at the same time, but when it comes to reporting- we have our ways, so the right hand side crew will inform the left hand side and they will inform me as their Purser for the Economy cabin. After they assured all the safety and security checks in their area, with no foreign object, then I will pass this info to my supervisor (in-flight manager) and he will inform the flight deck that all the cabins have been checked including the premium. When we are doing our checks we are also checking the interphone at every exit, it can be used to make all public announcements and is connected to all the speaker phone on boards. We some times make use of that medium.

5. **How do you contact or gain access to the senior flight attendant if he is not in close proximity?**

For my crew members, the same protocol applies they will do their best to get another person’s attention by calling out for assistance across the cabin or make an announcement but they will not leave the guest side. As per procedure we are supposed to use the flight attendant button, but we normally do not do that because it is weird and is meant for guests to call use, plus in that situation the presence of mind is completely gone. It is weird because it is placed either at a weird location that is near the guest lap or in the middle of their entertainment screen- it is not normally found at the top and is not easy to find. The natural instinct is always the fastest way, instead of trying to figure it out- it is always better to call out. It seems like an extra step.

Figure 3.1. Open Coding for interview Transcripts

Each highlighted sentence or a key idea had at least one code applied. For instance, the sentence highlighted as 1 in (Figure 3.1: “…the right-hand side crew will inform the left-hand side and they will inform me as their Purser for the Economy Cabin”, was assigned the code **[WA] for Workspace Awareness** as it consists of hand gestures that flight attendants use to inform safety and security checks. Another example is denoted by 2 in (Figure 3.1): “As per procedure, we are supposed to use the flight attendant button but we normally do not do that, because it is for passenger’s use and it is placed in a weird location, not easy to find and is not the fastest way. So, it's always better to call out." These two lines fall in the code **[CB] Communication Break and [TM]: Technology Mishaps**, because the flight attendant can not complete his/her task of communicating the situation due to the technical barrier.

This process created a total of 13 initial codes for how flight attendants collaborate and communicate amongst one another. Each new code was added to a 'bank of codes' and placed on a separate note with the participant's ID and page number, in case the data in incomplete as shown in Table 3.2.

Table 3.2. Bank of Codes

1. [CB] Collaboration Tools	[P5, pg. 8]
2. [CB] Communication Break	[P2, pg.2], [P5, pg.7]
3. [DC] Distributed Cognition	[P3, pg.4], [P4, pg. 3], [P4, pg. 6]
4. [INF] Information	[P2, pg.1], [P2, pg.2], [P3, pg.4], [P3, pg.2], [P7, pg.1]
5. [INS] Insights	[P4, pg.5], [P5, pg.8], [P6, pg.11], [P8, pg.2]
6. [OT] Others: Privacy, personality	[P3, pg.7], [P3, pg.6], [P6, pg.9], [P8, pg.3]
7. [PP] Passenger Problems	[P6, pg. 5]
8. [PI] Place Issues	[P5. pg. 6], [P5. pg. 8]
9. [RP] Reporting	[P4, pg. 3], [P5, pg.8], [P6, pg. 4], [P6, pg.11]
10. [SAC] Situation Awareness Communication	[P6, pg.7]
11. [TM] Technology Mishaps	[P3. pg. 3], [P3. pg. 8], [P4. pg. 4], [P5, pg. 7]
12. [WAC] Workspace Awareness Communication	[P3, pg. 4], [P7, pg. 5]
13. [TC] Team Cognition	[P3, pg.7], [P4, pg. 2], [P5, pg. 6], [P6, pg. 3]

Stages two (Developing Descriptive Themes): My next step was to look for the similarity and differences between the codes and group them accordingly on a separate large paper. The codes that were similar were grouped into categories and were posted on the wall. This process of grouping in a hierarchical tree structure is called an Affinity Diagram (Holtzblatt et al., 2004; Corbin & Strauss, 2008). An Affinity Diagram is a popular method for brainstorming and identifying the common issues, distinctions, work patterns, and needs without losing individual variation (Wood, 2007).

Using this method, I could draw out the relationships between the ideas and have a visual representation of how the descriptive themes and categories connect as shown in Figure 3.2.

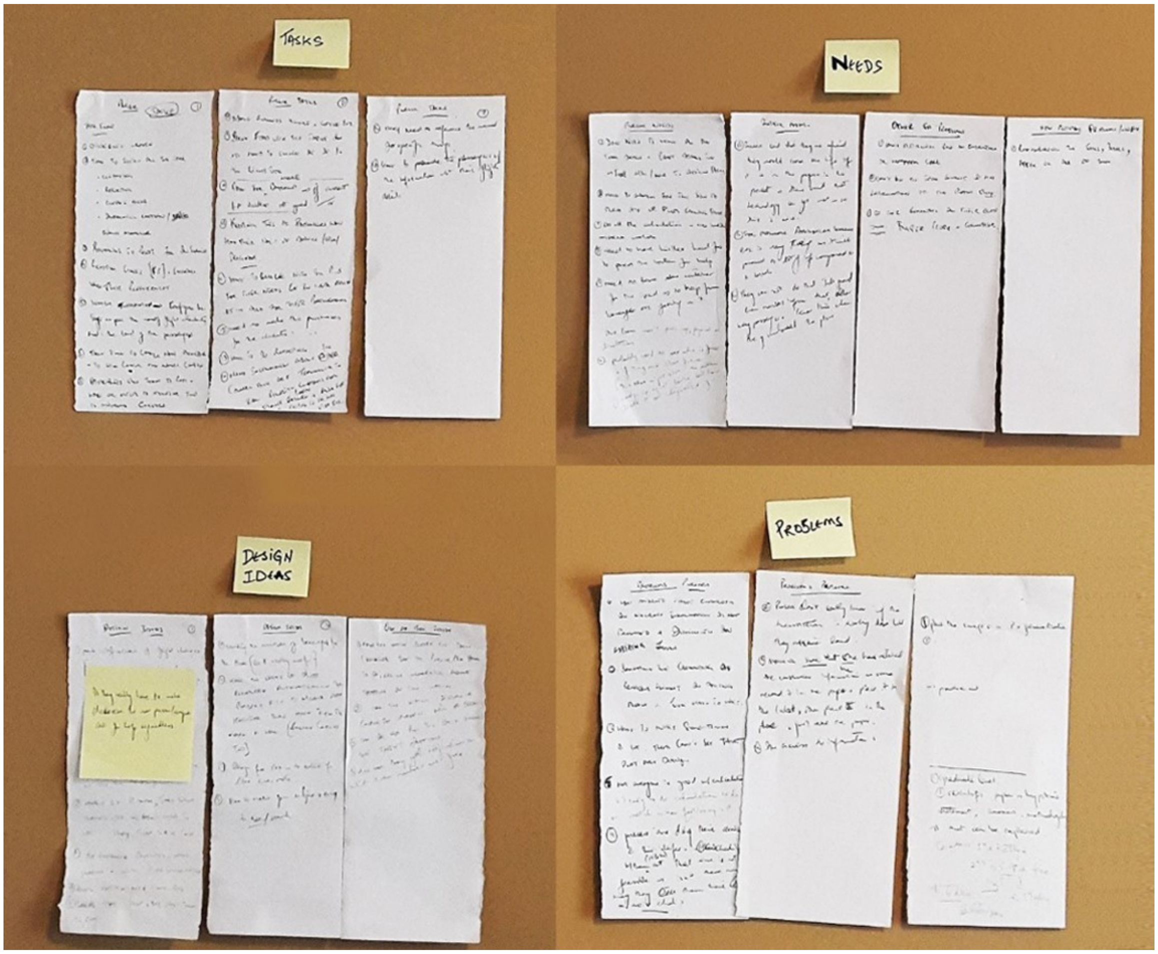


Figure 3.2. Creating themes using an Affinity Diagram

Stage three (generating analytical themes): In this phase, my supervisor and I assessed the affinity diagram and analyzed the related groups (descriptive themes) generated from the previous stage (Figure 3.2). The descriptive themes included the flight attendant's tasks, needs, design ideas and existing problems in the daily work practices. Based on several discussions and an analysis of the different implications of each theme, we further re-aligned the related groups to form higher-level analytical themes. These higher level analytical themes included roles and responsibilities (pursers, leads, senior cabin director and crewmember), flight attendant's activities, flight attendant's gestures, simplified communication, communication tools, shared information and reporting procedure. These analytical themes are my study's findings and are detailed in the next chapter.

3.3. Summary

In this chapter, I discussed the recruitment and backgrounds of participants as well as the method used to collect and analyze data. In summary, the study involved a qualitative research methodology that included semi-structured interviews of domestic and international flight attendants. These interviews were recorded and transcribed. The analysis of the raw data included three stages: open coding (gathering key ideas), descriptive themes (recoding key ideas into categories) and analytical themes (defining high level findings). These analytical themes are my study's findings and are detailed in the next chapter.

To have a complete and accurate picture, it is important to include methods such as observations of the current practices to verify/support the findings. However, we were not able to do so due to security, feasibility, and limitations in studying the factors of interest. Therefore, I asked flight attendants to tell us multiple stories (in the interviews) of similar situations in an effort to triangulate across situations. These efforts certainly do not mean that we have a completely accurate picture - at a high level, the details have face validity, yet at a low level, there may be nuances that are missed. Therefore, I have addressed them in our limitations (Chapter 8).

Chapter 4. Findings

In this chapter, I describe the study findings which focuses on addressing three research problems and goals identified in Chapter 1. First, I describe how flight attendants maintain situation and workspace awareness (RP.1). Second, I describe the challenges flight attendants face when using existing collaborative technologies in normal and emergency situations (RP.2). Third, I investigate how to design a smartwatch application that will support flight attendants' awareness and collaboration needs (RP.3). My findings are categorized into four broad themes. This chapter is organized per theme in the following order: a. I begin describing the ***roles and responsibilities*** of pursers, leads, senior cabin director and crewmember, b. I describe how the team cognition is developed from the collaborative ***work activities***, c. I describe how awareness is maintained via the ***collaborative system*** (face-to-face communication and use of technology)**,** and e. I describe how awareness is extended through the ***information and resources shared*** with other team members.

4.1. Roles and Responsibilities

Our participants explained that there are three main team member roles that are common in both domestic and international airlines: the captains (pilots), the leads/pursers, and the cabin crewmembers. The reporting lines are defined in that order from highest ranked to lowest rank. This is also represented visually in (Figure 4.1).

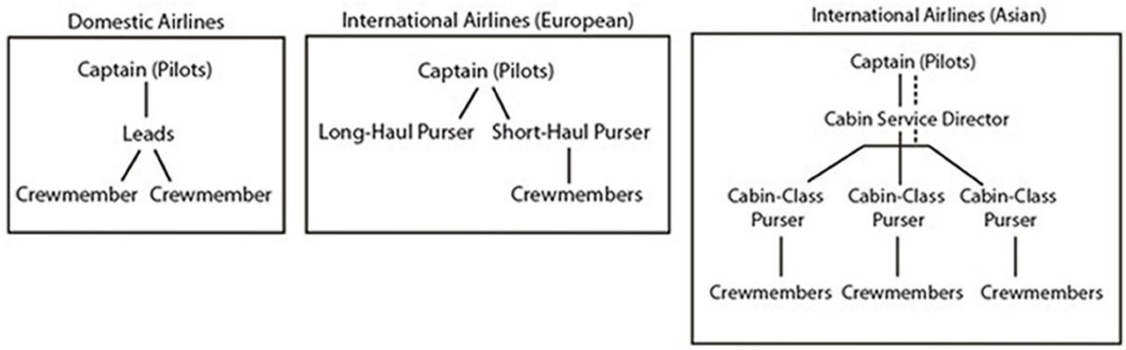


Figure 4.1. Hierarchy of Roles and Responsibilities

4.1.1. Domestic Airlines

For a domestic flight, the aircraft is typically small, has a limited number of passengers and the duration of the flight is relatively short (e.g., a few hours at most); thus, a maximum of three flight attendants are typically assigned. Flight attendants in the domestic airlines follow a compulsory rotation in the three positions of the aircraft: **Position 1, the fore (front); Position 2, the aft (back); and, Position 3, the middle.** Positions 2 and 3 act in the role of cabin crewmembers (Figure 4.2). Position 1, also known as the lead, is responsible for supervising and managing the team of flight attendants and overseeing the flight attendants' workflows to ensure a comfortable and safe flight. He/she acts as an intermediary between the pilots and crewmembers; Pilots will share information with the lead flight attendant who can then relay this information to the other flight attendants.

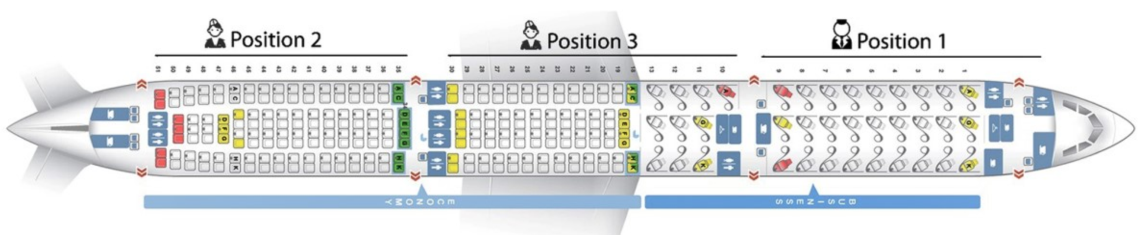


Figure 4.2. Air Canada Boeing A321
Source*: TripAdvisor, 2016*

Domestic flight attendants rotate between the three positions in successive flights. Thus, while they are assigned to a single position for an entire flight, over several flights, they will likely work in a series of different positions. As P1 explains: “It is part of the training to know what every position entails.” This means that typically flight attendants on domestic airlines have knowledge of what the other crewmembers should be doing; there is shared knowledge around roles, responsibilities, and who has what information.

4.1.2. International Airlines

Our participants told us that international airlines work somewhat differently. The aircraft is larger, has a higher number of passengers on-board, and the duration of flights is longer (e.g. 6-12 hours). Depending on the size of the plane and the culture of the airlines, the hierarchy of the crew can differ. For instance, we found that airlines based in Asia and the Middle East have two to three pursers onboard each flight where each one is assigned to a particular cabin (first/business/economy class). They also have a ***Cabin Service Director*** to whom the pursers report. ***Pursers*** are in charge of the same responsibilities as the lead on domestic flights and when they require help, the cabin service director oversees it. For European airlines, we were told that pursers are divided by two tiers: a short and long haul purser**.** ***Long haul pursers*** have the same seniority level as the Cabin Service Director, but they do not share the same responsibilities. They are mainly responsible for greeting passengers when they come onboard and are not responsible for ensuring the purser’s workflows. ***Short haul pursers*** are not dedicated to any particular cabin and are expected to assist and manage the entire crew of the flight. These roles and responsibilities can be seen in Table 4.1. Selection of Pursers for international airlines are specifically selected for their roles based on the amount of experience and training they have, whereas the role of the domestic flight lead is assigned based on who would like to do a position and who has not done a certain position in an effort to ensure that each person has a chance to work in every position.

Table 4.1. Roles and Responsibilities

Roles	Duties
Captain (Pilots)	• To enhance crew coordination and communication efforts, to include briefing specific levels/modes of automation to be used, and communicating active flight status and emergencies. • Maintaining situation awareness and managing difficult passengers when needed.
Long Haul Purser/Senior Purser	• Responsible for greeting passengers when they come onboard.
Cabin Service Director/ Senior Purser	• Responsible for greeting passengers when they come onboard. • Responsible for overseeing and managing purser's workflows and allocation of crewmember's positions. • Act as an intermediary between the captain and pursers when necessary.
Cabin Purser/ Short-Haul Purser/ Leads	• Responsible for supervising and managing the team of flight attendants including paperwork. Are allowed to leave their position to help other flight attendants. • Responsible for helping new Flight Attendants and Pursers to familiarize themselves with the work environment. • Overseeing the flight attendants' workflows to ensure a comfortable and safe flight. • Acts as an intermediary between the captain and crewmembers. • Substitute for the Cabin Service Director when necessary.
Crewmember	• Responsible for ensuring a comfortable and safe flight for the passengers.

4.1.3. Domestic and International Airlines

For both domestic and international flights, the careful assignment of roles and cabins to particular flight attendants means that there is a specific communication protocol where knowledge works its way from cabin crewmembers to leads/pursers to cabin service directors (if that role exists), to pilots. The opposite also occurs where information from pilots makes its way to flight attendants first through a cabin service director (if that roles exists) to leads/pursers to cabin crewmembers. It also means that different levels of knowledge must be maintained by different people. For example, it is not the case that each flight attendant will know the same level of information about a situation. Leads/pursers and cabin service directors need to maintain a broader understanding of what is happening across the entire aircraft, whereas other cabin crewmembers may only need to know information pertaining to their specific section of the plane. This only changes if emergency situations arise.

During emergency incidents, the hierarchy on planes is flatter: crewmembers are encouraged to directly communicate to the pilots to inform them of any danger to the safety and security of the flight. Thus, in times of emergency an understanding of who knows what changes and pilots attempt to maintain a larger degree of situational knowledge. The knowledge maintained by pursers/leads may be insufficient than under normal circumstances. In situations where crewmembers need help from each other, they may directly communicate with each other depending on who may be best to help them.

Lead/pursers on both domestic and international airlines typically take special care to note if there are flight attendants with less experience on board. They do this by making use of subtle cues like crewmembers' pace of work or visually scanning the tag number of employees; higher tag numbers often indicate new crewmembers. In an effort to ensure consistency of service, the leads/pursers will sometimes walk to the less experienced crewmembers and provide coaching tips in a discreet manner.

"If they are new - we take extra care to help them get their work done. I just go and offer if they need help physically completing the task or remembering the next task to do or all the tasks they need to get done." - P6, Female, Lead/Cabin Crewmember

Our participants explained that in both domestic and international airlines, crewmembers are frequently scheduled to work with new team members and switch into different roles (Ligda et al., 2015). This means that it can be difficult to get a sense of a particular person's experience at the beginning of a flight and flight attendants must trust the fact that a person will follow through with the appropriate actions for a given position based on their training. During international flights, flight attendants have more time and allowance from the airlines to interact with one another on a personal level. This occurs during breaks and ‘downtime’ when there is less work to do. The importance of these informal conversations is that they provide flight attendants with a better understanding of each other’s personalities, experiences, and attitudes towards life and work, which can help the flight attendants understand each other’s work practices and idiosyncrasies.

“We talk about everything under the sun. We call it ‘jump-seat confessionals.’ Our life is a bit strange. We are thrown into a situation with people you probably have not met before and probably will not again so lot of the people that I work with that I will never ever see again in my career. There is a certain kind of anonymity when we are talking to each other, so people tend to disclose lots of personal information.” - P3, Female, Lead/Cabin Crewmember

4.2. Work Activities

Flight attendants work-activities begin with a pre-flight briefing. A pre-flight briefing is held immediately before each flight. Depending on the availability of crewmembers and the culture of the airline, the briefing is carried out by the most senior crew member in the following order: captain, cabin service director, and lead/purser. He/she uses this discussion platform to introduce crewmembers to the team, assign the positions, and answer questions about the flight time, possible turbulence enroute, and strategies for dealing with safety and security issues that might impact the flight. Crewmembers also get an understanding of who is in what role so they can structure their communication appropriately during the flight.

After the briefing, flight attendants perform safety and security checks where they walk around and ensure all passengers are seated with their seatbelts done up, bags are properly stowed, etc. During this time, flight attendants look up and down the aisles to the next visible flight attendant. Once they are done their own check, they give a *“thumbs-up”* gesture to signal that their area is clear and ready. Flight attendants who were in close proximity to each other verbally say, *"Cabin is secure."* This information is relayed between flight attendants until all areas are secure.

"When it comes to reporting the safety and security checks; the right hand side will inform the left hand side and they will in return inform the purser for the Economy cabin." - P5, Male, Purser

During the in-flight stage of work, the lead/purser coordinates with crewmembers as to when each in-flight activity should occur. For example, crewmembers wait for the lead/purser to let them know which row to start serving through calls on an interphone (described more later). The lead/purser tries to coordinate serving amongst crewmembers (in a tightly-coupled style) to ensure the food is served at approximately the same time to all passengers in a particular cabin.

"I am responsible for coordinating with the other flight attendants and also doing the tasks of serving the guests in my area. I need to crosscheck to make sure that the meals are served hot when it is placed on a guest table." - P5, Male, Purser

During this time, the lead/purser periodically glances around the cabin to monitor the service's progress and see if anyone needs help.

"We are like Galitarians, who are always on the lookout for each other to make sure that things are working out as they are supposed to be in the environment." - P2, Male, Lead/Cabin Crew Member

Verbal communication is typically kept to a minimum since flight attendants are very busy and pressed for time. After takeoff, the plane's motors can be very loud making it hard to hear people. Instead of large portions of speech, our participants described relying heavily on gestures and jargon to simplify communication. P2 and P3 described using hand gestures for sitting down, picking up the phone, getting oxygen masks, and requests to *"please bring more blankets."*

Throughout the remainder of the flight, flight attendants perform routine checks to see if passengers need anything and ensure everything and everyone is safe. After the service, the lead/purser splits up crewmembers into two halves to either perform routine checks or to rest. For example, in the international airlines where P4 works, crewmembers can rest in the flight attendants' cabin, while other crewmembers make rounds every 15 to 30 minutes to check the toilets or serve beverages to the passengers. After half of the crewmembers have rested, the purser wakes the crew by calling them on an interphone and instructs the other half of the crew to take a rest.

"Just making sure that everyone gets to have their breaks and eat well. So some days that can be very challenging and I have to make sure that they are taken care of – as they in-turn will take care of my guests. Happy crew and happy plane!" - P6, Female, Lead/Cabin Crewmember

During this time, the lead/purser will also check with the pilots in the cockpit to see if they need anything. For example, in the case of P3, his airline's safety and security policy entails that two people have to be always present in the flight deck. This means that pilots sometimes ask the purser/lead to send a flight attendant to monitor the cockpit when they have to leave.

"If the captain needs to use the washroom, he has to call a flight attendant and she/he has to stay in there while he is out and then switch when he comes back in." - P3, Female, Lead/Cabin Crewmember

4.3. Collaborative Technologies

The airplanes that our participants worked on all contained three basic types of collaborative technologies: a series of interconnected interphones, flight attendant call buttons at each seat, and visual indicators in the form of lights and panels. We describe how each was used next.

4.3.1. Interphone

When flight attendants are unable to visually see each other to share information using body language and they are not in close proximity to talk, they make use of the interphone to communicate (Figure 4.3).

Figure 4.3. Qantas Cabin interior
Source*: Flight-report, 2011*

This communication occurs most often during their in-flight work such as during service rounds and routine checks. Regardless of their role, flight attendants will use an interphone when they need to talk to a crewmember that is far away, or when they need to make announcements to all passengers. Thus, interphones can be used for public announcements that are played on speakers throughout the aircraft, internal conference calls between all interphones, and cabin-to-cabin communication between pairs of interphones. An interphone is stationed at each key area: the cockpit, the galleys, and (most often) at each exit door. When calls come in, a panel indicates which other interphone initiated the call through a display panel (“Small Color-coded LED’s Above Boeing Exit Signs?,” 2016). The types of information that flight attendants share over the interphone include:

1. *Broadcasting of public announcements,* e.g., take off and fastening seat belts.
2. *Progress updates on activities,* e.g., readiness for lunch/water service.

3. *Giving and acknowledgement of orders/directions,* e.g., assisting pilots in their absence in flight deck
4. *Status updates requiring immediate assistance,* e.g., passengers being intoxicated and requiring assistance
5. *Transmission of emergency information to other team members,* e.g., notifying others about turbulence, bomb threats, etc.

Despite the range of uses for the interphone and its critical role in flight attendant communication and collaboration, participants told us that their use of the interphone faced several challenges. First, the sharing of information was static. For example, in cases of turbulence, the pilot will typically notify the purser/lead by calling him/her on the nearest interphone and explain the situation once. The lead/purser will then disseminate the information to the other crewmembers by calling them on an interphone, this time with a one-to-many call. However, information on situations such as turbulence can change rapidly and pilots typically do not repeatedly call to relay new information because they are busy dealing with the situation themselves. Thus, up-to-date knowledge of the situation is unknown and difficult to share.

"The hardest part is that we don't have a face-to-face communication with the pilots and that is hard as sometimes we cannot relay a complete message on the interphone." - P2, Male, Lead/Cabin Crewmember

Many of our participants desired to have more frequent information in such situations as it was related to the safety of all passengers and the time to begin their service.

"The reason why the flight is delayed is because this information comes from the captain and no one is allowed to go in the cockpit, when it is 'secure cabin' during take-off. We are then supposed to wait. We waited for an hour last time and we didn't know what was happening." - P1, Female, Lead/Cabin Crewmember

Second, flight attendants need to be in close proximity to the interphone in order to hear it ring and answer it, as interphones are permanently fixed in particular locations on the plane. However, our participants described many incidents, particularly during lunch/water service, when they were highly mobile and not close to an interphone within their own cabin area.

"Once, I was standing at the back and a gentleman fainted after using the washroom. Although, I got hold of him and landed him down on the ground, but the other crewmembers especially in the front, could not see this happen as both of us were on the ground and the bathroom door was left open." - P3, Female, Lead/Cabin Crewmember

In the above situation, P3 was pulled into the washroom and could not release herself as the passenger was on top of her. The only way she was able to get out of the situation was to ask the closest passengers for help. Thus, she was unable to call the other crewmembers on an interphone and they could also not see her since they were too far away.

Another instance comes from P5, who was caught in the middle of two kitchens when a passenger had first-degree burns. Other cabin crewmembers could not see them and so P5 was unable to visually notify them that there was a problem.

"The passenger had not only spilt coffee on his hand but also on the metal watch he was wearing, which exasperated his pain. I needed help to wash off the coffee and at the same time I wanted to ask for medical assistance and inform the captain about the incident." - P5, Male, Purser

Luckily P5 could reach a nearby interphone to call for immediate assistance. Yet there were no flight attendants close enough to another interphone to hear it ring. P5 decided that the only way to communicate with the other crewmembers was to make a public announcement over the interphone to indicate to the cabin service director that he needed help. This unfortunately made the incident public and gave the cabin service director the wrong impression that his cabin crewmembers were not efficient enough in assisting one another.

Lastly, several participants said that it was difficult to know whether sounds were coming from the interphone or the flight attendant call button and whether or not it was a normal or emergency call. All audio alerts coming from a particular destination had the same sound. For instance, if a flight attendant called another flight attendant using either the interphone or the flight attendant call button, it would play double twin chimes, but there would be no difference in the ringtones. Participants felt that distinguishing calls was important as it could indicate the urgency of a situation.

4.3.2. Flight Attendant Call Button

Unlike the interphone, flight attendant calls buttons are installed in each passenger seat (Figure 4.4) or adjacent to them (Figure 4.5). Thus, they are fairly ubiquitous throughout the plane.

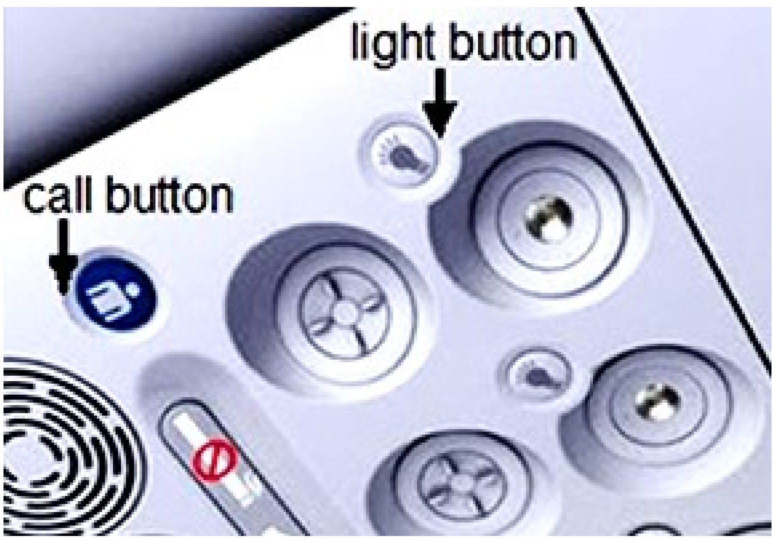


Figure 4.4. Boeing 737 flight attendant call button
Source*: Primm, 2011*

While flight attendant call buttons are meant for mainly passenger use, they have been appropriated by flight attendants as a part of their own communication practices. Here they are routinely used as a means for notifying other flight attendants for assistance regardless of the flight attendants' role or position in the plane. For example, during service rounds and routine checks, a flight attendant in the aft may require help from someone in the back of the plane. To alert this person, she might push a passenger call button near her. This creates an audio alert that is heard in the present and adjacent cabins. Flight attendants can then look at the flight attendant panel next to an interphone to see which passenger’s seat light is illuminated. While certainly beneficial, the call button raises several challenges for flight attendants. First, a press of the call button is sometimes not heard since the alert is only played in the present and adjacent cabins and the noise from the aircraft is generally loud. If it is an urgent situation, participants said they will push multiple call buttons to notify a team member.

“If six call buttons go out at the same time, you know that it is a serious situation and that way you will get their attention.” - P3, Female, Lead/Cabin Crewmember

Second, it can be difficult for a flight attendant to push a call button rendering it an ineffective tool for notifying others. On domestic flights, our participants said that the call button is usually easy to reach and always in the same position: above the passengers’ heads on a ceiling control panel. Yet international airlines often have the call button in varied locations (depending on the aircraft) and not all locations are easy to find or natural for flight attendants to reach. For example, sometimes the call button is located on the armrest of a passenger’s seat as shown in Figure 4.5. Pushing these call buttons may require asking a passenger to do it, which is less desired, or, awkwardly reaching in front of a passenger or under their arm. As such, our participants felt hesitant to make use of such call buttons.

“It is placed either at a weird location that is near the guest’s lap or in the middle of their entertainment screen - it is not normally found at the top and is not easy to find.” - P5, Male, Purser

Figure 4.5. Lufthansa Boeing 744, flight attendant call button
Source*: Airliners.net, 2011*

Third, it can be difficult to know if a flight attendant or a passenger pushed the call button. Flight attendants are able to push the call button in a certain configuration to create a different alert sound, yet, in times of emergency, it may be difficult to remember to do so. The configuration for using the call button is: one push creates a single chime meaning a passenger is calling, while two pushes creates double twin chimes which flight attendants sometimes use to signal that they are calling. However, P5 said that in an emergency situation their *"presence of mind is completely gone,"* so knowing the button's location or the configuration is an extra cognitive step. In these situations, flight attendants will opt to try to call out loud (yell) to others in order to get their attention. However, this practice is contrary to what is taught in CRM training about passengers' in-flight experience. Flight attendants are not supposed to create panic amongst the passengers.

4.3.3. Visual Indicators

The planes that our participants flew on also contained various visual indicators that were used as a part of their work routine. Again, this was regardless of the flight attendant's position, be it cabin service director lead/purser, or crewmember. For example, visual indicators included the 'no smoking' and seat belt signs, which had audio alerts associated with them (as shown in Figure 4.6). When the seat belt sign is turned on, a single chime is heard and it means flight attendants have to stay seated. In times of service and heavy passenger load, this visual cue and sound can be easily missed as flight attendants are not paying attention to them.

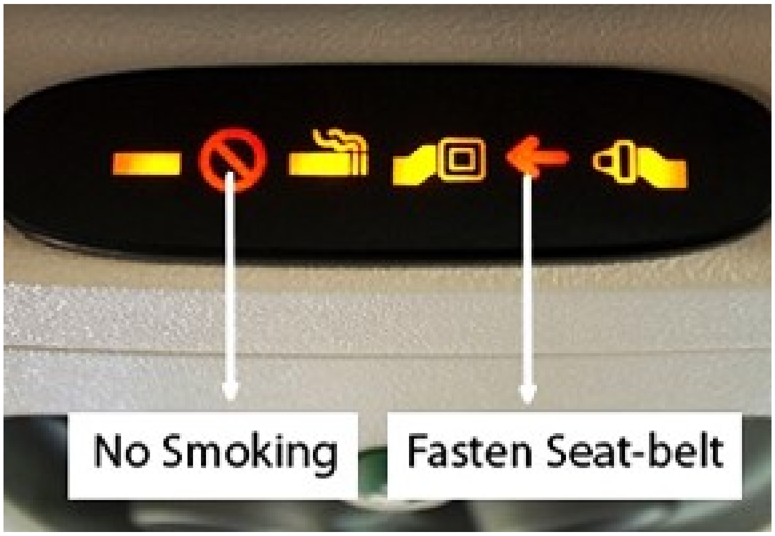


Figure 4.6. Lufthansa Visual Indicators
Source*: AirTeamImages, 2007*

Each interphone also had a flight attendant display panel next to it that showed which seat call button was pushed or which interphone was calling (Figure 4.7). Participants said this panel saved them from unnecessary search and directed them to the specific location that required their attention when call button notifications came in. Such calls occurred throughout their in-flight work, including during service rounds and checks. All cabin crewmembers had to respond to such calls, including leads and pursers.

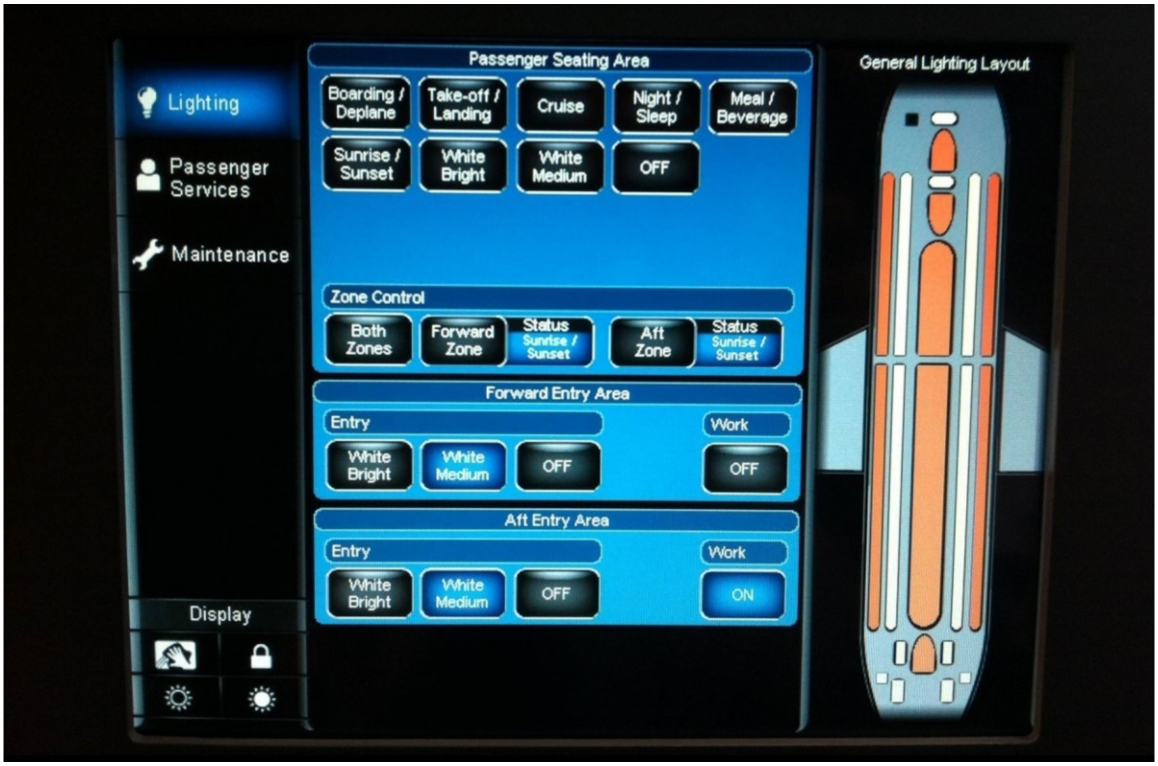


Figure 4.7. Flight Attendant Panel
Source*: Beckett, 2014*

"The aircraft is huge, so when a passenger call is heard, we do not start looking everywhere, but simply look at the display of the flight attendant panel. It will tell me exactly which row and seat the passenger is calling from." - P2, Male, Lead/Cabin Crewmember

A corresponding visual cue to the flight attendant panel is the seat light above the passenger's seat, which is turned on when the passenger presses the flight attendant call button. Participants said that seeing the light was generally easy if they knew which general area to look in. But those that served on international flights faced challenges because the amount of space to look in was larger. Flight attendants would look at the flight attendant panel to see which area they needed to go to and memorize the seat number. However, on their way, they might be distracted by another passenger's request. This sometimes made them forget the seat number. While they could look for the seat light, if they did not remember the approximate location, this task was very difficult.

"I kept repeating the passenger seat number so that I would not forget and was looking for the seat light too, suddenly this lady who did not press the flight attendant call button asks me to get her a glass of water and some other items. I was upset as I had to attend to the one who pressed the button first; I told her politely that I will attend to her as soon as possible. However, I realized I forgot the passenger seat number and had to go back to check again." - P5, Male, Purser

Another problem came from not remembering to reset the flight attendant button to neutral after they attended to the passenger. Most flight attendants focus on attending to the needs of the passenger and it is easy to forget to reset the button so that the passenger's seat light and the light on the flight attendant panel are turned off. This can create miscommunication for the other crewmembers and, at times, can cause multiple crewmembers to attend to the same passenger.

4.4. Shared Knowledge and Resources

Flight attendants share resources related to their training while they are in-flight. The Flight Attendant Manual (called the FAM by flight attendants) and the guest experience manual (GEM) are on hand when in-flight so that flight attendants can reference them as needed. In contrast to people's typical views on manuals as being underused artifacts, flight attendants refer to manuals frequently because they contain instructions for each city that they might fly into, along with detailed information on all passengers.

"I reference it fairly often almost every day. As I am pretty familiar with it and I can recall a lot of information without having to look it, so I am usually showing people where they can find that info or if they doubt what it says because maybe it was different before-thence I use it for the team." – P6, Female, Lead/Cabin Crewmember

Depending on the airline's policies, some provide flight attendants with manuals in a paper-based format. Others have started allowing flight attendants to use their own mobile devices to check manuals, while others provide pursers with a tablet for the whole team to share. Flight attendants also actively discuss their work procedures at various points with each other while in-flight and they routinely ask one another if something is unclear. In this way, flight attendants can continue to train and mentor each other throughout their work time in addition to the training that flight attendants receive prior to their first flights. Sometimes discussions involve flight attendants referring to the manuals and other times they discuss knowledge that might augment them.

4.4.1. Paper-Based Manuals

Participants who used the paper-based manuals explained that it was difficult to find information in them and they were large, heavy, and cumbersome to carry around and prone to pages going missing.

"I don't like carrying the manual around. It weighs about 2 or 3 pounds. I would like to see a PDF copy." - P2, Male, Lead/Cabin Crew Member

"*Sometimes the Guest Experience Manual is missing a whole bunch of pages or sections* – *we need to reference it and we don't have that information on our finger tips."* - P3, Female, Lead/Cabin Crewmember.

The paper format also did not carry the updated version of unfamiliar places or when the policies and rules of a country suddenly changed.

"It is better to better memorize the information, so you do not have to reference the paper, but if you are flying to Cancun and you don't fly there very often, so it is harder to keep Cancun specific information fresh in mind so it is definitely handy to have that sheet for reference." - P3, Female, Lead/Cabin Crewmember

Information about a crew's flight can also change at the last minute. If this happens for a domestic flight, our participants told us that the leads typically do not find it difficult as they have to only reconfigure the seating arrangements. However, for the international airlines, the pursers in our study said that such changes had a large impact on their work. Last minute changes meant they did not have a chance to learn information for the new location.

“Every aircraft is designed differently so we need to study before boarding. I studied the aircraft the whole night and when I came the next morning it was all changed and my team was asking me for their tasks.” - P5, Male, Purser

4.4.2. Digital Manuals and Information

Some of the airlines that our participants worked for had introduced policies that allowed them to bring their personal devices to work such as laptop, tablets, and mobile phones. One of the international airlines had even started allocating iPads to the pursers so they would have access to flight attendant manuals, the pre-briefing flights details, and reporting forms.

P5 said it *“makes us look very professional, well informed and knowledgeable about customer’s profile.”* P5 felt that the iPad allowed him to build customer relationships more easily because it contained details about each passenger. He would use it to greet important and frequent passengers and also to confirm their preference of meals, seats and connecting flights in a short time. P5 described how his team also benefitted from the tablet as they were able to cross-reference each other on updated information in the manuals, ideas about changes in the procedures, and also about suggested policy changes that they noted in their shared reports.

Conversely, despite the iPads being of great convenience, the pursers in our study found them to be overwhelming to manage for issues like low battery, sharing with the team and security issues. Having only one iPad for the entire cabin, made pursers having to ensure that it was charged for them to work and for others to use when needed.

“There are some difficulties using this technology as it crashes from time to time and because it is just one iPad it runs out of battery fairly quickly when carried to the other crewmember.” - P5, Male, Purser

Participants said that sharing the iPad was not easy. At times, they would be completing a report on the iPad and another crewmember wanted to access the flight attendant manual. They would then need to negotiate its use and also ensure there would be enough battery power to complete their work later. Naturally, they could plug the iPad in to charge, but this was awkward and confined them to a single location.

"We can not really do many things on the iPad and use it some times as there are only three in total for three pursers. In case of emergencies, we would reference it for the manuals, but otherwise we can see only some information about the flight, the aircraft layout and the seat number and connecting flight of the passengers." - P8, Female, Cabin Crewmember

The pursers in our study felt that the iPads did little to improve their work practices and, instead, added more responsibilities for them. For instance, P5 explained the iPad contained personal details of each passenger and it was his responsibility to ensure its privacy, so he had to keep it near him all the time. Given the size of the iPad, it did not easily fit into his pockets and so he was forced to hold it in his hands as a result. This made the iPad prone to accidental damage.

"I am always carrying the iPad, when I am serving the food to the guest I place it on the cart. There are times and chances of coffee spilling over the iPad or the screen becoming crack - in that case I find this gadget might not be useful." - P5, Male, Purser

4.4.3. Reporting

Our participants described needing to complete mandatory reports at the end of each flight. This was necessary in case situations arose that might cause passengers to complain to the airline. Thus, having a flight attendant's record of the event was valuable. We found that retaining and compiling this information was challenging for our participants. The leads and pursers in our study wrote this information out on paper or their mobile phones during the flight so they would remember. Those who collected it on paper worried that their hands would be occupied and the information could be lost. Other participants struggled to compile the reporting information because of a lack of time and energy. It was mandatory for pursers/leads to complete reports, but an optional task for other crewmembers. Thus, sometimes pursers/leads needed to collect information from other crewmembers who might know more about a situation.

“The problem with the current way of reporting is that there is the time lapse, that you lose the information when you leave the aircraft and some time you don't even get to it, because you only have to report it within 24 hours and people won’t do it in their own time, as they are not paid for that.” - P1, Female, Lead/Cabin Crewmember

Several participants felt that if they had in-flight access to WiFi (which not all planes had), they would be able to complete their report immediately before leaving the plane.

“I would like to report incidences from the aircraft so that it is done before I leave, so that the information is even fresher in my brains. With WiFi, the management could have the report before we even reach the ground. That is one piece of the job that I would like to complete on the aircraft, rather than at home.” - P6, Female, Lead/Cabin Crewmember

4.5. Summary

In this chapter, I detailed the findings from my user research. These included four broad themes: first, the roles and responsibilities (captain, cabin service director, pursers, leads and crewmember); second, the collaborative work activities; third, the collaborative system and; fourth, the information and resources shared with other team members. I described the roles and activities of the flight crew based on the different airlines (domestic and international) and regions (North America, Asia and Europe). Then, I illustrated how these roles extend to the hierarchy of reporting - these included crewmmembers reporting to pursers/leads and they further reporting to cabin service director/pilots. Based on a critical situation, the reporting hierarchy can be flat and all crewmembers regardless of airlines and region are advised to report to the pilot. I also enlisted the details on how information is provided in resources and how new information is communicated via face-to-face in collaborative work activities and through technology. The study findings highlight the problems where team cognition and technology fails to support awareness and collaboration needs, as assessed in the different situations, phases of flight and placement of tools. Examples include sharing of the resources, the proximity and complexity of using the tools, and the disbursement of information for emergency situations.

Chapter 5. Discussion

In this chapter, I explore my results by analyzing them in terms of team cognition and distributed cognition as explored in chapter 2. I begin the chapter with an overview of how flight attendants maintain their situation and workspace awareness. Then, I provide an overview of how information is shared among the crewmembers. Finally, I focus on the implications of my findings for informing the design of collaborative technologies for flight attendants. I provide suggestions on how flight attendants' workflow can be optimized. I conclude with insights on why team and distributed cognition is found to be challenging to implement across different airlines.

5.1. Maintaining Situation and Workspace Awareness

My findings revealed that the CRM training only provides the necessary groundwork or common ground for implementing theories of team and distributed cognition, yet, in actual practice, engaging in such acts is more challenging for flight attendants given their working environment and the availability of appropriate technology. Team and distributed cognition starts to develop early at the pre-flight briefing when a shared mental model is developed amongst crew members. This model is extended by the lead/purser each time they communicate and coordinate with the pilot, cabin senior director and the cabin crewmembers. To avoid miscommunication and information breaks, the lead/purser tries to make the workflow efficient by communicating the mental model of the flight to the other flight attendants using the in-flight collaboration tools. However, my results show that these collaboration tools do not always enable flight attendants to work more efficiently or to improve the level of situation awareness needed for collaboration. Flight attendants face problems in maintaining situation awareness, during both routine and emergency situations, and sharing pertinent information with others.

For instance, in a normal service routine, the leads/pursers gain an awareness of the cabin crew's work activities by personally walking to each crewmember's station to inquire and provide assistance. An alternative is to use the interphone or the flight attendant call button, but these can not be relied on for immediate feedback or to provide a visual display of each crewmember's current activity. Crewmembers need to be in close-proximity to where these tools are located (galleys, exit doors) or where the sounds can be heard. This can cause delays in waiting times or interference with current tasks. In an emergency situation (such as a threat or turbulence), these collaboration tools become more inaccessible or are burdensome to use (locating flight attendant call button). In addition, these tools do not provide visual access to the flight deck or to each other's position, which leads to crewmembers feeling uncomfortable in relaying or asking for further information for clarification. A common practice to mitigate this problem amongst crewmembers is to gesture or shout to others for help. Although this is a fast approach to receive information, gestures can be hard to see and shouting is easily not heard in the distributed setting. Also, the audio alerts from the interphone and the flight attendant call button do not indicate what level of emergency and assistance is required. Only when an interphone call is answered or when the crewmember physically moves to the passenger's seat to assess the situation can the crewmember understand its level of urgency.

This illustrates that the current technology used by the flight attendants I studied does not strongly support collaboration. The objective of these tools is meant to help maintain workspace awareness when face-to-face interaction is not possible, however the findings reveal that proximity is a precursor for collaboration and collaboration is only smooth when flight attendants are in close physical proximity. Yet the challenge is, this is rare. In terms of sharing common knowledge, the flight attendants in our study were not always able to retain, share or disseminate information to other crew members at the right time or at the right place. Team cognition is effective, when the lead/purser is constantly creating the shared mental model and updating the flight crew about the flights or passenger's situations. However, the study reflects that when the lead/purser is having problems, there is a disconnect in the team cognition. Maintaining situation awareness and taking collective actions is thence rendered difficult, resulting in leads/pursers improvising and appropriating the tools to create their required awareness.

An example of the participant pressing all 6 buttons on the flight attendant call buttons to gain the attention of the fellow colleague.

Due to a lack of feedback provided, in-flight technologies should be potentially redesigned to better facilitate smooth collaboration and awareness amongst flight attendants. Here, we see that an emphasis should be placed on notifying flight attendants with real-time emergency information first and then other routine information second. Designs should also provide immediate access for flight attendants and for leads/pursers to communicate with other crewmembers, regardless of where they are on the plane or what situation they are facing.

5.2. Information Sharing and Optimizing Workflow

The responsibility of sharing information with crewmembers and updating the captain and cabin senior director is the responsibility of the purser. They have to ensure that the information they have is updated and accurate, so that others may be able to follow their mental model and take the next decisions or action. In our findings, we found this took place during both formal and informal conversations/interactions amongst flight attendants. Conversations often involved the sharing of contextual information that was either static or dynamic in nature. Static information included information embedded in manuals, pre-flight briefings, and reporting details. Our results showed that participants used either the paper or the digital format of the information and were not necessarily satisfied with either. Paper information was easy to lose, difficult to search, and heavy to carry. This discouraged most participants from active usage of the flight attendant manuals. For digital information, our participants found that the act of sharing tablets created, perhaps, more challenges than benefits. Flight attendants had a difficult time holding an object that could easily break if dropped. It could also easily be stolen.

This offer suggestions for the future design of technologies for flight attendants as it relates to static information. Such needs equate to technology that is lightweight, robust and easy to carry or hold on oneself (without the constant need to use one’s hands) as well as the use of multiple devices amongst groups of flight attendants. Dynamic information includes customs regulations, crewmember details, and passenger details. As recorded in our results, pursers prepared themselves in advance about the aircraft, customs and the people they would work with, so that they could be efficient in maintaining situation and workspace awareness while in-flight and working. However, this information was prone to last minute changes. As such, paper-based copies of this information did not work well and flight attendants would highly value technologies that give them quick access to dynamic information. Overall, both the static and dynamic information highlighted the loss of opportunity in creating social good and the inefficiency in improving one's development. Crewmembers continue to struggle when learning and sharing their ideas. To improve and encourage information sharing practices amongst crewmembers, future designs may want to consider how dynamic information could be made easily available to flight attendants so that it is ready-at-hand when they need it and that they can quickly discern what has changed.

5.3. Distributed cognition

The framework of distributed cognition helps to understand how the factors leading to a break in team cognition occurs, however the study also highlights why all four parts of the activity awareness can not be fully applied in the present flight attendant scenarios. Firstly, flight attendants do not work together for a long period of time. In a five year span, a particular crewmember must have worked twice with the same crewmember. This means that crewmembers can not develop the sense of familiarity which helps to predict the actions of another crewmember. Thence, crewmember common ground is built from the CRM training and by their knowledge in flying with different crewmembers. Second, for creating the community practice amongst crewmembers, airline operators make it mandatory for flight attendants to participate in the pre-flight briefing, where previous case scenarios and everyone's mental model on different approaches to solve the problems are discussed. The interactions could be enforced via the informal interactions/conversations discussed above or when reporting in-flight, however it was realized that the artefact/technology/time-lapse issues do not motivate team-members to participate. Therefore, even though participants have satisfactory interaction in terms of assisting one another with stress, crewmembers would not have a social bond that could tailor to social good and eventually human development. This suggests that the values and beliefs that make a highly effective team would then extend only to airlines that have crewmembers operating together. In this case, the European airlines where crewmembers have the option to fly together could benefit from this strategy. For other airlines, they would have to rely on the present technological tools until a policy to work with the same crewmembers could be applied.

5.4. Design implications

Without the proper integration of the collaborative tools with the current work practices, flight attendants lack the support necessary to easily communicate and collaborate when in-flight and in a distributed setting. In this thesis, I presented these results that suggest directions for the design of communication and awareness technologies for flight attendants with an emphasis on real time access to situation awareness information and hands-free interactions to assist work activities. These suggestions focus on: providing real time location awareness of all crew members; mechanisms to send and receive status information about flights on the go (e.g., turbulence, weather); interactions to send short status updates or longer messages; and, awareness of passenger needs via call button interactions.

Based on these suggestions, there are many potential solutions. One might imagine, for example, the use of wearable technologies that could let flight attendants send messages to each other or view status information about the flight at-a-glance without having to hold a device such as a tablet or smartphone. Smartwatches could allow crewmembers to receive calls from any part of the aircraft and simultaneously help to clarify and communicate messages with one another. Other design solutions may involve the increased use of embedded devices throughout the plane so that flight attendants can access technologies more readily or gather awareness information from them regardless of where they are on the plane. These sensors would be embedded into flight attendants attire and could track the locations and activities of crewmembers and send warnings of emergencies or notifications for help (talk2myshirt, 2015).

One could also explore the use of embedded shared displays controlled with speech and gesture recognition by flight attendants. During periods of high workload, these shared displays could provide the benefit of real-time information and hands-free interactions. Flight attendants can stick these displays like Smart Stickers to any part of the aircraft such as on the food cart or doors of overhead storage bins, and use speech/gesture to access the dashboard for new information or access the whiteboard for collaborating tasks/reports (“Indiegogo,” 2015). The drawbacks for shared displays is that flight attendants in emergency situations may either forget to take off these shared displays or lose them, which may lead to passengers accessing the displays’ information and compromising security issues. This means that flight attendants have to be careful with the type of information stored on the shared display or access control would need to be used. Also, the drawback with speech recognition is, at times there are loud background noises from the aircraft motors or from passengers, or flight attendants can become sick and develop variations in their voice. In these situations, the system might not recognize their voice, thence rendering the device as being impractical.

Likewise, one could consider studying and designing headgear (e.g. Google Glass, Microsoft Hololens, EyeTap) that streams situational awareness from embedded sensors in the flight (“EyeTap Digital Eye Glasses,” 2016; “Rockwell Collins,” 2017). Headgear could benefit flight attendants by providing instructions and past records for handling complex situations (e.g. giving CPR to passengers) which could be displayed on the headgear, leaving flight attendants hands free to follow step-by-step procedures (“Industrial Situational Awareness,” 2017). The data captured by the headgear can also provide replays of flight activities and be submitted as a formal report of the visual cues during errors, so flight attendants can practice and improve their situational awareness. Yet I see three main drawbacks with using headgears: a.) high cost, b.) privacy concerns, and c.) the battery life. For airlines to develop a fully functional system, it would be quite costly to record video in-flight, and provide online streaming of past videos. Secondly, there may be privacy concerns and permissions required to record passengers and flight attendants in-flight. Flight attendants may not want to be recorded as they may be reprimanded by their supervisors and passengers may be offended if their personal data is shared with strangers. Lastly, the current battery life of headgear products is not optimal for usage over long periods of time. If it is assumed that flight attendants have only one pair of headgear to use and during a step-by step procedure for recuperating a passenger, it runs out, it would be a challenge for a flight attendant to charge the headgear.

These suggestions are certainly speculative, however, and future work would find promise in pursuing such design explorations.

5.5. Summary

In this chapter, I reflected on the findings from the user study conducted across 11 flight attendants for both domestic and international airlines. I discussed the difficulty in maintaining situation and workspace awareness despite having the Crew Resource Management Training. I detailed how team cognition although being constantly maintained by the leads/pursers, efficient collaboration is not supported in the routine and emergency situations. Participants used collaboration tools as the main source of communication, but they experience it to be burdensome for exchanging information, multitasking between services, asking or sharing for immediate feedback. This signifies that new technologies should emphasize on real time access to situation awareness information and hands-free interactions to assist work activities. They also need to be light-weight, robust, easy to carry and can easily retain, share or disseminate information to other crew members at the right time or at the right place. In lieu of these problems highlighted, various solutions including wearables are suggested. Wearables provides flight attendants with the flexibility to communicate and collaborate with one another at any time and at any place.

Chapter 6. The Design of SmartCrew

The design of SmartCrew was completed in collaboration with Samsung Canada as our grant partner for ten months. This chapter addresses my RP.3, *We do not know how to design new technologies such as smartwatches that will support flight attendants' awareness and collaboration needs.* The purpose is to provide a solution for RP.3, based on a user-centered design process. This includes using the contextual analysis from my findings (Chapter 4) to derive a list of design requirements to solve the current problems and to guide the design process and design-informing models for a proposed solution (smartwatch applications).

6.1. Design Requirements

In this section, I discuss the design requirements derived from the findings (in Chapter 4). I focused on the usability and emotional aspects that created a hindrance in flight attendants' work activities. This involved looking at 1) the technical barriers of the collaboration tools to support a user activity, 2) the emotional aspect (i.e. pain points) for a user to complete a certain task. I created a list of flight attendant needs and pain points: thirty for the pursers and eighteen for the flight attendants (Appendix G).

6.1.1. Routine Checks

Problem 1: Gestures could not be seen due to a flight attendant being occupied and also the layout of the plane blocks the flight attendant's view.

Requirements for Routine Checks

- Easy visualization of the performance of safety and security checks (teams who have completed or are still behind)
- Features to provide immediate notification to a group/individual

6.1.2. Service Run

Problem 1: Flight attendants need to be in close proximity to the interphone (or in the galley) in order to communicate with each other. This requires them to be present in the galley leaving their current tasks.

Problem 2: In case of the unavailability of the intended person, flight attendants must remain engaged to the interphone or return to the galley to call again. In some cases, access to the interphone or alternatively the flight attendant call button is not possible.

Requirements for Service Run

- To make it easy for flight attendants and purser to coordinate and communicate simultaneously while performing their services.
- To be able to access any crewmembers from any part of their aircraft.
- Allow for written and short instructions to help new and older flight attendants to confirm the same interpretation of the situation and adjust accordingly.

6.1.3. Assisting Crewmembers

Problem 1: Leads/pursers are required to physically make rounds in each cabin to ensure smooth operations and customer service. This means they will look out for members if they need assistance during service time. As crewmembers are too busy and cannot reach out to the interphone – it is difficult for leads/pursers to identify who requires immediate help.

Problem 2: There is confusion as to who requires help when the flight attendant call button is pressed; the passenger or the flight attendant. Most time, flight attendants use the same configuration to ask for team help, as they do not remember the configuration and need emergency help. This does not indicate clearly to other team members that a crewmember needs help.

Problem 3: Crewmembers face difficulty in memorizing information such as seat number whenever there is a higher workload or there are too many interruptions while attending passengers. The use of jargon and gestures frequently used by the senior flight attendants may create confusion for the new members.

Requirements for Assisting Crewmembers and Passenger Emergency

- Provide location and activity awareness of crewmembers to see who is available and from where.

- To make it clearly distinguishable if fellow crewmember or a passenger is calling for help, without having to walk back to the galleys for verification.

- Reduce cognitive work-load.

- Provide real-time messaging and feedback. Allow exchange of written and short instructions to help new and senior flight attendants to confirm the same interpretation of the situation and adjust accordingly.

6.1.4. Passenger, Seat Belt and Turbulence Emergency

Problem 1: There is no difference between the call made for normal versus emergency situations. Tasks of low priority as well as high priority are received at the same time by the recipient.

Problem 2: Information is shared based on proximity of the recipient or how fast they can access the interphone or hear the flight attendant call button. For crucial situations such as a passenger having a heart attack, there is a delay in informing the flight crew.

Problem 3: Flight attendants are instructed to begin their service once the seatbelt indicator is off. However, the task to constantly watch the seatbelt sign becomes difficult especially during turbulence i.e. when waiting time is not defined.

Requirements for Passenger, Seat Belt and Turbulence Emergency

- Provide clear and easily identifiable notifications in emergency situations. Make it easy for flight attendants to receive live information on the tentative service time and the cause of delay.

- Provide immediate access to assistance from group or individual crewmembers from any part of the aircraft.
- Provide immediate feedback to crewmembers to counter any error or prepare for any threat in a given situation.

6.2. Design Informing Models

I now present a series of personas and user scenarios based on my study findings, to inform the design of applications for flight attendants.

6.2.1. Personas

The purpose of personas is to develop a realistic and reliable representation of the key audience (Hartson & Pyla, 2012). This helps to tailor features and functions of the final design to a specific user's needs. As I did not interview the pilots and the cabin service director in my user study, I could not construct the personas for these work roles. Thence, based on the contextual data (Chapter 3) and my study focus on flight attendants' collaboration (Chapter 4), I constructed personas for two key audiences, i.e. the Purser and the Cabin Crewmembers. These personas included a description of their tasks, background (experience, education) and the motivation towards their work. In addition, I also depicted their technical proficiency to ground our understanding of their use of different technology.

6.2.1.1 Persona 1: Purser

Persona 1 represents Daniel, who is characterized to represent the Economy Cabin Purser (Figure 6.1 describes Daniel). Given the leadership role of a purser, he is highly motivated to learn and use technologies to improve their workflow and the efficiency of operations inflight. Most international airlines provide the Purser only with technologies such as tablets.

6.2.1.2 Persona 2: Flight attendant with Technical Proficiency

Persona 2 represents the flight attendants who do not use technology frequently, but when necessary they are able to use the devices to complete their tasks (Figure 6.2 describes Melissa). Such as Melissa, who uses it connect to family members, friends and to listen to music when she is not working.

6.2.1.3 Persona 3: Flight attendant without Technical Proficiency

Persona 3 represents flight attendants who do not prefer to use technology and who are also not technically proficient (Figure 6.3 describes Tania). Tania depicts this category of cabin crewmembers and only uses technology when she has to contact family members or to schedule roster appointments. Even for mandatory reporting, she prefers to verbally provide her feedback to the Purser or write it on paper and submit to the head office.

Figure 6.1. Persona 1 Represents the Purser (cabin crew manager)

Figure 6.2. Persona 2 represents the cabin crewmember

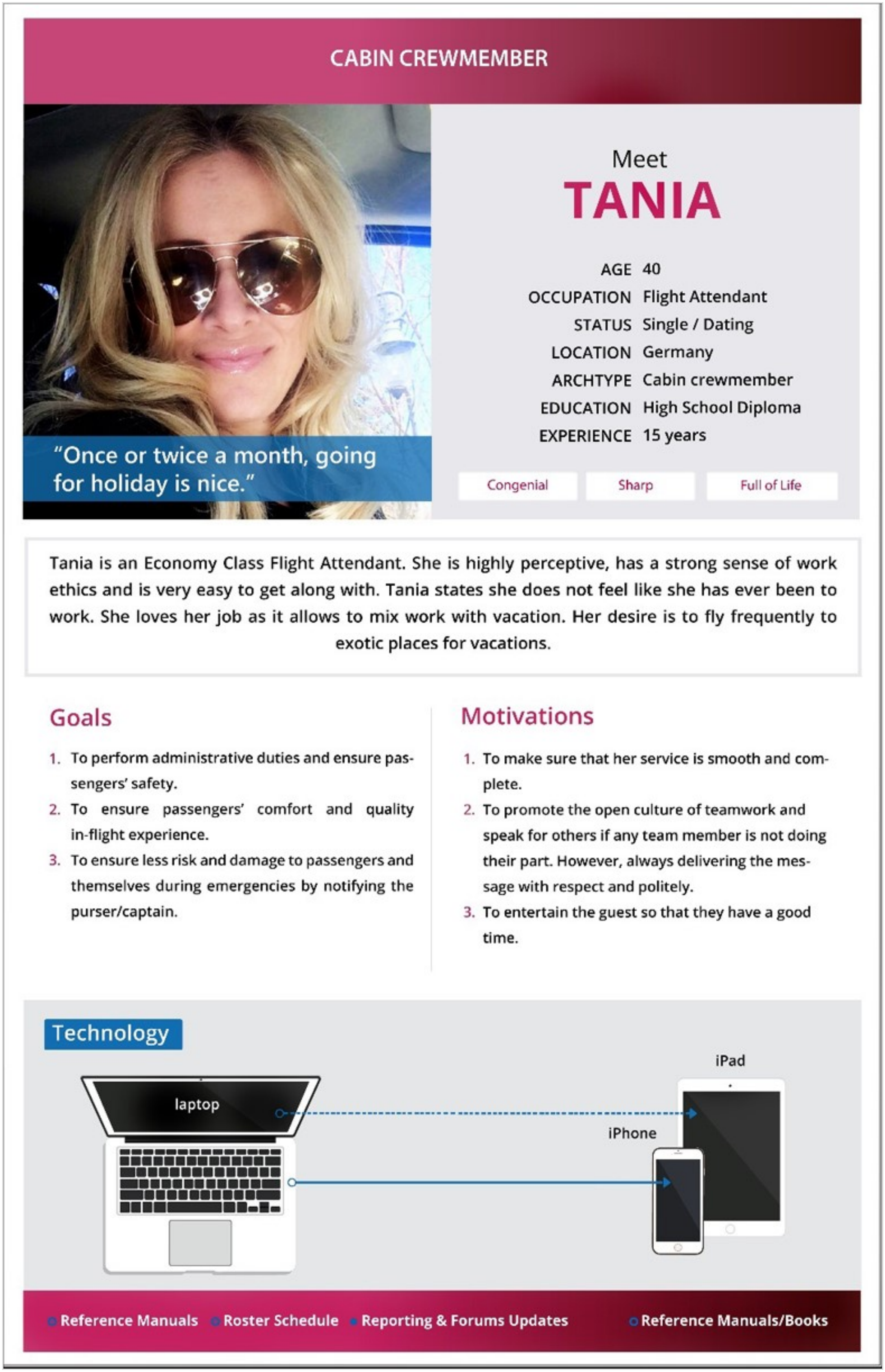


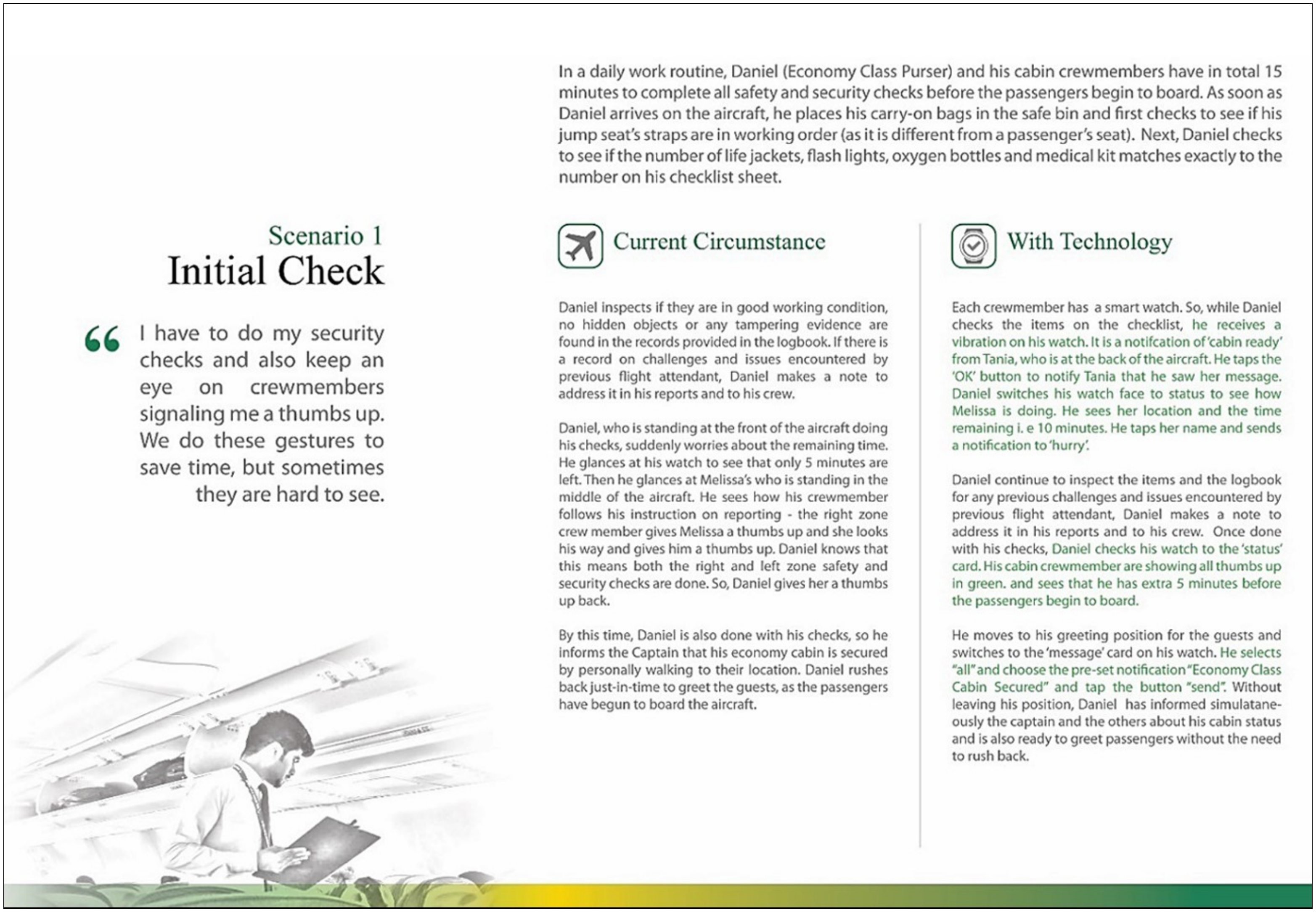
Figure 6.3. Persona 3 represents the cabin crewmember

6.2.2. User Scenarios

A user scenario is a detailed description of what users do with a given product/system and more importantly why they do it (Hartson & Pyla, 2012). It offers powerful tools to gain insight on a user's needs and activities to support the phases of an interaction design lifecycle. There are two types of scenarios: 1. a usage scenario that is extracted from the contextual data to reflect the actual usage of work practice (Hartson & Pyla, 2012), 2. design scenarios which are stories that project how the future usage will look like in the new design. I combined both types of scenarios in one design to visualize both the current practices and compare it with a new design which is envisioned as a proposed solution. I wrote my scenarios based on the key personas and how they perform their tasks in the various stages of the flight. At this point, I brainstormed for potential ideas such as how a smartwatch can be used to optimize flight attendants' collaboration and communication inflight. The scenarios helped to inform my early designs.

6.2.2.1 Scenario 1 Initial Safety and Security Checks

Figure 6.4 shows the pre-flight phase, when all flight crew are performing their safety and security before passengers begin to board. The panel in the left introduces the problem the purser encounters when exchanging thumbs up gestures, the panel in the middle reflects the problem in more detail, and the panel in the right reflects the envisioned way to resolve the problem. The green text in the right panel shows the changes that are made to the current circumstance using a smartwatch; the purser can simultaneously perform his safety and security check, track the crew's status, alert others who are behind schedule and as a team send a notification to the pilot about his cabin ready status.



In a daily work routine, Daniel (Economy Class Purser) and his cabin crewmembers have in total 15 minutes to complete all safety and security checks before the passengers begin to board. As soon as Daniel arrives on the aircraft, he places his carry-on bags in the safe bin and first checks to see if his jump seat's straps are in working order (as it is different from a passenger's seat). Next, Daniel checks to see if the number of life jackets, flash lights, oxygen bottles and medical kit matches exactly to the number on his checklist sheet.

Scenario 1
Initial Check

“ I have to do my security checks and also keep an eye on crewmembers signaling me a thumbs up. We do these gestures to save time, but sometimes they are hard to see.

Current Circumstance

Daniel inspects if they are in good working condition, no hidden objects or any tampering evidence are found in the records provided in the logbook. If there is a record on challenges and issues encountered by previous flight attendant, Daniel makes a note to address it in his reports and to his crew.

Daniel, who is standing at the front of the aircraft doing his checks, suddenly worries about the remaining time. He glances at his watch to see that only 5 minutes are left. Then he glances at Melissa's who is standing in the middle of the aircraft. He sees how his crewmember follows his instruction on reporting - the right zone crew member gives Melissa a thumbs up and she looks his way and gives him a thumbs up. Daniel knows that this means both the right and left zone safety and security checks are done. So, Daniel gives her a thumbs up back.

By this time, Daniel is also done with his checks, so he informs the Captain that his economy cabin is secured by personally walking to their location. Daniel rushes back just-in-time to greet the guests, as the passengers have begun to board the aircraft.

With Technology

Each crewmember has a smart watch. So, while Daniel checks the items on the checklist, he receives a vibration on his watch. It is a notifcation of 'cabin ready' from Tania, who is at the back of the aircraft. He taps the 'OK' button to notify Tania that he saw her message. Daniel switches his watch face to status to see how Melissa is doing. He sees her location and the time remaining i. e 10 minutes. He taps her name and sends a notification to 'hurry'.

Daniel continue to inspect the items and the logbook for any previous challenges and issues encountered by previous flight attendant, Daniel makes a note to address it in his reports and to his crew. Once done with his checks, Daniel checks his watch to the 'status' card. His cabin crewmember are showing all thumbs up in green. and sees that he has extra 5 minutes before the passengers begin to board.

He moves to his greeting position for the guests and switches to the 'message' card on his watch. He selects "all" and choose the pre-set notification "Economy Class Cabin Secured" and tap the button "send". Without leaving his position, Daniel has informed simulataneously the captain and the others about his cabin status and is also ready to greet passengers without the need to rush back.

Figure 6.4. Scenario 1 Initial Safety and Security Checks

6.2.2.2 Scenario 2 Service Run

Figure 6.5 shows the inflight phase after take-off. The panel in the left introduces the problem that the cabin crewmember encounters when waiting for the pilots to give them the clearance to begin service. The panel in the middle reflects a turbulence scenario, where the purser is communicating over the interphone and asking the crewmembers to keep watch of the time to begin service. The panel in the right reflects an envisioned way to resolve the problem. The green text in the right panel shows the changes that are made to the current circumstance using a smartwatch. In the envision panel, instead of looking up at the seatbelt sign to be turned off, cabin crewmembers can receive an alert from the purser to stay seated and a notification for how long should they wait before service time. Also, the purser does not have to call the crewmembers to confirm if they received the message, an ‘OK’ feedback is sent when crewmember receives the alert.

Scenario 2

Service Run

> "It is really tiring to keep looking at the seat belt sign to be turned off, especially when it is 'on' for more than 15 minutes. There should be another way to update us more frequently about how much time should we wait to begin the service.

After the aircraft takes off, Tania (First Class Flight Attendant) and her cabin crewmembers have to wait for the seat belt sign to be turned off. She observes her watch for the standard 5 minutes of waiting time.

Current Circumstance

After 5 minutes has passed, Tania sees that the seatbelt sign is still on. The interphone rings and Tania knows that it must be Daniel, the purser. Tania picks up the phone and Daniel informs her that they will have to wait for another 20 minutes to begin service. Tania puts a timer on her watch and waits for 20 minutes to pass and looks at the seatbelt sign again.

In the meantime, the aircraft is having jerky movements. Tania holds on to her seat tightly, the timer buzzes her that 20 minutes has passed; she looks back at the seat belt sign and finds that it is still on. Tania figures that if the turbulence continues for a longer period of time, they would have to combine the planned tea service with the lunch service.

The interphone rings and Daniel tell her that the turbulence will soon end and to get ready for a lunch service in the next 10 minutes. Tania sees that it would be around 3:30am and continues to wait for the seat belt sign to be turned off and for the turbulence to calm down. After 10 minutes, the seatbelt sign is turned off, but there are still jerky movements. However, as they have the clearance, Tania makes her way towards the galley to prepare her carts for the lunch service.

With Technology

As soon as 5 minutes has passed, **Tania watch vibrates and she sees that there is a 'seatbelt' notification from the purser to stay seated. Tania taps the 'OK' button to send her acknowledgement.** Soon, another notification follows displaying that they have to stay seated for another 20 minutes. Tania sets the timer on her watch for 20 minutes, and experiences the aircraft jerky movements.

Tania focuses on her passengers in her zone to see if there are not anxious or if they need any assistance. She tries to calm one of the passenger's children from her seat. The timer buzzes her that 20 minutes has passed. **She glances at her watch to see that Daniel sent her a notification of "Lunch service in next 10 minutes". Tania sees that it would be around 3:30am.**

At 3:30am, the seatbelt sign for the passenger is turned off and there are still jerky movements, but they have the clearance to start service. So, Tania makes her way towards the galley to prepare her carts for the lunch service.

Figure 6.5. Scenario 2 Service Run

6.2.2.3 Scenario 3 Assisting Crewmembers

Figure 6.6 shows the inflight phase, when pursers and crewmembers are conducting their food/water/lunch service. The panel in the left introduces the challenge the purser encounters when multitasking between his service, and ensuring there is no problem in the overall crew service. The panel in the middle provides more details about how the purser visits each position to assist crewmembers that need help. In addition, he maintains communication with the flight deck and other crewmembers via the interphone. The panel in the right reflects the envisioned way to resolve the problem. The orange text in the right panel shows the changes that are made to the current circumstance using a smartwatch. The purser does not have to personally visit each crewmember, or move back to the interphone location to communicate with others, instead he can receive notifications from those who need help and coordinate with others from any location.

After doing the food service for his zone, Daniel (Economy Class Purser) remembers that there is a higher load of passengers in the middle of the aircraft, where Melissa is working.

Scenario 3

Assisting Crewmembers

“Have to ensure service is smooth and other cabin crewmembers have the immediate assistance they need. I can only do this by making rounds of the cabin, as they are all busy with the service and no one will pick the phone.

Current Circumstance

Daniel walks to the middle of the aircraft, where Melissa is busy with the food service and the passengers are asking her for different beverages that are not available on her cart. Daniel asks her if she needs help. Melissa tells him that she is relieved to see him, as she thought she had to go back to the galley. She requests him to bring two cartons of orange juice. Daniel gives her a quick nod and walks back to the galley and brings back two cartons of juice. While he is helping Melissa, the interphone rings. As Melissa is blocking the aisle, he has to walk back all the way to his zone's interphone. The captain requests Daniel for a flight attendant in the flight deck. Daniel informs him that he will see who is available and will send someone soon. He comes back to Melissa and tells her that he will come back in a few minutes.

He then walks to the rear of the aircraft, where Tania is working. He sees that she is done with all her service and asks her if there are any problems with the passengers. Tania tells him that all was fine. Daniel asks her if there is anything that needs to be monitored as he wants her to visit the flight deck for a few minutes as the captain needs to use the washroom. Tania happily agrees and tells him not to serve any more alcohol to the passenger at R5, S 15A. Daniel identifies him and tells her ok. Daniel then gives a call to Melissa to see if she has completed the service. Melissa picks up the interphone and tells him that she has just finished her service. Daniel asks to rest and have her lunch, later he wants her to begin her rounds around 1:40 pm and continue for 30 minutes till Tania comes back and takes over. In the meantime, he will make the 30 minute rounds for the entire economy cabin.

With Technology

As Daniel (Economy Class Purser) puts his cart away, he receives a vibration. He glances at his watch and see a notification from Melissa asking him to bring two cartoons of orange juice. Daniel looks at his watch and sees his cabin crew's location and status. He sees that Tania status shows 'free' from her service and is moving in the rear galley, whereas Melissa is still in the mid-cabin. Daniel picks up the two cartons of juices and makes his way towards Melissa. Daniel gives her the juice cartons and helps her with the service- when suddenly he feels his watch vibrate; he glances at it and sees a notification from the captain. The captain is requesting for a crewmember to be in the flight deck for 10 minutes.

Daniel sends them an 'OK' notification. He glances at his watch 'status' card and sees that Tania is free. He switches to the 'message' card and sends Tania a message to visit the flight deck for 10 minutes. Daniel continues to help Melissa finish the service when he receives another vibration. He knows it is Tania sending him an 'OK' notification, along with any important details about the passenger in her zone. He glances at his watch, confirms the notification of her status and the passenger's details. He then continues to finish the work with Melissa. Once Melissa's service is completed, Daniel tells her she can rest and have her lunch, later he wants her to begin her rounds around 1:40 pm and continue for 30 minutes till Tania comes back and takes over. In the meantime, he makes the 30 minute rounds for the entire economy cabin.

Figure 6.6. Scenario 3 Assisting Crewmembers

6.2.2.4 Scenario 4 Passenger Emergency

Figure 6.7 shows the inflight phase when the purser encounters a passenger emergency during service time. The panel in the left introduces the challenge the purser faces when trying to communicate with the crewmembers and the panel in the middle provides more detail about a typical scenario of a passenger spilling coffee on their hands. Given that the passenger can receive burns, the scenario depicts how pursers needs immediate assistance, but can not reach for other's help. The panel in the right reflects the envisioned way to resolve the problem. The blue text in the right panel shows the changes that are made to the current circumstance using a smartwatch. The purser does not have to reach out for the flight attendant button or the interphone, he can request for immediate help from any part of their airplane. While others can also tell his location by viewing the aircraft seat map or through the smartwatch vibrations when in close proximity.

Daniel, as the Economy Class Purser is supposed to take care of the important and frequent passengers' dietary details and comfort. During his meal service, one of the important passengers accidentally spills hot coffee on his own hands. The passenger is wearing a steal band, which causes the hot liquid to enhance his pain. Daniel looks around him to see if there are any cabin crewmembers in view.

Scenario 4

Passenger Emergency

> "I have an emergency and can not easily contact another crewmember to receive help. I made a public announcement with the interphone; however, this contradicts the goal of keeping the situation private from passengers.

Current Circumstance

Daniel knows that looking for a flight attendant call button to notify them would waste more time. So, he tries to resolve the problem on his own. He needs two important items quickly: a room temperature water bottle to clean the coffee and a medical kit. So, he asks the passenger to walk back with him to the galley. The passenger obliges, but in the middle of the two galleys the passenger stops and refuses to move.

Holding Daniel's hand, he tells him that the pain is intolerable. Daniel wonders what he should do, as he cannot release his hands and as they are not in view - he can not reach out to any passengers or to his cabin crewmember. Daniel tries to convince the passenger to move closer to where the interphone is. The passenger agrees and Daniel quickly rings the closest zone flight attendant. The interphone keeps ringing, but there are no cabin crewmember picking it up. While the redness on the passengers hand starts to become more obvious, Daniel thinks the fastest strategy would be to make a public announcement via the interphone. He picks up the interphone and announces the passenger's status and request for any available doctor onboard to come to the location between the two galleys.

The announcement makes his cabin crewmembers and the captain aware of his emergency situation. Within a minute, two of his crewmembers come to the location to help them. He asks them for a water bottle and the medical kit.

With Technology

When Daniel sees there is no one in sight, he looks at his watch, which displays the map of the aircraft and his cabin crewmembers' location and status. He taps on Tania's location, as she is the closest from his cabin. Tania receives his location and notification for help on her watch. She finishes dealing with her passenger and makes her way towards them. In the mean time, another notification from Daniel requests her to bring a room temperature water bottle and a medical kit.

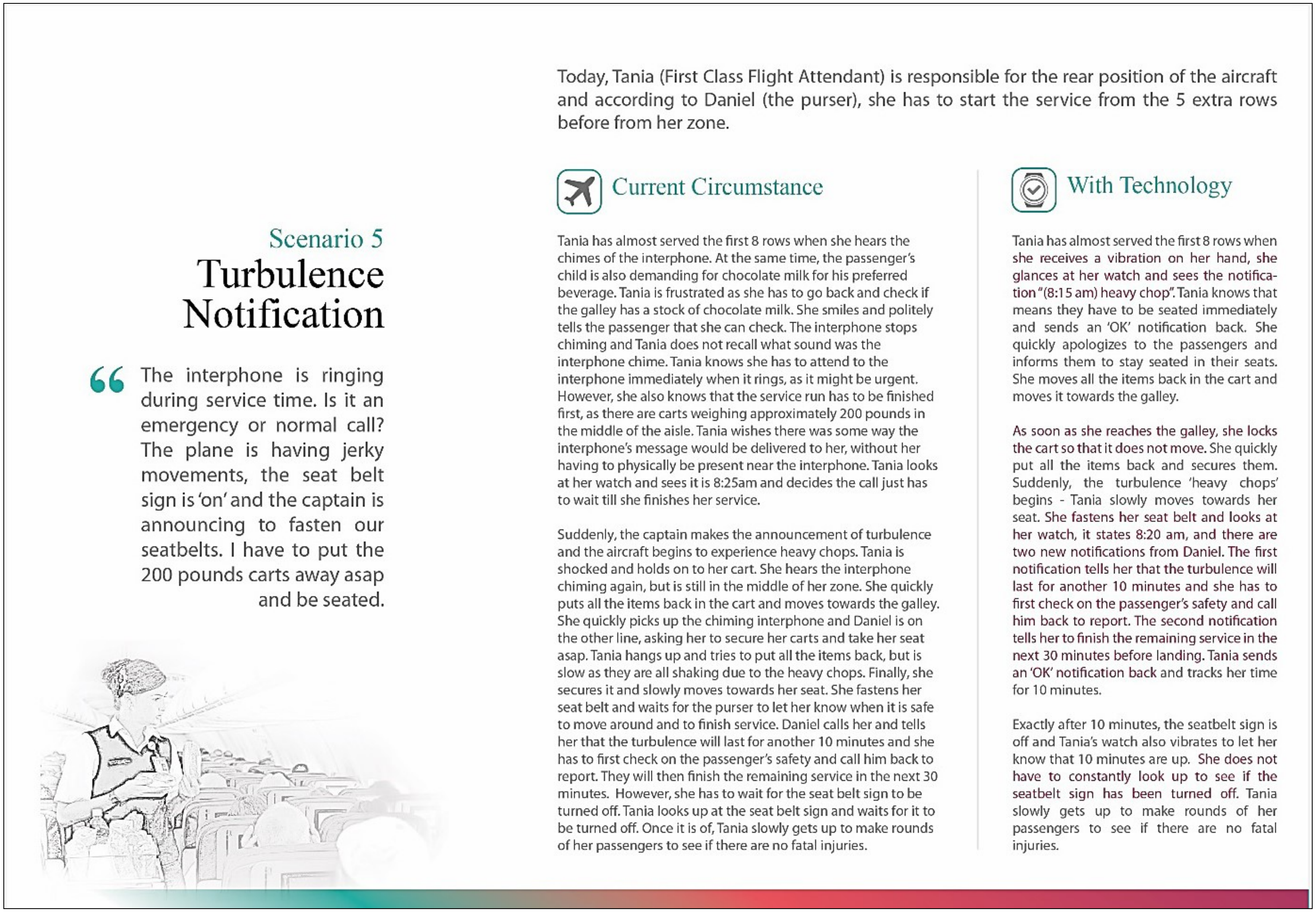
Daniel and the passenger moves towards the galley to wash off the coffee. The passenger agrees to follow Daniel, but in the middle of the two galleys, he refuses to move. Holding Daniel's hand, he tells him that the pain is intolerable. Daniel can not release his hands and tries to convince the passenger to move closer to the galley.

While, Tania brings the two items to Daniel's previous location- she finds him missing, but her watch vibrates to indicate that Daniel is close by. She sees his location on her watch and as she heads towards them; her watch vibration begins to grow stronger. She does not have to track the location by continuing to glance at her watch. Finally, she sees them and rushes to assist Daniel with the washing of the coffee and the applica-tion of the medicine on the passenger's hands.

Figure 6.7. Scenario 4 Passenger Emergency

6.2.2.5 Scenario 5 Turbulence Notification

Figure 6.8 shows the inflight phase, when a crewmember is faced with a sudden turbulence while doing their food service. The panel in the left introduces the information challenges the crewmember faces when trying to comprehend the situation, the indicators, and the immediate actions to be taken. The middle panel explains the challenges in more detail; highlighting how a communication break can easily take place and how crewmembers can put their own and the passenger's safety in danger by not being able to quickly respond. The panel in the right reflects the envisioned way to resolve the problem. The purple text in the right panel shows the changes that are made to the current circumstance using a smartwatch. The critical information about turbulence being expected is clearly communicated through the smartwatch. Crewmembers can skip the extra steps of delay (receiving the interphone, watching over the seatbelt sign), instead focus on promptly taking the next step to ensure their own and passenger safety.



Today, Tania (First Class Flight Attendant) is responsible for the rear position of the aircraft and according to Daniel (the purser), she has to start the service from the 5 extra rows before from her zone.

Scenario 5

Turbulence Notification

" The interphone is ringing during service time. Is it an emergency or normal call? The plane is having jerky movements, the seat belt sign is 'on' and the captain is announcing to fasten our seatbelts. I have to put the 200 pounds carts away asap and be seated.

Current Circumstance

Tania has almost served the first 8 rows when she hears the chimes of the interphone. At the same time, the passenger's child is also demanding for chocolate milk for his preferred beverage. Tania is frustrated as she has to go back and check if the galley has a stock of chocolate milk. She smiles and politely tells the passenger that she can check. The interphone stops chiming and Tania does not recall what sound was the interphone chime. Tania knows she has to attend to the interphone immediately when it rings, as it might be urgent. However, she also knows that the service run has to be finished first, as there are carts weighing approximately 200 pounds in the middle of the aisle. Tania wishes there was some way the interphone's message would be delivered to her, without her having to physically be present near the interphone. Tania looks at her watch and sees it is 8:25am and decides the call just has to wait till she finishes her service.

Suddenly, the captain makes the announcement of turbulence and the aircraft begins to experience heavy chops. Tania is shocked and holds on to her cart. She hears the interphone chiming again, but is still in the middle of her zone. She quickly puts all the items back in the cart and moves towards the galley. She quickly picks up the chiming interphone and Daniel is on the other line, asking her to secure her carts and take her seat asap. Tania hangs up and tries to put all the items back, but is slow as they are all shaking due to the heavy chops. Finally, she secures it and slowly moves towards her seat. She fastens her seat belt and waits for the purser to let her know when it is safe to move around and to finish service. Daniel calls her and tells her that the turbulence will last for another 10 minutes and she has to first check on the passenger's safety and call him back to report. They will then finish the remaining service in the next 30 minutes. However, she has to wait for the seat belt sign to be turned off. Tania looks up at the seat belt sign and waits for it to be turned off. Once it is of, Tania slowly gets up to make rounds of her passengers to see if there are no fatal injuries.

With Technology

Tania has almost served the first 8 rows when she receives a vibration on her hand, she glances at her watch and sees the notification "(8:15 am) heavy chop". Tania knows that means they have to be seated immediately and sends an 'OK' notification back. She quickly apologizes to the passengers and informs them to stay seated in their seats. She moves all the items back in the cart and moves it towards the galley.

As soon as she reaches the galley, she locks the cart so that it does not move. She quickly put all the items back and secures them. Suddenly, the turbulence 'heavy chops' begins - Tania slowly moves towards her seat. She fastens her seat belt and looks at her watch, it states 8:20 am, and there are two new notifications from Daniel. The first notification tells her that the turbulence will last for another 10 minutes and she has to first check on the passenger's safety and call him back to report. The second notification tells her to finish the remaining service in the next 30 minutes before landing. Tania sends an 'OK' notification back and tracks her time for 10 minutes.

Exactly after 10 minutes, the seatbelt sign is off and Tania's watch also vibrates to let her know that 10 minutes are up. She does not have to constantly look up to see if the seatbelt sign has been turned off. Tania slowly gets up to make rounds of her passengers to see if there are no fatal injuries.

Figure 6.8. Scenario 5 Turbulence Notification

6.3. Summary

In this chapter, I used the contextual analysis from my findings (Chapter 4) to provide a complete list of the problems that flight attendants face in their work activities. I derived design requirements from the listed problems. Next, I used these design requirements to inform and construct design-informing models. The design-informing models included user personas and user scenarios that depicted a holistic view of the current work practices of the flight attendants and identify the challenges faced by them. In the next chapter, I will discuss how the design requirements with the design informing models are integrated into a smartwatch application that supports and maintains flight attendants' communication and awareness.

Chapter 7. SmartCrew Prototype

In this chapter, I describe the prototypes designed for “SmartCrew”; a smartwatch application that does not require synching with cellphones to enhance communication and collaboration in an aircraft setting. It is designed with an emphasis on real time information access and direct communication between flight attendants regardless of their location. The purpose of prototyping is to provide a quick and basic idea of the envisioned design practice (Hartson & Pyla, 2012). I adopted the T-prototype approach as it provided the benefits of both the horizontal and vertical prototype i.e. an equal level of breadth and depth of features/functionalities. In this chapter, I refer to both features and functionalities as features. I first explain the low and mid level fidelity prototypes that are designed based on the design requirements and the design informing models. Then, I describe the high-level fidelity prototype.

The prototype design is based on the round user interface and the interaction features of Samsung Galaxy S2 smartwatch. To get a better understanding on smartwatches as the proposed medium, I conducted a heuristic evaluation of three smartwatches—Apple Watch, Samsung Gear S and Samsung Gear S2—which I tested for several weeks across a six to eight months period. With each of these smartwatches, I studied the interface and analyzed its pros and cons. The major difference was the screen size among the watches; Apple Watch’s screen was square; Samsung Gear S’s screen was rectangular while the Samsung Gear S2 screen was round. The Samsung Gear S2 smartwatch met the objectives of our design requirements, which were: a. easily customizable watch face, b. high resolution to see the aircraft seat maps in a low-inflight setting, c. is able to work without the phone being synched and d. looks similar to an ordinary watch and not a computational device (which is preferred by flight attendants). I chose the Samsung Gear S2 smartwatch, which was also desired by our industry partner, Samsung. The development work was done by my fellow colleague, Samarth Singhal. Each of these prototypes are detailed next.

7.1. Design Process

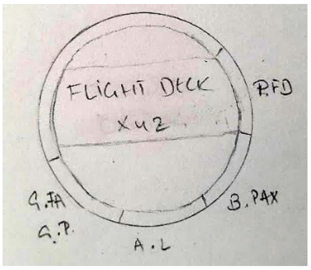
For ideation and conceptual design, my goal in the low-level fidelity prototype was to generate ideas and solutions to a maximum number of user needs. I created hand drawn sketches on paper to explore the different conceptual designs for the Samsung Galaxy Gear S2 smartwatch. The process included two iterations of sketches based on the features listed earlier. The interaction of the smartwatch used for the low-level fidelity prototype included tap, dial and swipe features to navigate within a widget board and for selecting items. Sample sketches showing the first iteration are found in Table 7.1. Sample sketches showing the second iteration are found in Table 7.2. The complete iterations first and second are provided in Appendix.

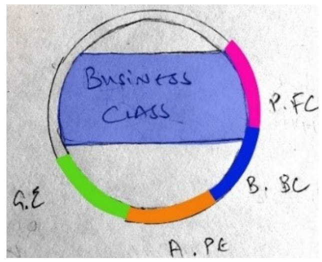
The mid-level fidelity involved the transformation of hand-drawn sketches from the low-level fidelity prototype into schematic diagrams called wireframes (Hartson & Pyla, 2012). The lines in the wireframe represented the navigation/task flow from one screen to another. Figure 7.1 represents a sample of the wireframe that shows how users will send a turbulence message to the crewmembers. Designing these wireframes provided an estimated visual layout of the look and feel and the behavior for an interaction design (Hartson & Pyla, 2012).

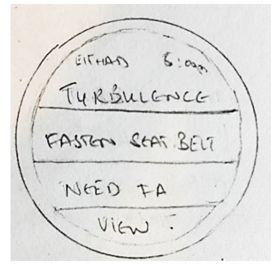
For the high-level fidelity prototype, the wireframes were made interactive using Adobe Illustrator and Adobe Experience Design. All wireframes can be found in Appendix. As the high-level fidelity prototype is close to the final product in term of material, functionality and aesthetics (Hartson & Pyla, 2012), it was my final prototype for this research. In the next section, I describe the finalized user interface, user experience, interactions, and features. This comprised of the graphics, the entire specification on the look and feel of the application such as navigation details, screen design, layout etc. It also included the development i.e. HTML, CSS, and JavaScript coding so that the smartwatch application can be tested technically and can function as a marketing and sales tool.

Table 7.1. Sketch 1 (First Iteration)

Watch face and navigation menu



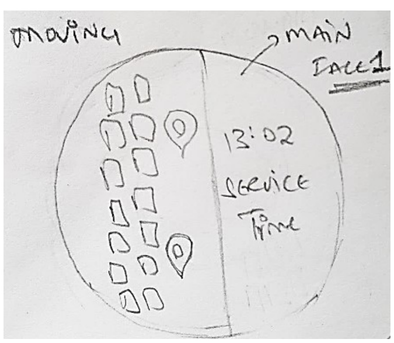


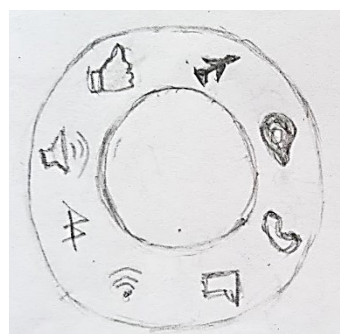


Note. **Image left:** Application watch-face divided as per the present visual indicators inflight: Pink for Flight Deck (P.FD), Blue for Passenger (B.Pax), Amber for Lavatory (A.L) and Green as Flight attendant (G.FA). **Image center:** Application watch face divided per cabins: Pink for First Class (P.FC), Blue for Business Class (B. BC) and Green for Economy (G.E). **Image right:** The main navigation for accessing all features: turbulence, fasten seatbelt, need flight attendant (FA), request to view and reporting.

Table 7.2. Sketch 2 (Second Iteration)

Watch face and navigation menu





Note. **Image left:** Application watch face divided per flight phase, current time and flight seat-map. **Image right:** The main navigation for accessing all features: turbulence, help, call, message, Wi-Fi, Bluetooth, volume, and cabin ready status.

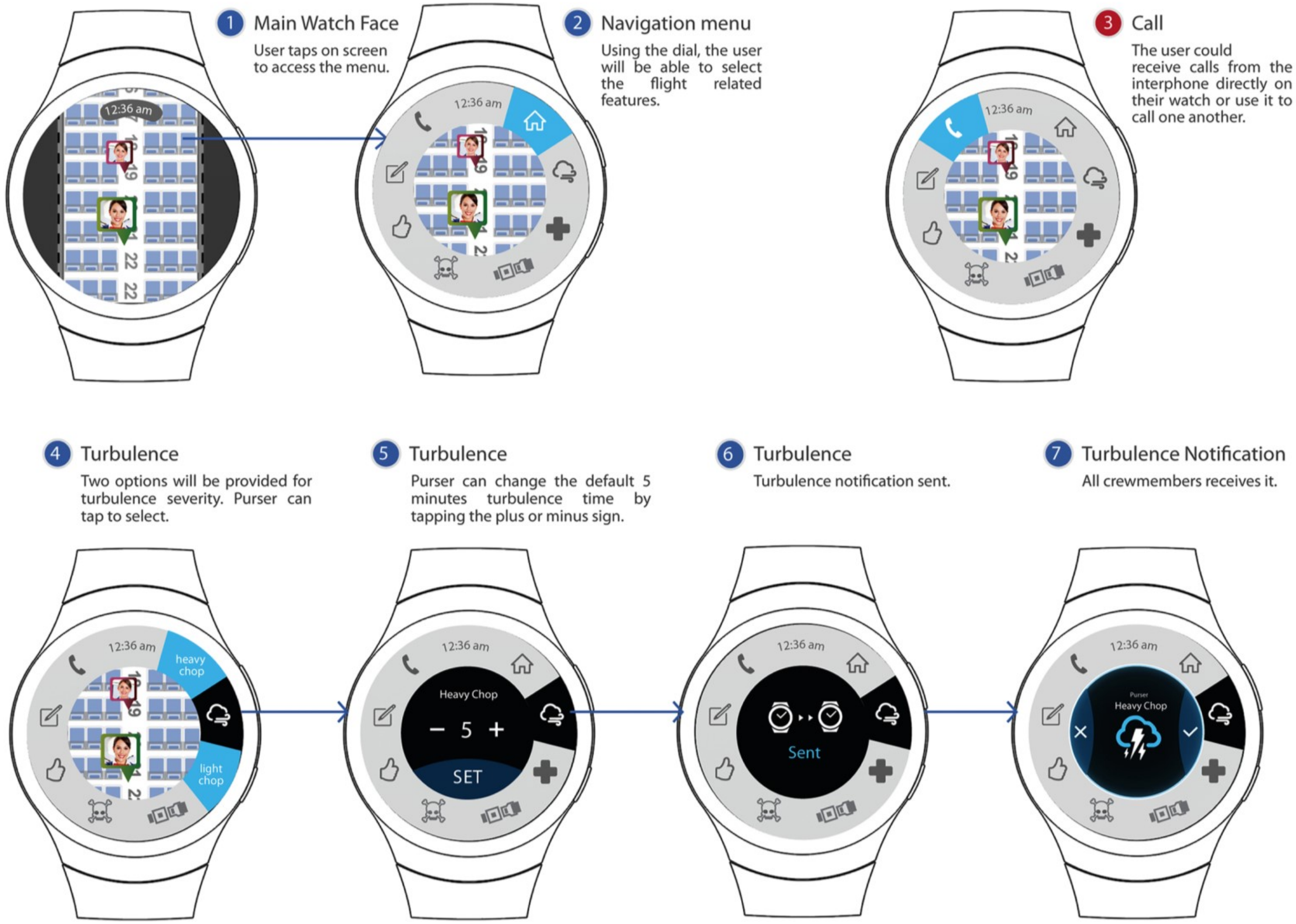


Figure 7.1. Mid-level Fidelity Prototype Sample

7.2. SmartCrew Final Design

In this section, I describe the rationale behind the elements created for a SmartCrew. According to Bank & Cao, (2016), consistency reduces cognitive load, which lowers the learning curve of the application. Therefore, I designed each of these elements keeping consistency, accessibility, and usability in mind. I first describe how flight attendant can interact and access the main features of the smartwatch for their work activities. Then I describe the design/aesthetics i.e. the use of colors, icons, widgets, sizes, shapes, fonts, spacing, and placement in the layout. Lastly, I focus on the use of the tone, vocabulary, and language used to convey the information.

7.2.1. Interactions and Layout of the UI

Users interact with the SmartCrew application mainly by swiping, tapping and using the dial control. The layout of the watch face was designed to have the flight seat-map active, this give a constant awareness to crewmembers of each other's physical location, and flight attendants can swipe up/down on the watch face to move within the spatial map of the plane as shown in Figure 7.2. Notifications appear on top of the spatial map and more details are available by tapping on the three dots on the right side of the watch face. This provides users with access to the main menu that shows the application's functionality and features (Figure 7.2). To make the user task flow more intuitive and natural from one task to another, I used the dial of the Samsung Gear S2 as a navigation input. Users can use the dial to navigate the features in the main navigation menu. According to (Nielsen, 2016), users behave differently and may not know how to find their way through a new feature, therefore designs should include shortcuts for easy accessibility. Thence, I also provided a shortcut, i.e. users can tap on the menu icon or in the center of the main navigation menu for selection of the feature. This is useful as flight attendants are always pressed for time. Similarly, I placed 'Time' in a consistent position in both the watch face and the main navigation menu. This ensures easy access and visibility for the flight attendants. SmartCrew consists of six features described below.

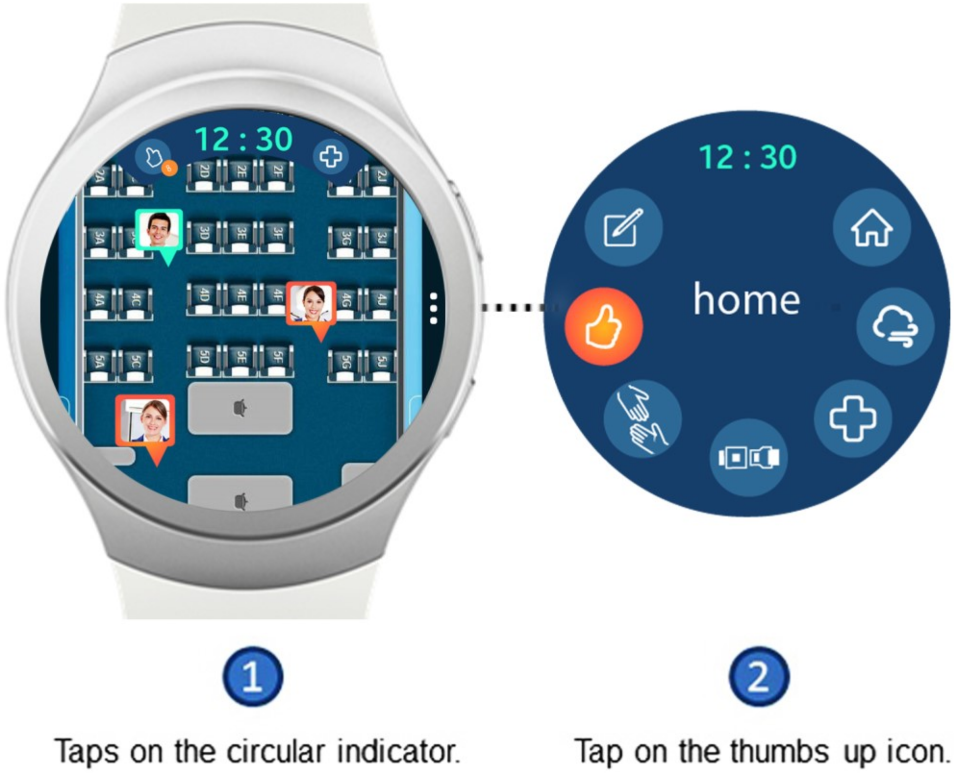


Figure 7.2. SmartCrew User Interface

Turbulence: Flight attendants can identify clearly between a normal situation versus a call made for emergency situation using SmartCrew. Flight attendants see additional details about notifications such as “turbulence is coming” and for how long. These come from the pilots, or can be set by lead flight attendants using the watch interface. As shown in Figure 7.3, critical situations are communicated immediately and collectively to the entire crew such as in passenger emergency and fastening of seat-belt during turbulence. The Steps 1 and 2 in Figure 7.3, show Daniel selecting the ‘Turbulence Emergency” icon from the main menu to notify all crewmembers. The feature further provides a submenu with two options of Light Chop and Heavy Chop in Step 3. The default time is 5 minutes, which can tap to increase or decrease. As shown in Step 4, Daniel selects ‘Heavy Chop’ indicated in white background. Step 5 and 6 shows the crewmembers’ smartwatch display and the notification being displayed. If the crewmember press ‘Ok’, the message will snooze, else the notification will remain active to remind them of the safety issue.

Passenger Aid: Flight attendants see alerts about any medical emergencies with passengers. They can also post any new situations which are then transmitted to all flight attendants. As shown in the Figure 7.4, Daniel taps the ‘Passenger Emergency’ icon from the main menu as Step 1 and 2. Step 3 shows that all crewmembers receive the notification. Melissa who is available is shown to tap on the “ok” button in Step 4. A feedback loop (highlighted in yellow) is enabled as shown in Step 4; it is a shared screen displayed on both Daniel’s and Melissa’s smartwatch, giving Daniel a sense of which crewmember is assisting him and providing Melissa the route and location of Daniel.

Fasten Seatbelt: Flight attendants see the details about notifications for fastening their seatbelt for safety. These come from the pilots, or can be set by lead flight attendants using the watch interface. As shown in Figure 7.5, Daniel taps the ‘Seat-belt’ icon from the main menu as Step 1 and 2. Step 3 shows that all crewmembers receive the notification. If all crewmembers press ‘Ok’, the message will snooze, else the notification will remain active to remind them of the safety issue.

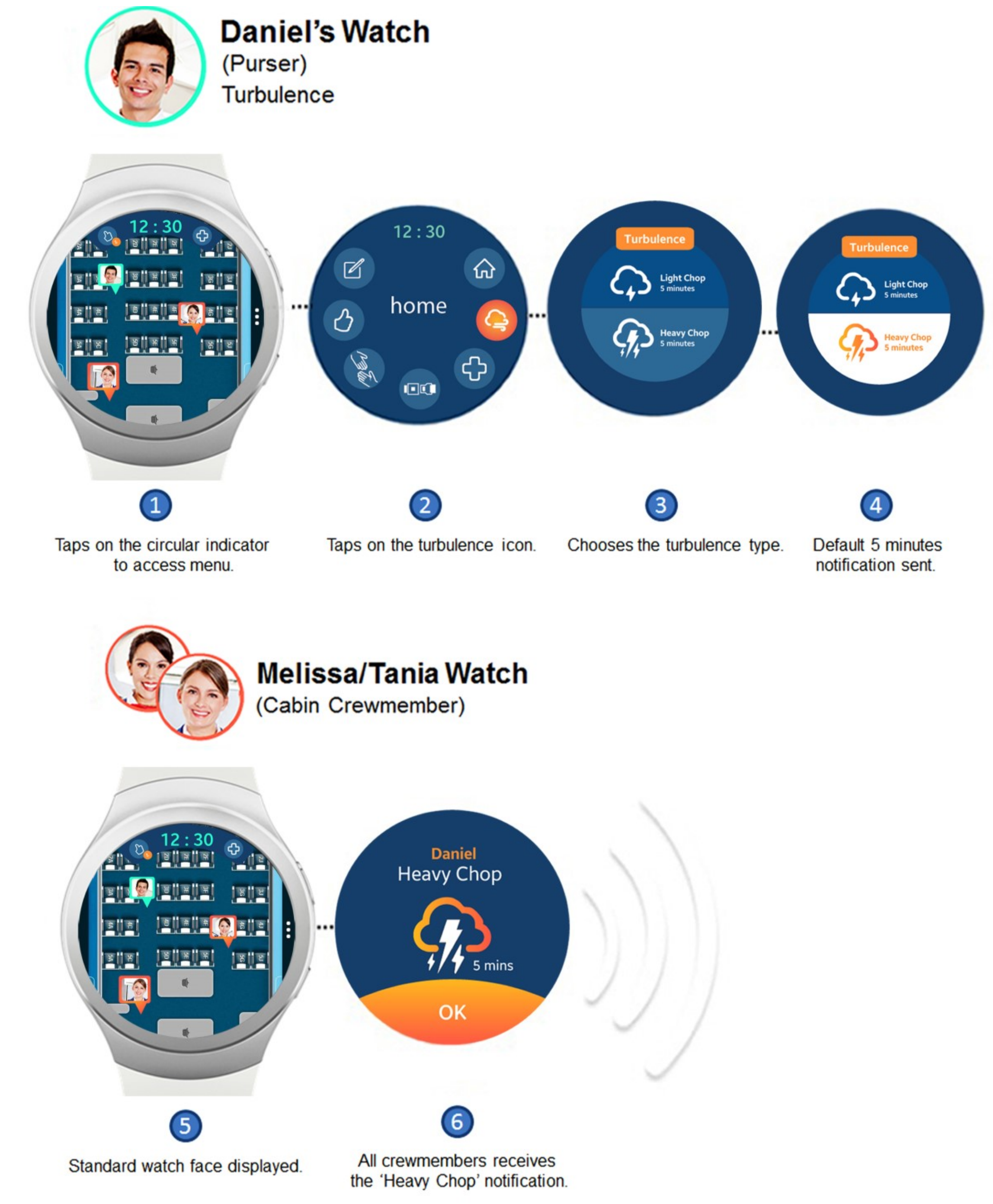


Figure 7.3. Turbulence Emergency

Figure 7.4. Passenger Emergency

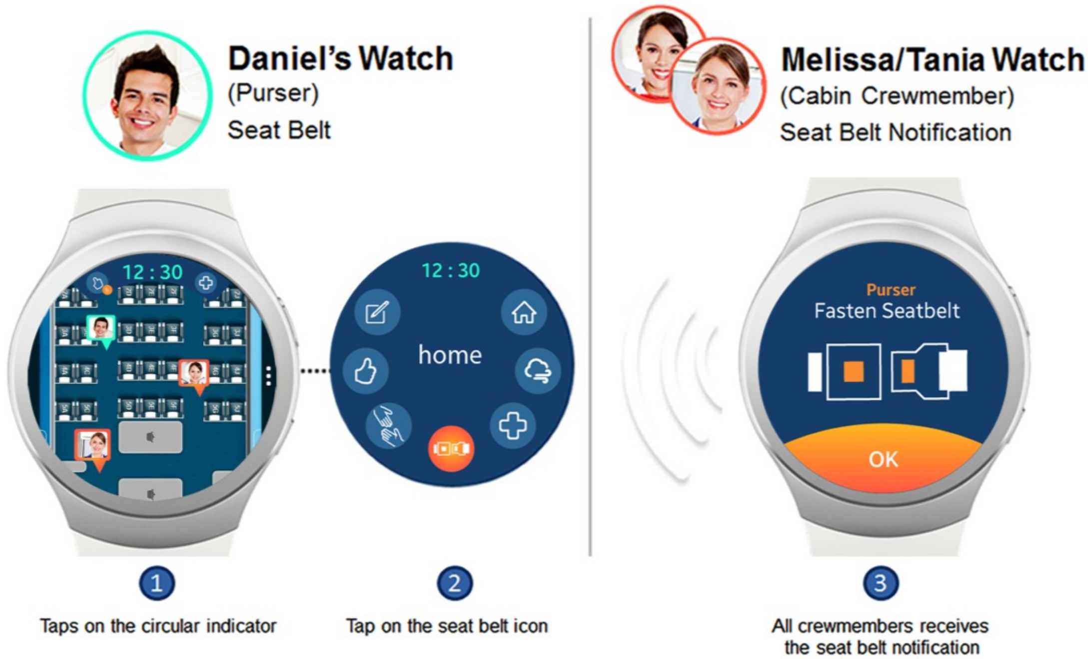


Figure 7.5. Seatbelt

Crewmember Assistance: In situations when flight attendants cannot afford to make hand-gestures or are facing some other limitation on mobility, SmartCrew enables flight attendant to request for help from the entire crew without having to reach out to the interphone or calling out for help. This is especially useful during a Service Run, when all crewmembers are busy serving passengers. SmartCrew enables flight attendants to see notifications about a particular crewmember requiring immediate assistance, the type of help required, and the person's location. They can also report the need for someone to assist them. As shown in Figure 7.6, Daniel access the main menu and taps the 'Crew Aid' icon. This causes their icon on the map to change colors so that other flight attendants know they require assistance as shown in Step 3. While he is handling the situation, the crewmembers who are closest or are available to help can respond to the notification as shown in Step 4. An immediate notification is sent back to Daniel's smartwatch to confirm that his message was received, and the crewmember who will be assisting him is shown in Step 5.

Cabin Check: Flight attendants also see notifications about which crewmembers completed their safety and security checks and how many flight attendants have yet to finish. This feature in the prototype allows the confirmation of safety and security checks to be communicated seamlessly and efficiently. Flight attendants do not have to look out for gesture or the interphone to inform the purser, they can use SmartCrew to report when they are done their cabin check at the start of the flight as shown in Figure 7.7.

Messaging: Flight attendants can coordinate tasks, or communicate new information or ask for immediate assistance real-time and irrespective of the location. Flight attendants can select from predefined text messages or create new ones and send them to one or more flight attendants. As shown in Figure 7.8, Daniel navigates to the main menu and taps the ‘Messaging’ icon, then taps either all or selected crewmembers (Step 3). In Step 4, there are ten predefined messages displayed, each are associated with a unique vibration for each. Daniel taps ‘hurry up’ and in Step 5, when a message arrives, flight attendants can either look at the watch to read it, or feel the vibration pattern. Over time, the aim was that users can recognize the vibrations so they no longer need to glance at the watch to see the message. This would allow them to continue on with their current task without additional interactions.

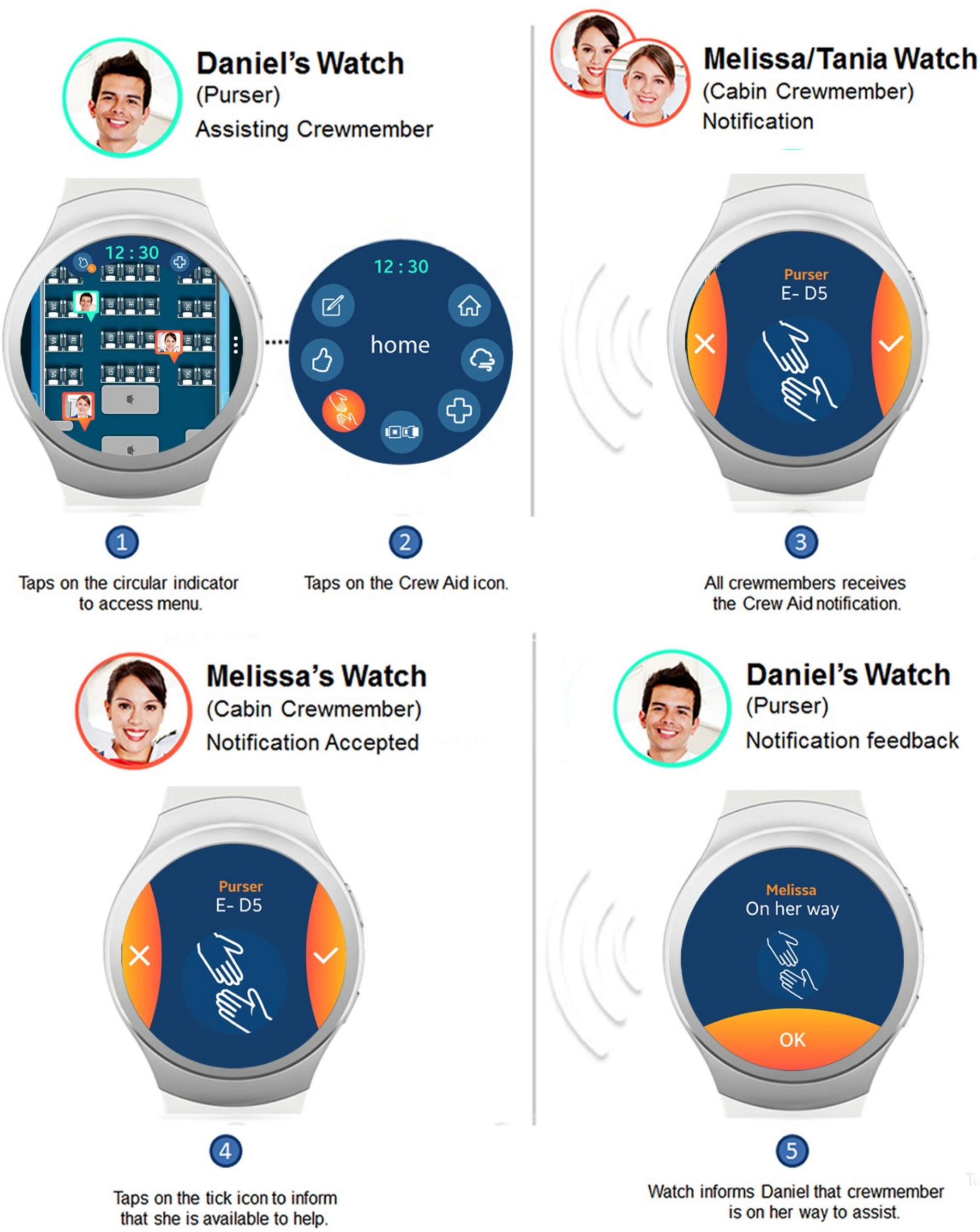


Figure 7.6. Assisting Crewmembers

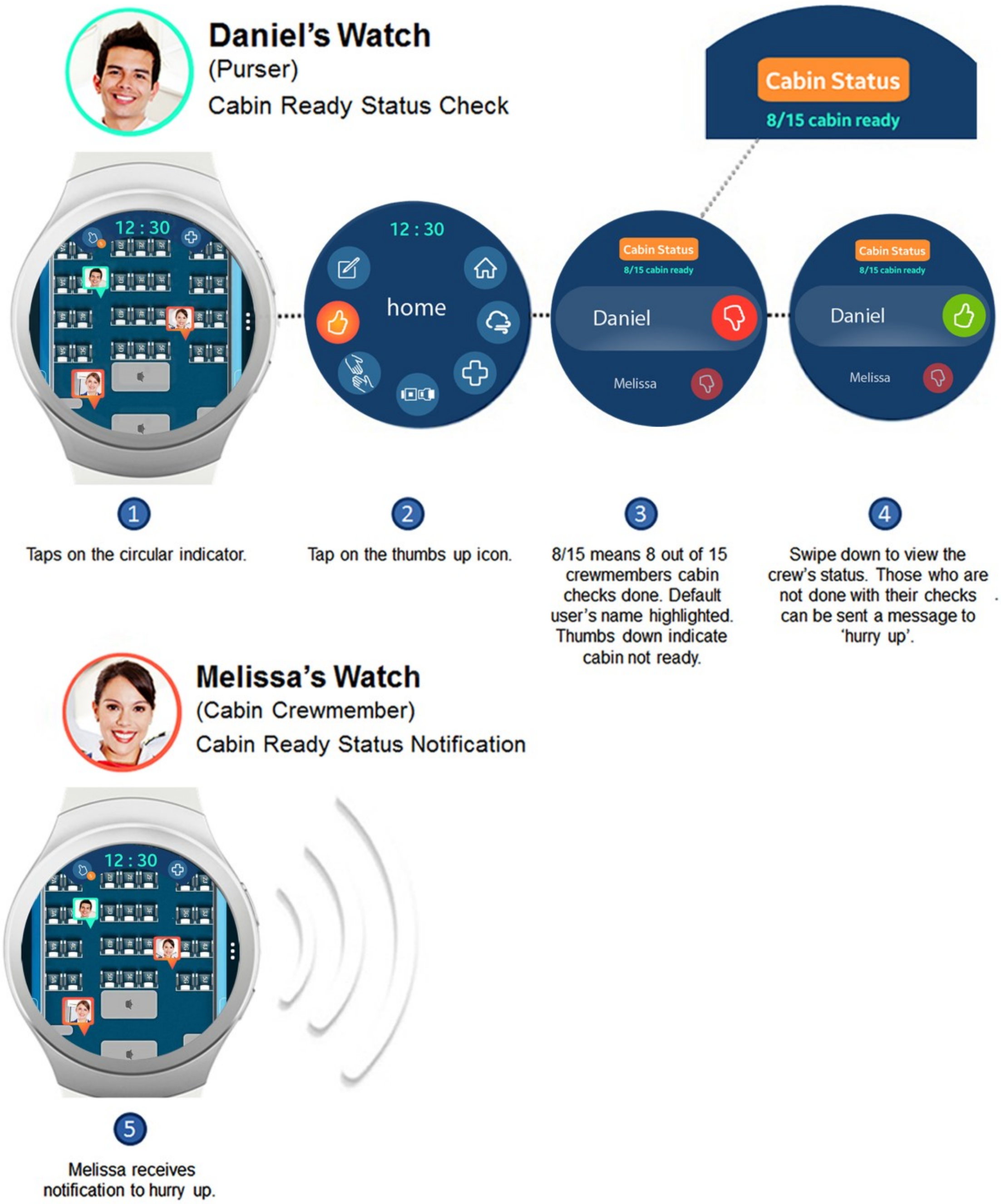


Figure 7.7. Routine Checks for Cabin Status

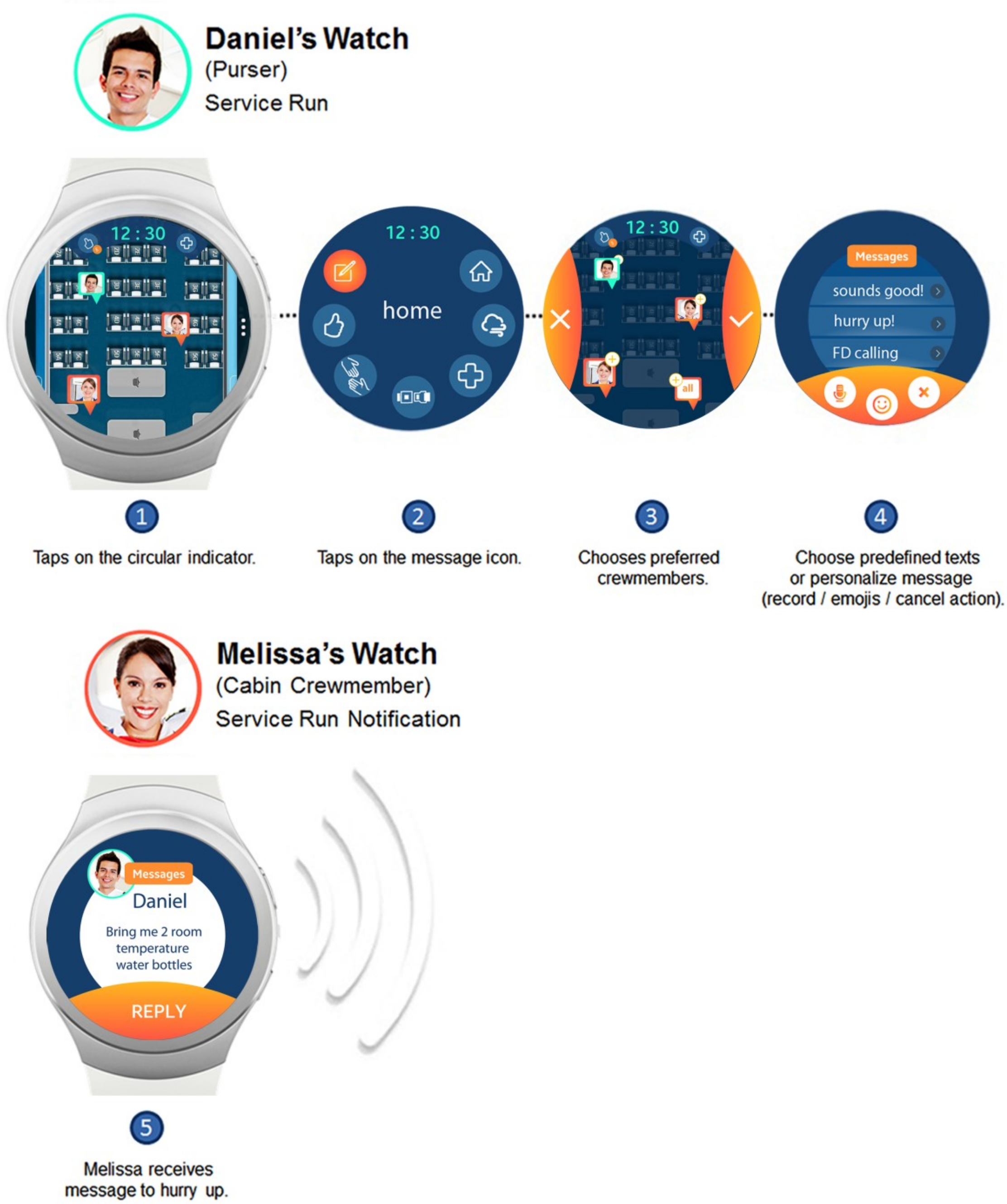


Figure 7.8. Service Run Access

7.2.2. Colour Palette

Colours are useful in setting an ambiance and have a neurobiological meaning for the product (Adamsmorioka, 2008; Bank & Cao, 2016). I used colours to create the flight attendant's association with their work, their values and 'call to actions' for communication and collaboration. The colour palette chosen was a combination of blue, orange and green. This can be seen in the splash screen (Figure 7.9), which is displayed when the application SmartCrew application is being loaded.

Figure 7.9. SmartCrew Splash screen

Colour Palette and the Rationale for Choosing them

- **Blue Colour:** represents the sky and symbolizes trust and responsibility necessary for a team. Given that the flight attendants spend most of their time in the sky and in team collaboration, this colour was appropriate to represent them and the team values.

- **Orange Colour:** relates to social communication and stimulates a two-way conversation. To encourage crewmembers to think and communicate more, this colour represents them and is useful in providing physical and mental stimulation.

- **Green (Lime) Colour:** represents harmony or balance. It is used to represent items that require attention, but are not alarming. This colour suits the leadership role of the lead/purser, so I used it to represent their role and other items that needed to be distinguished.

- **Red Colour:** represents danger, violence or items that needs immediate attention such as the traffic stop sign. I used red to represent notifications that required immediate attention of the crewmembers.

7.2.3. Graphic Design and Icons

Graphic design refers to the images used in a user interface, where as icons are pictorial representations of a person or thing (Bank & Cao, 2016). According to Bank & Cao (2016), icons are useful for establishing connections to the tasks, call-to-actions and as navigation items. They are used as a support for the colour palettes and helps to clarify the purpose of the tasks. For SmartCrew, I used a combination of images and icons as cues for helping users to effectively complete their tasks. Images for SmartCrew included the seat-map of the aircraft, which is the main watch face. While the icons included the notifications, the navigation items and the crewmembers profile. An example is shown in Figure 7.10, where the thumbs-up and turbulence icons are displayed as notifications on either side of the Time. Pursers and crewmembers are represented in a message form icon, with the purser's icon illustrated in lime green colour and the crewmembers icons illustrated in orange color (Figure 7.10)

Figure 7.10. SmartCrew Watch Face

SmartCrew's main navigation has seven icons, each representing a certain feature (Figure 7.11). These icons represent Home, Turbulence, Passenger Aid, Seatbelt-sign, Crew Aid, Cabin Ready and Messages. Each icon is carefully designed and derived from the user-study to represent what flight attendants are socially familiar with, such as home (common icon for navigating back to the home page/main watch face), the seat-belt sign (indication to stay seated), thumbs-up sign (indication that cabin is ready) and messages (common indication of a conversation). The purpose of having familiar icons is to allow the users to easily and quickly search the desired feature and complete their task (Bank & Cao, 2016).

Figure 7.11. SmartCrew Main Navigation Menu

7.2.4. Terminology

Most air carriers have the culture to use standard terminology that are derived from the flight attendant's manual. It helps flight attendants to communicate faster and avoid the need to explain further. To allow for the easy adoption of the prototype for flight attendants, I incorporated common terminology in my design menu items and message notifications (Figure 7.3 and Figure 7.8). These include: ***Pax*** for Passenger, ***FD*** for Flight Deck, ***High Chop*** for High Turbulence, ***Low Chop*** for Low Turbulence, and ***L2*** for Door to the Left, 2 means the second one from the back.

7.3. Development and Implementation

In this stage, I detail the technicalities of implementing the SmartCrew application. Most applications developed for Samsung Galaxy Gear S2 are built on the Tizen watch framework, which requires the phone to be synched with the smartwatch.

To encounter these issues, my supervisor hired a developer, Samarth Singhal to assist me in this area of coding to ensure that the final smartwatch application would be technically feasible and would be easy to implement. We chose to develop a web-based application over a native application. The web-based application allows the smartwatch application SmartCrew to be fully functional without the need of the cellphone. Instead of the data being saved on the cell phone, the data can be shared over the Internet making the smartwatches as an independent collaboration tool.

The developer deployed the web-based application using a chat server NodeJs and websocket. Also, by using a low-range BLE beacons, we were able to track the location of the crewmembers inside the aircraft. When the beacon detects the crewmember's smartwatch, their icon with the corresponding flight attendant's picture is displayed on the watch face. Thence, when the crewmember moves, the beacons would update their location. This way, the application SmartCrew supports real-time communication with all or selected crewmembers. The SmartCrew was implemented on the smartwatch as one of the applications. Users can tap into the application board and run the SmartCrew application. Once the application loads, by default the user interface of the watch face and navigation menu becomes the SmartCrew application.

7.4. Summary

In this chapter, I described the level of iterations (low-mid and high level fidelity prototypes) that I designed for the SmartCrew prototype. The low-level fidelity prototype includes hand drawn sketches and is the exploration of all design ideas and possible features to meet the user's needs. I provided samples for the iterations on the low-fidelity prototype and the mid and high-level fidelity prototype (the complete set is provided in the appendix). Both the latter prototypes include the transformation of the hand drawn sketches in the low-level fidelity prototype into interactive wireframes. The wireframes illustrate the basic user's task flow from screen to screen and the main features of the smartwatch application. In the high-fidelity prototype, the features are more defined and geared towards flight attendant's awareness, communication and collaboration. Features that facilitate passengers or flight deck were removed to focus on the crucial elements.

The high-fidelity prototype is a close resemblance to the final product. In this detailed design, SmartCrew splash screen and complete user experience. This included graphic details, colour palette, terminology, the layout and the interactions with smartwatch application. I also highlighted the final features and the development and final implementation for the prototype. In total, there are 6 features incorporated in the main menu, which includes: Routine checks for cabin status (Cabin Ready), Service Run Access (Messages), Assisting Crewmembers (Crew Aid), Passenger Emergency, Seat-belt Sign and Turbulence Emergency.

Chapter 8. Conclusion

The purpose of this chapter is to conclude the thesis by summarizing the research problems addressed and the completeness of the research goals. Following this, I described my research that future work can build on.

8.1. Research Problems

The overarching problem addressed by this thesis is that: *we do not know how flight attendants collaborate and how we can best design technology to support this collaboration.* This is divided into several sub-problems listed below:

Research Problem 1: We do not know how flight attendants maintain situation and workspace awareness.

Research Problem 2: We do not know what challenges flight attendants face when using existing collaborative technologies in normal and emergency situations.

Research Problem 3: We do not know how to design new technologies such as smartwatches that will support flight attendants' awareness and collaboration needs.

8.2. Research Contributions

To address the research problems, the goal of the thesis was to understand the collaborative practices of flight attendants and to inform the design of future technologies that will facilitate them in providing inflight customer service and on-board safety. These goals were divided into three research sub-goals outlined below. Each one presents the significant contributions in the area of new technologies for the aviation industry.

Research Goal 1: Describe how flight attendants maintain situation and workspace awareness.

I have completed this goal by conducting a user study with eleven flight attendants from domestic and international airlines to understand what awareness information is pertinent in each work role/position/responsibilities. Using a qualitative research methodology, I discovered that leads in domestic airlines and pursers in international airlines manage crewmembers and coordinate with the pilots. They are responsible for building a shared mental model and having the flexibility to move about in the airplane in their positions. The completion of Research Goal 1 presents several insights into flight attendants maintaining situation and workspace awareness with the flight crew. The findings revealed that for both types of airlines, flight attendants used gestures (e.g. thumbs-up) to communicate in the shared workspace and body language to determine if someone needs help. For longer duration flights, helping others is difficult as there are more passengers and services. Thence, leads/purser maintain their situation and workspace awareness by physically monitoring each crewmember's position and updating their shared mental model. Also, to maintain their awareness crewmembers benefit by having common ground (CRM training/SOPs), communities of practice (pre-flight briefing) and social capital (sharing knowledge, stress moments and assisting one another's workload/position) to maintain awareness, however, my research highlights the difficulty in achieving human development (i.e. ability to solve ill - defined problems). As flight attendants' do not typically work with the same crewmembers, they may not easily form social bonds with their fellow crew members. This could lead to ineffective teamwork. This suggests that the values and beliefs that make a highly effective team would then extend only to airlines that have crewmembers operating together. In this case, the European airlines, where crewmembers have the option to fly together, could benefit from this strategy. For other airlines, they would have to rely on the technological tools currently in airplanes until a policy to work with the same crewmembers could be applied.

Research Goal 2: Describe the challenges flight attendants face when using existing collaborative technologies in normal and emergency situations.

I have completed this goal by investigating the activities, and challenges that flight attendants encounter when performing with the collaborative technologies. The completion of Research Goal 2 presents insights into the activities (communicating procedures, coordinating activities or for task assistance) where situation awareness and collaboration needs are not supported. The findings revealed that where team members must cognitively think and resolve issues together in high uncertainty, collaboration tools make it cognitively challenging and burdensome (Chapter 4 and 5). Team members are inaccessible, information is delayed and new information is not provided when required, especially in emergency situations. The physical location of the tools, the different phases of the flight and the lack of clarity and feedback in the communication channel makes it more challenging for flight attendants to collaborate in a distributed setting. Therefore, there is less opportunities for crewmembers to re-assess situations, prioritize strategies or attain a high degree of situation awareness during emergency or routine situations.

Research Goal 3: Investigate how to design a smartwatch application as a proposed solution that will support flight attendants' awareness and collaboration needs)

I completed this goal by eliciting design requirements that are user centered and apply to flight attendants in a distributed setting. The completion of Research Goal 3 presents design implications for technology to make communications clearer and technology that is easy to use and accessible. Technologies should provide real time information access, be hands-free to assist work activities, and be ubiquitous enough to assist in emergency situations. Informed by the design requirements, I proposed a smartwatch prototype called SmartCrew as one possible solution to support real-time communication and collaboration from most locations within the aircraft. SmartCrew was developed as a web-based application and involved iterative design across a series of design steps listed in Chapters 6 and 7. These steps include listing the design features and constructing design-informing models (personas and user-scenarios) and various prototypes (low, mid and high level fidelity). SmartCrew assists flight attendants in maintaining their awareness of the workspace and flight's situation with its six main features: Routine checks for cabin status (Cabin Ready), Service Run Access (Messages), Assisting Crewmembers (Crew Aid), Passenger Emergency, Seat-belt Sign and Turbulence Emergency.

8.3. Limitations and Future Work

The study does not include observations that are real-time or in laboratory/simulation settings. The results of the study interview could have been validated or extended with observations of work practices in real work situations, laboratory studies or in simulation settings. After all, people's recollections of what they do are not always reflective of what they actually do (Schuler & Namioka, 1993). Observations would have been an effective way to define the problem areas and confirm the findings based on the actual practices. However, physical observations could not be carried out due to security protocols, feasibility, and limited control over the environmental or operational conditions to study the factors of interest. While a laboratory setting and simulations from the training could provide controlled and reliable data, they lacked the operational realism to confidently generalize findings to the real world as per Kanki (2010). Thence, I used verbal recordings and transcripts from the interviews as my main source of data gathering. That said, the study should act as a basis for understanding what types of observations would be valuable to make as a part of future studies, if one is able to observe flight attendants' practices during flights.

Also, the study does not contain interviews or data collected from crewmembers that were not flight attendants, such as pilots and cabin service directors. This would have provided further details on the communication practices/patterns occurring within airplanes and a different perspective from the flight attendants that we studied. I chose to study flight attendants as an initial step, however, future work should consider including pilots and other ground members. Nonetheless, the study results should be interpreted with this limitation in mind. Also, the study does not provide the disclosure of the name of the airlines with whom the flight attendants worked for and the specific types of aircrafts that they flew on. This information may have helped the reader understand if there are particular differences across airlines and how various cultures are represented in the study. To ensure that participants' privacy is protected and respected as a part of ethical procedures, and for safety reasons, I had to exclude the name of participants' organizations. The last limitation is the time, design and cost constraints that are present as part of collaborating with Samsung over a restricted period of time as part of grant work. These constraints may have influenced the direction for the proposed solution and also the next steps of evaluating SmartCrew. SmartCrew was not evaluated because it would require funding to recruit more flight attendants and such an evaluation was outside the scope of a Master's thesis. As such, I have proposed it as future work.

8.4. Design Reflections

In this section, I provide a critical analysis on my proposed solution, which includes the design informing models and the design of SmartCrew. I provide reflections on the possible gaps, and implications of using SmartCrew by flight attendants in-flight. This would provide future researchers with a clear understanding of the requirements that are met and those that have yet to be explored.

The first reflection is the design of the personas, which are created based on flight attendants' current practices and my observation of the participants' personalities. Although I have tried my best to be objective, there may be a possibility that the final personas reflect gender bias or racial issues that are present in the current practices of flight attendants and the aviation industry. Secondly, the customer experience map could be developed for additional roles of the flight crew such as cabin service director, cabin crewmembers and pilots. By having only one customer experience map, there is a possibility of missing variations, complexities and opportunities that may emerge from different users' contexts.

The third reflection is the selection of features for the SmartCrew application. In the low-fidelity prototype, the feature to incorporate reporting on SmartCrew and accessing the updated manual information was enabled to enhance crewmember's communication. This would have resolved the challenges faced in accessing information in a paper and digital format and also encourage sharing. However, in the mid and high fidelity prototype, as part of the collaboration process with Samsung, these two features were placed as lower priority due to technical and accessibility limitations. Technical limitations would require the manual to be either saved on the flight attendants' cellphones or uploaded to the Internet to provide easy access. The same applies for the recording of the flight reports. This requires data storage space and Wi-Fi access, which is currently not supported in-flight. Also, there is a need to have an application that can sort the manual information quickly as it is not practical to access large amounts of information on the small display of smartwatches. For these reasons, these features were not considered for the high-fidelity prototype.

The fourth reflection is the potential loss of empathy that might come from using SmartCrew application in the current work practices of flight attendants. Flight attendants' work environment is complex and their interactions with passengers and fellow crewmembers need to reflect being empathic and caring. These casual interactions that flight attendants exchange is what makes the difference in delivering a high customer service and successful teamwork. Such interactions include making eye contact and smiling at the passengers to reflect attentive care or leads/purser picking up on subtle cues to assist and provide personal coaching to new crewmembers. If SmartCrew is assumed to be extensively used in the future, there may be a loss of such interactions that are necessary to engage with passengers or to motivate a crewmember to provide a warm customer service. Without these interactions, crewmembers could also lose the opportunity to learn from one another. Lastly, if SmartCrew was enabled to take passengers' requests, there is also a possibility that flight attendants may be distracted and confused about whether they should focus on the smartwatch or the passengers.

8.5. Final Words

To have effective team cognition and distributed cognition, flight attendants need interactions that correspond to a dynamic shared mental model. In this research, we saw that interactions lacked for both domestic and international airlines. Flight attendants have appropriated the tools, resources, and workarounds in their activities. Amongst the participants, none have encountered any fatal accidents or errors in their past, however the current work practice does not ensure that these risks can be mitigated or managed properly for daily routines and emergency situations. Having said that as User Experience Designer and Researcher, I am motivated to improve the process and find solutions that can make the experience more delightful, easy and useful for the user. Therefore, I am hopeful that future HCI researchers and UX designers would use this thesis as a basis for further design explorations that can enhance flight attendants' team performance and impact the overall safety and security of the flight. The next crucial steps for the research is to study the SmartCrew prototype with the actual participants (flight attendants) to see if it is effective and usable for them in the actual setting.

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Appendices

Appendix A. Study Recruitment (Print)

Title of Study: Wearable Devices for Workplace Collaboration and Awareness

Ethics Application Number: tbd

Document Version: 4, Jan 21, 2016

Sample advertisements for flight attendants

Are you a flight attendant?

Researchers from Simon Fraser University are looking to understand how flight attendants collaborate, coordinate and communicate with their crew members during typical work activities. The goal of the project is to understand your work practices to inform future technology design.

How can you participate? There are two options.

1. Complete a short online survey of less than 15 minutes here: http://clab.iat.sfu.ca/flightattendants.
2. Complete an interview with an SFU researcher in person or over Skype. It will last less than 60 minutes. Participants who complete the interview will be provided with a remuneration of $30. Refusal to participate or withdrawal/dropout after agreeing to participate will not have an adverse effect or consequences on the participant's employment.

If you are interested in an interview, please email […]@sfu.ca.

Appendix B. Study Recruitment (Email)

Title of Study: Wearable Devices for Workplace Collaboration and Awareness

Document Version: 4, Jan 21, 2016

Sample Email Script for Recruiting

Hi! I'm reaching out today to ask you if you would be willing to help me connect with flight attendants who are currently working in Air Canada or West Jet. We, as researchers from Simon Fraser University, are looking to understand how you as flight attendants collaborate, coordinate and communicate with their crew members during typical work activities. The goal of the project is to understand your work practices to inform future technology design. We would appreciate your help.

The study involves an interview with an SFU researcher in person or over Skype. It will last less than sixty minutes. Participants who complete the interview will be provided with a remuneration of $30.

If you are interested in an interview, please email […]@sfu.ca

Appendix C. Informed Consent

Research Project Title: Wearable Devices for Workplace Collaboration and Awareness

Document Version: 4, January 21, 2016

Granting agency: NSERC

Investigators:

- Stephanie Wong, SIAT, Simon Fraser University
  778- […], […]@sfu.ca
- Carman Neustaedter, SIAT, Simon Fraser University
  778- […], […]@sfu.ca

You are invited to participate in a research study. This consent form is made available to you, is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask the investigator(s). Please take the time to read this carefully and to understand the information.

Purpose

Our research goal is to understand how you as flight attendants' collaborate, coordinate and communicate with your crew members. We aim to understand and document your work practices such that we can learn where new technologies may best fit within your existing work practices.

Participant Recruitment and Selection

To be recruited for this study, you must be over 18 years of age and work in the airline industry.

Study Method

We will use the method of interviewing to understand your work practices as flight attendants. Questions will focus on understanding your work activities with a focus on how you communicate with others and access information while in-flight. You will not be required to wear any sort of a device during this study. Interviews will take place in-person or online using systems like email or Skype. Confidentiality of information transmitted electronically cannot be assured. Thus, it is at your discretion if you choose to be interviewed over such systems.

Your Participation

You will participate in one or more of the above study methods. Participants who complete the interview will be provided with a remuneration of $30. If you agree to participate, you will be free to withdraw at any time for any reason. Refusal to participate or withdrawal/dropout after agreeing to participate will not have an adverse effect or consequences on your employment. However, data collected up to that withdrawal point may still be retained and used by the researchers. If you withdraw prior to completing the study, you will still receive the above remuneration. If the Principal Investigator intends to re-contact you as part of the study or after the study, you will be given the option to approve that re-contact. Research results, such as published papers, can be obtained by contacting any of the investigators:

▪ Stephanie Wong	778- […]	[…]@sfu.ca
▪ Carman Neustaedter	778- […]	[…]@sfu.ca

What Type of Personal Information Will Be Collected?
Confidentiality will be strictly maintained. The only personally identifying information collected will be your name, which will only be used for administration of payment. Any data collected will be labeled with an anonymous participant ID.

Are There Risks or Benefits if I Participate?
The risks of participation are intended to be none or minimal. There is a chance that you may describe unsafe work situations or practices to us; however, this information will be kept in confidence and should not pose any risks to the participant. The benefit is the remuneration and your contribution to scientific knowledge which may, in the future, improve the technology usage at your work. The benefit for the researcher is his/her contribution in creating the technology that can help flight attendants improve their daily work practices. There is a risk that you may reveal information that affects your employment in some way. Given the nature of the questions being asked, the negative affects are likely minimal since the questions focus on somewhat mundane job details. You are also free to disclose only the information that you are comfortable discussing.

What Happens to the Information I Provide?
No one except the researchers and their assistants will be allowed to see or hear any of your data. All information collected will be anonymized. No identifying information will be kept alongside the data. The collected information will be digitally recorded and transcribed; transcriptions will be kept on an external hard drive and stored in a locked cabinet in the secure office of the primary investigator at the School of Interactive Arts and Technology until 2018 or until the study analysis is completed. At this point, it will be permanently destroyed. Public presentations of the results will primarily present the results in an anonymized form. Where individual participant data is disclosed, such as exemplar comments via quotes, we will ensure that the selected data does not suggest participant identities.

Acceptance of this Form

Your signature on this form indicates that you 1) understand to your satisfaction the information provided to you about your participation in this research project, and 2) agree to participate as a research participant.

Participant's Name (please print):

____

Participant's Signature:

____

Date: ________________________

YYYY/MM/DD

Questions/Concerns; If you have any questions or concerns about the study, you can ask the principal investigator Stephanie Wong: […]@sfu.ca or 778- […] or the supervisor: Carman Neustadter: […]@sfu.ca or 778- […]. Concerns and/or complaints should be addressed to Dr. Jeffrey Toward, Director, Office of Research Ethics at […]@sfu.ca or 778- […].

Appendix D. Sample Study Questions

Qualifier Questions

1. Are you:

- Male
- Female

2. Are you okay with telling me your general age? We are recruiting adult participants over the age of 18 years who work in the airline industry.

3. What is your current marital status?
- Separated
- Divorced
- Married
- Widowed
- Never married

4. What is your first language? What languages do you speak?

5. What country do you live and work in?

6. What is the highest level of education you have completed?
- 12^{th} grade or less (no diploma)
- High School diploma
- Vocational/technical school (2year)
- College degree
- Bachelor's degree
- Master's degree
- Doctor degree
- Other

Appendix E. Interview Questions

1. Please describe your main duties as a flight attendant?

2. What are the mandatory items/documents you need to carry with you to perform your duties? Where do you keep them? **Points to probe:**

   a. Where this is manual kept?

3. What information do you need to obtain and provide during your work day? How and when do you obtain it? **Points to probe:**

   a. Can you tell me how the nature of the information is different from each other?
   b. Is the information mutually understood by all crew members?
   c. How critical is the information to have?
   d. Do you handle information differently depending on how critical it is?

4. Can you walk me through a typical day of work? What are your duties, responsibilities, workload and expectations? **Points to probe**:

   a. prior to boarding the plane, on-board the flight, during takeoff, while mid-flight, during landing, after landing
   b. Most of the duties are memorized or do you have a checklist that helps you to gather the information you need to make a security clearance?

5. How do you communicate with your crew members? Is there a common terminology? **Points to probe:**

   a. What do you talk about and when? Why is this information important?
   b. How do you know if a certain task is finished and other crew member could require your assistance?
   c. Do you ever watch or see what others are doing around you? If so, when? What do you watch for or notice? "Do you ever watch or see what others are doing around you? If so, when? What do you watch for or notice?"
   d. What impact does it have on other crew members' morale and flight safety?

6. What works well about the way you communicate with crew members?

7. Can you tell me about the training you receive and what does it teach about gaining awareness about other co-workers and communicating with them?

   a. Have there been any chance of miscommunication or such that you think that was easily solvable?

8. Were there times when any emergency or abnormal situations occurred that made it difficult to coordinate with crew members? **Points to probe:**

   a. How do you contact or gain access to the senior flight attendant if he is not in close proximity?

b. How is the emergency situation communicated to other crew members- is there an order of precedence of distributing information?
c. Can you tell me about the last time you were frustrated and not able to communicate with crew members, if any such time existed? What does not work well about the way you communicate with crew members?

9. Does your duty include any communication with the cockpit and the captain? If so, can you tell me when and how do you communicate? **Points to probe:**

   a. Has the communication been smooth each time or did you encounter any incidents, which made it difficult?

10. Do you need to communicate ever with ground crew members? If so, when and why? How do you perform this communication?

11. Are you able to use technology as part of your in-flight work? If so, how? How does using technology help? Are there any drawbacks or obstacles to using it? Are there any benefits to using it? **Points to probe:**

   a. Is there anything in the present technology that you would like to change or be added?
   b. Points to probe: What is the device type? Can all crew members use it? How long have you had it? Why did you get it? How much do you use it when you are in-flight? Do you get training to use it? Where do you place it when you are working? Are there any technologies you would like to use but can't? Why can't you use them?

12. Are there times when it might be valuable to have information recorded automatically for future reference?

13. Are there times when it might be valuable to have information available at a glance on your wrist, on a watch, while in-flights? **Points to probe:**
   a. What type of information do you think one may require but is not available?
   b. How do you keep track of the information in-flight?

14. Now imagine, you had a magic wand and it gives you the ability to change anything in your job, what would you like to change?

15. Do you think that technology can fit in any one of these areas that might be a possibility in the future?

16. Among your duties, what are the common tasks you have to perform repetitively? **Points to probe:**

   a. Can you tell me any tools you use to perform these tasks?
   b. Have you defined any mechanisms that help you to manage them better?

17. Is there anything you want to tell us that we haven't talked about?

18. Do you communicate with your family and friends in-flight? If so, how and for what purpose? **Points to probe:**

    a. Are there any organizational set times for such purposes or are there strict restrictions? Is your communication with family and friends enough for you? Or do you desire more? Is it easy or hard to communicate with them when traveling? How do you integrate your work and personal life in the job?

Appendix F. Brainstormed Names for Prototype

Shorter Names	Other Names
1. CrewHub	14. Crew Connect Buddy
2. SmartCrew	15. Crew Connect You
3. EveryCrew	16. Crew Connect All
4. CrewAtlas	17. Crew Connect points
5. CrewHQ	18. Crew Connect Communications
6. CircleCrew	19. Crew Connect Galaxy
	20. Lean Crew Connect
Longer Names	21. Area Crew Connect
7. Crew Connect HQ	22. Everyday Crew Connect
8. Snappy CrewConnect	23. Crew Connect Spots
9. Zap CrewConnect	24. Crew Connect Better
10. Crew Connect Atlas	25. Crew Connect Plus
11. Crew Connect Gateway	26. All Crew Connect
12. Crew Connect Care	27. Crew Connect Pro
13. Crew Connect On	28. Crew Connect Direct
	29. Crew Connect Central
	30. Crew Connect House
	31. Crew Connect Point
	32. Crew Connect Me
	33. Happy Crew Connect
	34. Crew Connect Kit

Appendix G. List of Flight Attendant Needs and Pain Points

As a purser

1. **Need to be check-in:** I have to collect the flight information sheet on who my crew for that day is and what tasks should I assign to the crew member with the particular background and job skills.
2. **Need to be up-to-date (Pain point):** I have a new flight and this aircraft I have not studied- what tasks will I assign my team.
3. **Need to be up-to-date:** I will have a dual time zone on my watch so that I will track the flight time and be able to inform the passenger about the time left to land.
4. **Monitoring staff:** I will see if the catering person has filled up the stock and galley crew members has checked it then I will sign the sheet.
5. **Preflight Notifications to each other:** I have to do my security check and also keep an eye on crew signaling thumbs up, so that we can make it on time.
6. **Preparing for greeting passengers:** I will open my iPad before boarding takes place so that I can recognize and greet our frequent flyers when they arrive.
7. **Tracking crucial check lists** I need to get the entire checklists of each item ready so that I can inform the captain so that we can take off.
8. **Preparing for Service (Pain point):** It is tiring to keep watching the seat belt sign to turn off, especially when it is on for more than 15 minutes. I have to that I can inform my crew members and begin service.
9. **Need to make sure passengers are safe (Pain point):** I need to have this information from the captain on how much time they need so that I can allow passengers to get up from their seat or when we will serve. I am having trouble in connecting via interphone because they are not picking.
10. **Communicating with flight deck (Pain point):** I can not tell them there is an issue with a passenger or what they are doing as I can not see what is

happening in the flight deck.

11. **Communicating with flight deck (Pain point):** I finally get them on the interphone and I want my crew members to know so I will call them on the interphone on the time to serve.

12. **Multitasking with own zone and others (Pain point):** I have to check the meal list of my cabin and make sure that the food is warm and all carts are ready to go. I have to get my own cart ready too.

13. **Normal Routine:** I want to make it pleasing for the passenger to travel, so I will use my iPad and address their name, confirm the meal and give it to them.

14. **Normal Routine:** Some passengers are giving problem about the food; I will check the iPad again and confirm if that is what they ordered.

15. **Technology (Pain point):** I have no place to put the iPad and have to use the cart for support while doing service. I am afraid that the information will be lost if it falls down or any beverage falls on it.

16. **Normal Routine:** I have to make sure the service is smooth, so I will check to see if anyone needs help.

17. **Normal Routine:** There is turbulence, the captain has put the seat belt sign on and made an announcement. I have to go back to the galley to make a call to all the crew members to understand if it is a light or heavy turbulence because we have to put the carts away and also take our seats.

18. **Coordinating status of crew member (Pain point):** I want to make sure I know where and what my crew members are doing so that I can help them or vice versa. The only way is to make rounds.

19. **Normal Routine:** I want to make sure that there is always some one to do the rounds according to the given time, but have rested too. I will go to the galley physically to see if that is taken care of.

20. **Coordinating flight deck meals (Pain point):** I have to ask the pilots if they need their meal etc. I am having difficulty as they are requesting me to give

them the passenger’s meal and that we can not do.

21. **Need to finish service and pick the call (Pain point):** I need to finish my selling service, the interphone rings- I have to finish the service and can not leave this in the middle and walk away. Have to call back.

22. **Status of cabin crew member unknown (Pain point):** Flight deck has asked me to send them a flight attendant, I need to go and check who is free and for how long will she be unavailable. Who will be his/her standby.

23. **Normal Routine:** My crew is asking me for some rules, I will use the manual printed or from the ipad for cross reference.

24. **Normal Routine:** I want to time myself to see how much time I spend in coaching and if I need to make another round to the flight deck.

25. **Helping the passenger and asking for help (Pain point):** There is an emergency, I am in between two galleys and the passenger is in pain. I am not seeing anyone in sight to help, no one is responding to the interphone and I have to get in touch with the senior cabin director or the captain. The passenger won’t let my hand go.

26. **Miscommunication because of crew (Pain point):** I finally have a back up but she can not understand my accent and does not follow instructions well. I have to find ways to do her part and my own.

27. **Emergency Notification:** We take care of the passenger and I notify the ground crew member for the ambulance or care we need for the passenger.

28. **Normal Routine:** I have to check the landing time again and make sure to be near the interphone if flight deck call. I will make sure everyone seals all the items and then we take our jumpseats.

29. **Need to Report today’s events (Pain point):** I have problem storing this information for reporting, it is on paper and I am sure I will lose it.

30. **Normal Routine:** I have to make sure to the security check again for a crew change or next flight take off. If it is next flight, I will check the time zone and

get ready to welcome new guests.

As a crewmember

1. **Need to be check-in:** I have to collect the flight information sheet on who my crew for that day is and where am I in that list of seniority and what position I want to be in that day.

2. **Need to be up-to-date:** I will have a dual time zone on my watch so that I will track the flight time and be able to inform the passenger about the time left to land.

3. **Normal Routine:** I have to do my security check and see if any items need to be replaced, refilled- I will inform the purser with my checklist.

4. **Performing the request by passengers (Pain Point) :** These passenger bags are so big and I don’t understand why the security did not check, how to fit in the cabin.

5. **Normal Routine:** I need to make sure that all passengers seat belts are properly fastened, no trays are down, no one is the lavatory and all bags are under the seat. Give a thumb up sign to the purser.

6. **Normal Routine:** I have to take my seat and be ready for the seat belt sign to be turned off or wait for the purser to call us.

7. **Have to walk to galley to see the passengers’ list of meals (Pain point):** I need to go back to the galley to see the list of meals if a passenger said it is not the meal requested.

8. **Interphone call access only throught panel (Pain point):** I am in between service and the interphone is ringing, I can not tell if it is an emergency call or normal. I have to physically be present to view the screen to see whose calling.

9. **Immediate collaboration difficult for emergency (Pain point):** I have an emergency and all flight attendants are some where and I do not know where the flight attendant call button is. I have to ask the passenger to find me help or walk to the interphone.

10. Same as Purser: There is turbulence, the captain has put the seat belt sign on and made an announcement. I have to go back to the galley to make a call to all the crew members to understand if it is a light or heavy turbulence because we have to put the carts away and also take our seats.

11. **Normal Routine:** I have to keep watch on what passengers have left their seat too often and to do what.

12. **Information not relevant (Barrier):** I want to use the iPad, but besides the plane's layout and the customer detail- it does not provide me with any new information and the purser is using it.

13. **To check on flight deck is difficult (Barrier):** I am asked by the pilot to visit, I find it difficult to go through my floor and then through two doors to meet them. I think it is easy for others closer to check on them.

14. **Same as Purser:** We take care of the passenger and I notify the ground crew member for the ambulance or care we need for the passenger.

15. **Coordinating with the Flightdeck (Pain point):** I will call the captain if I do not know which country the plane is moving over, I have to wait for the time when they are free and then inform the client.

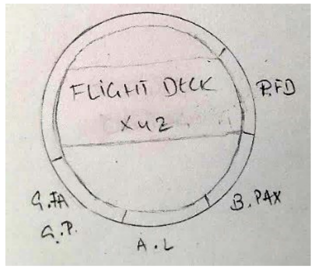
16. **Same as Purser**: I have to check the landing time again and make sure to be near the interphone if flight deck call. I will make sure everyone seals all the items and then we take our jumpseats.

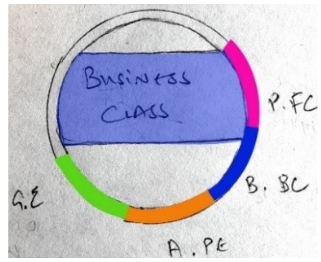
17. **Same as Purser** I have problem storing this information for reporting, it is on paper and I am sure I will loose it.

18. **Same as Purser** I have to make sure to the security check again for a crew change or next flight take off. If it is next flight, I will check the time zone and get ready to welcome new guests.

Appendix H. Low-Level Fidelity Prototype

Sketch 1: The First Iteration

<table>
<tr>
<td>Watch face and navigation menu</td>
<td>




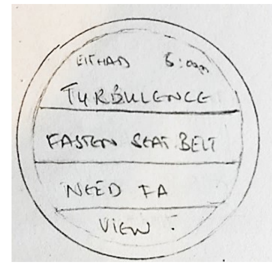
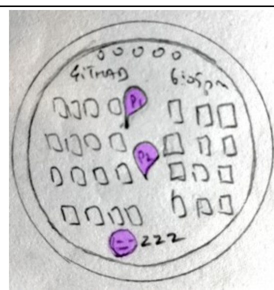
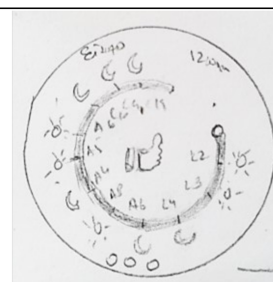


Image left: Application watch-face divided as per the present visual indicators inflight: Pink for Flight Deck (P.FD), Blue for Passenger (B.Pax), Amber for Lavatory (A.L) and Green as Flight attendant (G.FA).
Image center: Application watch face divided per cabins: Pink for First Class (P.FC), Blue for Business Class (B.BC) and Green for Economy (G.E).
Image left: The main navigation for accessing all features: turbulence, fasten seatbelt, need flight attendant (FA), request to view and reporting.
</td>
</tr>
<tr>
<td>Easy search</td>
<td>


Two options were sketched to see the status and position of crewmembers. Emojis, cabin ready, sleep and awake icons were used to represent the activity of the crewmember.
</td>
</tr>
</table>

<table>
<tr>
<td>Integrate passenger's services

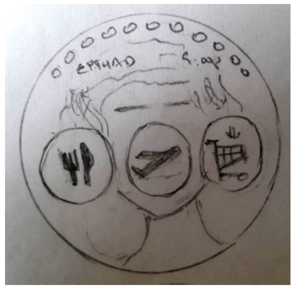
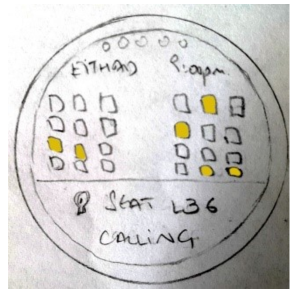
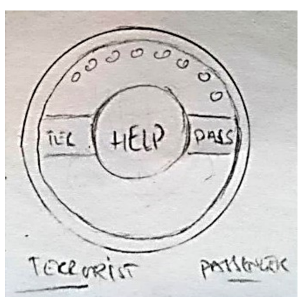
Provides flight attendants the customer details as they move from row to row.</td>
<td>



Image left: Displays the passenger profile: image, food prefence, flight details and past shopping data.

Image center: Provides a quick glance of the seatmap of the passengers (golden passenger highlighted in gold colour) and the location of the passenger calling.

Image right: Flight attendants can tap on the plus sign to record the number of alcohol served to a passenger.</td>
</tr>
<tr>
<td colspan="2">Optimize teamwork</td>
</tr>
<tr>
<td>Passenger emergency/ threat detection</td>
<td>


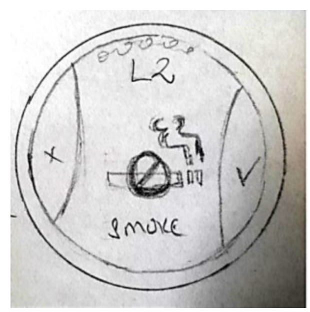
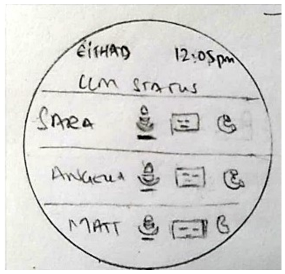
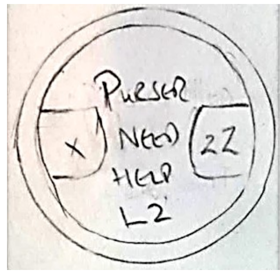


Image left: User can make a quick input, swipe left for passenger emergency and right for terrorist threat.

Image center: All crewmembers receive this notification of smoke detected in Lavatory close to gate 2. Those who are close or responsible for that area are to tap the tick icon.

Image right: All crewmembers receive this notification for terrorist attack. Crewmembers can tap the tick icon to notify they received the alert.</td>
</tr>
</table>

<table>
<tr>
<td>Real time crew aid</td>
<td>



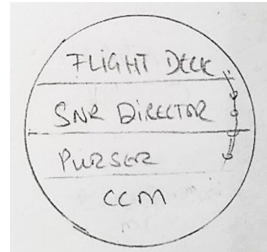


Image left: Shows the list of cabin crewmembers and the different format for sending message.

Image center: Displays the notification requesting for help.

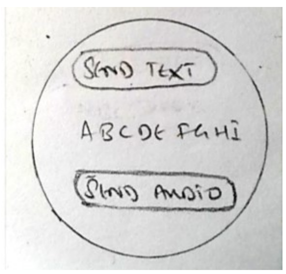
Image right: Displays the message received by the crewmember.
</td>
</tr>
<tr>
<td>Reporting on the wrist</td>
<td>


Image left: User is provided two options to either enter text or record an audio for a report.
Image right: Displays the screen to record the report.
</td>
</tr>
<tr>
<td colspan="2">Stay informed</td>
</tr>
<tr>
<td>Cabin ready</td>
<td>

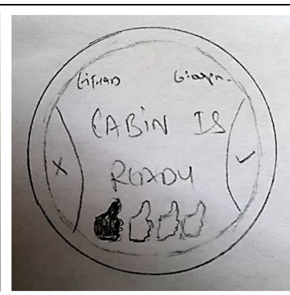
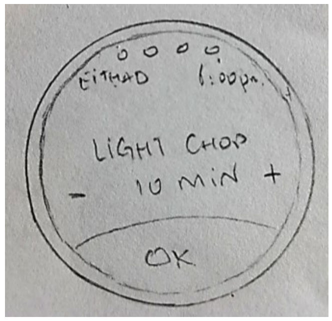



Image left: Displays the screen to inform crewmembers, in particular to the purser about completing the safety and security checks.

Image center: Displays the screen of the purser who receives the crewmember cabin-ready status notification.
</td>
</tr>
</table>

<table>
<tr><td>Turbulence</td><td>

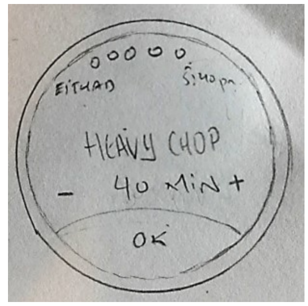


Image left: Displays the screen for setting the time for light chop or low severity turbulence.
Image right: Displays the screen for setting the time for heavy chop or high severity turbulence.</td></tr>
<tr><td>Flight deck assistance</td><td>

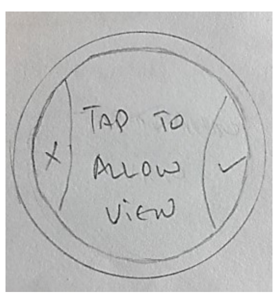
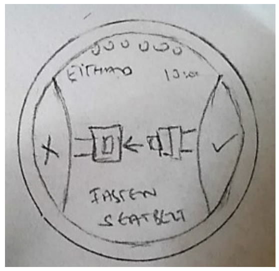
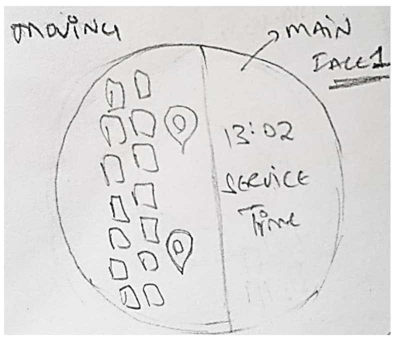
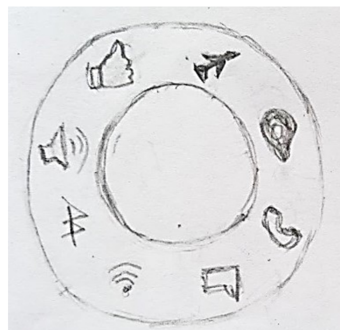
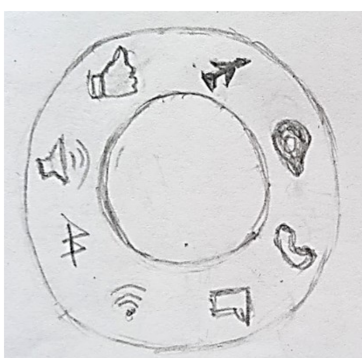
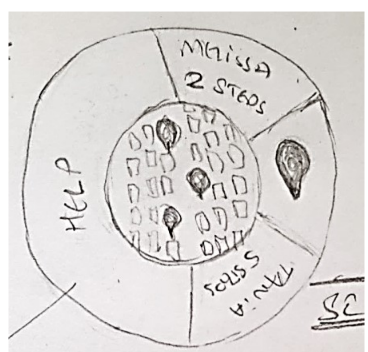
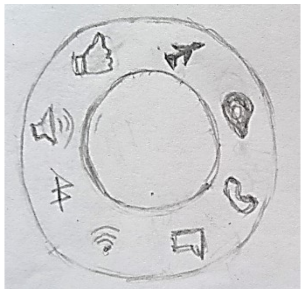
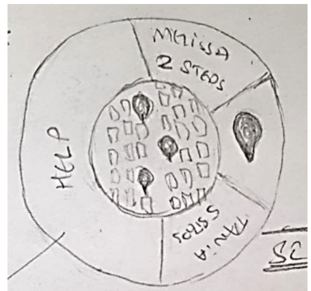
Image left: Displays the flight deck request for a flight attendant assistance.
Image center: Displays the notification received by purser. Tapping on the tick icon sends the flight deck the message to “On their way”. Tapping on the cross icon snoozes the notification.
Image right: Displays the message about pilot’s food preferences.</td></tr>
<tr><td></td><td>

Image left: Displays the crewmember’s request to have a visual view of the flight deck.
Image right: Displays the screen where the visual view is exchanged. The user can simply end the call and view by tapping the phone icon.</td></tr>
<tr><td colspan="2">Stay safe</td></tr>
</table>

Seat belt	 Displays the notification sent by the purser to fasten seatbelt to all crewmembers. If user taps the tick icon, the purser will know the crewmember received the notification. If the user taps the cross icon, it will snooze, but will appear after thirty seconds - till a confirmation notification is sent to the purser.

Sketch 2: The Second Iteration

Watch face and navigation menu	  **Image left:** Application watch face divided per flight phase, current time and flight seat-map. **Image right:** The main navigation for accessing all features: turbulence, help, call, message, wifi, Bluetooth, volume and cabin ready status.
Easy search	  **Image left:** User can see the location in the middle display and simply hovering over the watch will enable the main navigation menu. **Image right:** Displays the flight seat-map and crewmember's position.
Optimize teamwork	

<table>
<tr><td>Passenger Emergency</td><td>



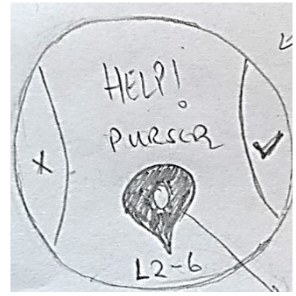
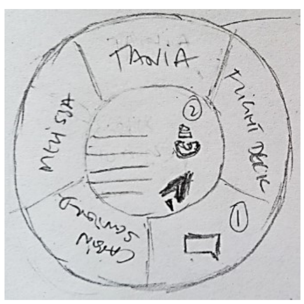
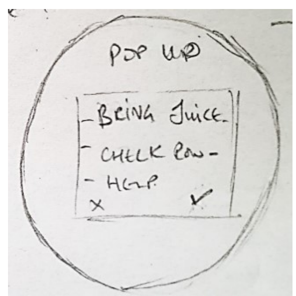


Image left: To alert for passenger emergency, user can tap on the location icon from the main navigation menu.
Image center: A sub- menu displays the option to choose either individual crewmember who are in close proximity or send ‘Help’ to access the full cabin crewmembers.
Image right: All crewmembers receive this notification for Purser needing Help. Crewmembers can tap the tick icon to notify they received the alert.
</td></tr>
<tr><td>Real time crew aid</td><td>




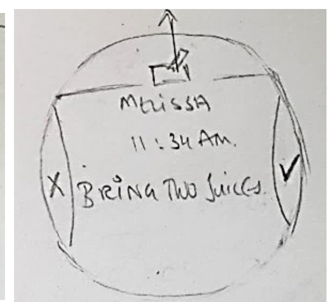


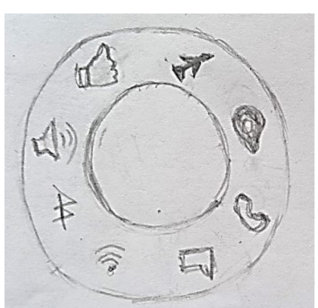
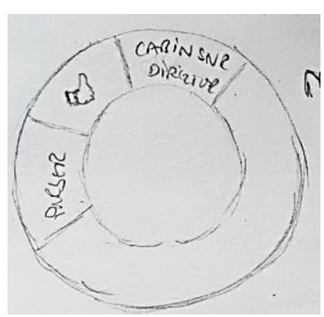
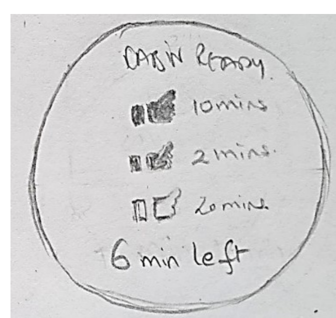
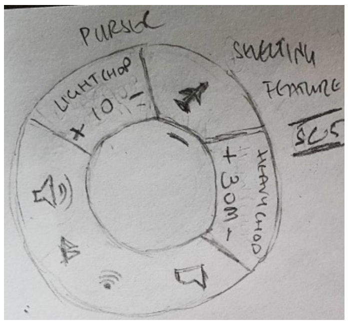
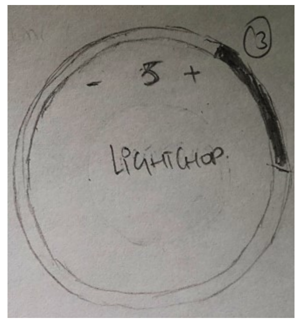
Image left: Shows the list of cabin crewmembers and the different format for sending message.
Image center: Displays the pre-defined messages that user can choose to send and save time from tapping customized messages.
Image right: Displays the message received by the crewmember.
</td></tr>
<tr><td colspan="2">Stay Informed</td></tr>
<tr><td>Cabin ready</td><td>




Image left: User taps on the thumbs-up icon to notify his/her status of safety and security checks.
</td></tr>
</table>

<table>
<tr><td></td><td> Image center: Two options will be displayed. Depending on the role of the user, if the user is a purser, he/she would tap the cabin sernior director option. While a cabin crewmember will tap the purser option. Image right: Displays the screen that the purser uses to send time alerts to crewmembers who are running behind schedule. </td></tr>
<tr><td>Turbulence</td><td>





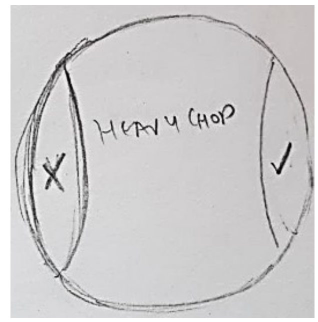
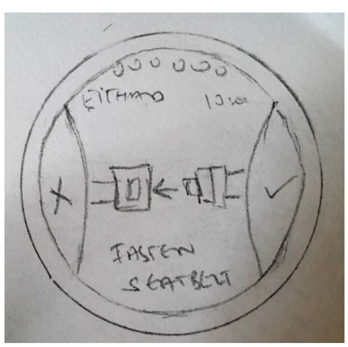
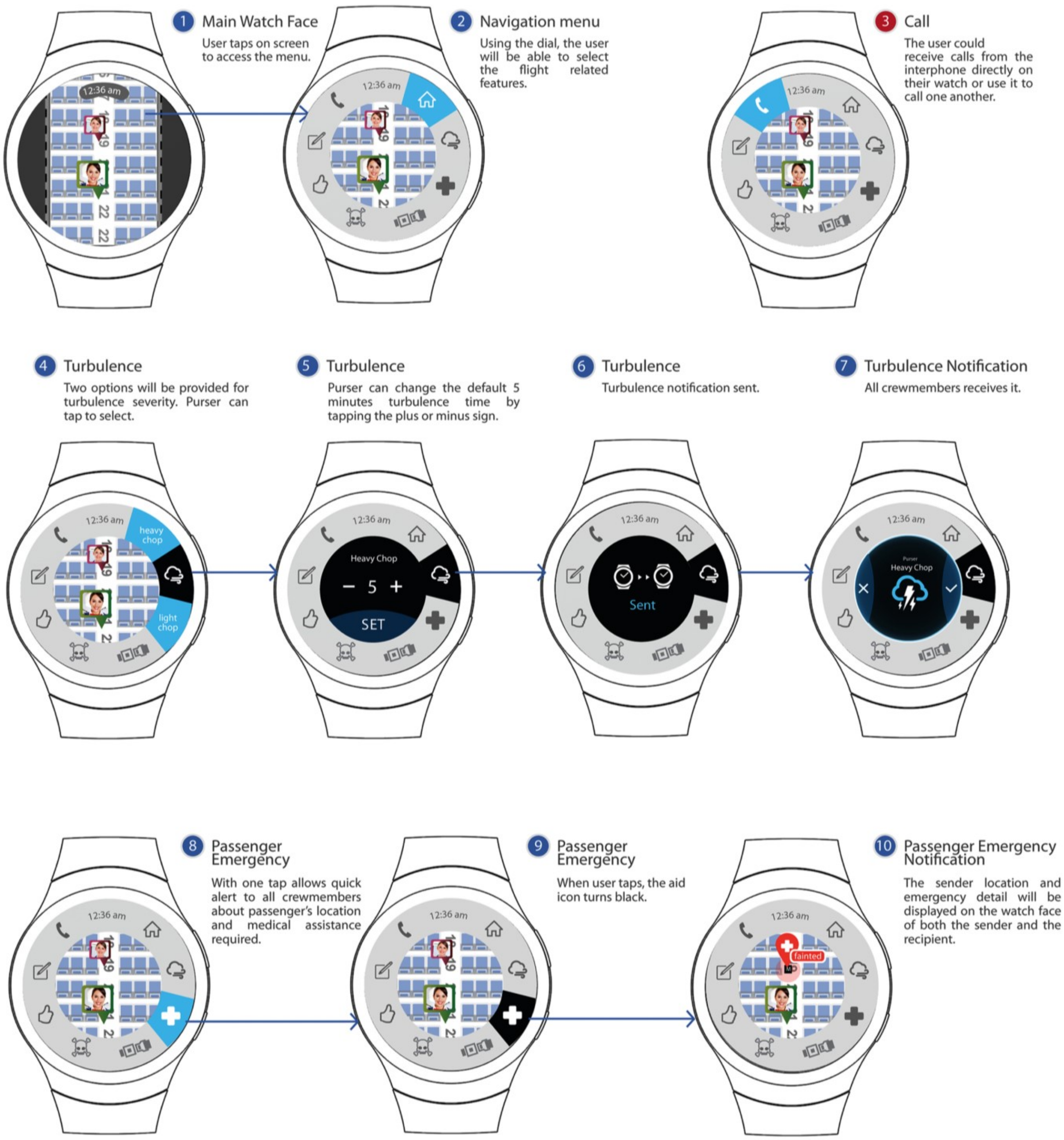


Image left: Displays the screen with two type of turbulence options: light chop /low severity turbulence or heavy chop/high severity turbulence. User can choose the default 10 minutes time or tap on either one to customize the default time. Image center: Displays the screen for setting the time for light chop or low severity turbulence. Image right: All crewmembers receive this notification for Heavy Chop. User can send a feedback notification back to the purser, when he/she taps on the tick icon. Tapping the cross icon will make the notification ‘snooze’ for a few minutes and then reappear till the user send a feedback notification back to the purser. </td></tr>
<tr><td colspan="2">Stay safe</td></tr>
<tr><td>Seatbelt</td><td>



Displays the notification sent by the purser to fasten seatbelt to all crewmembers. If user taps the tick icon, the purser will know the crewmember received the notification. If the user taps the cross icon, it will snooze, but will appear after thirty seconds - till a confirmation notification is sent to the purser </td></tr>
</table>

Appendix I. Mid-Level Fidelity Prototype

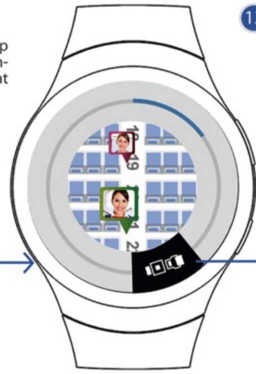


11 Seat-belt

Purser with one tap informs all crewmembers to take their seat immediately.

12 Seat-belt

Notification status displayed for seat-belt.



13 Seat-belt Notification

All crewmembers will receive the purser's notification and vibration to fasten their seat-belts.

14 Crew Aid

For user who need immediate help from crewmembers from anywhere in the plane.

15 Crew Aid

User can select the crewmember they want to ask for help and then tap the 'tick' icon to continue.

16 Crew Aid

Crew Aid notification sent.

17 Crew Aid Notification

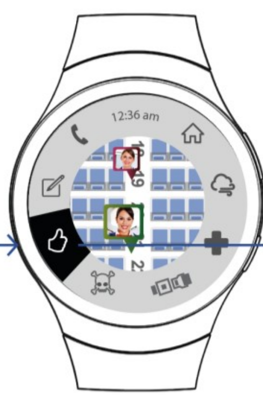
Crewmember/s receives notification.

18 Cabin Ready

User can now send their safety and security check by the thumbs-up icon.

19 Cabin Ready

Thumbs-up sent by user.

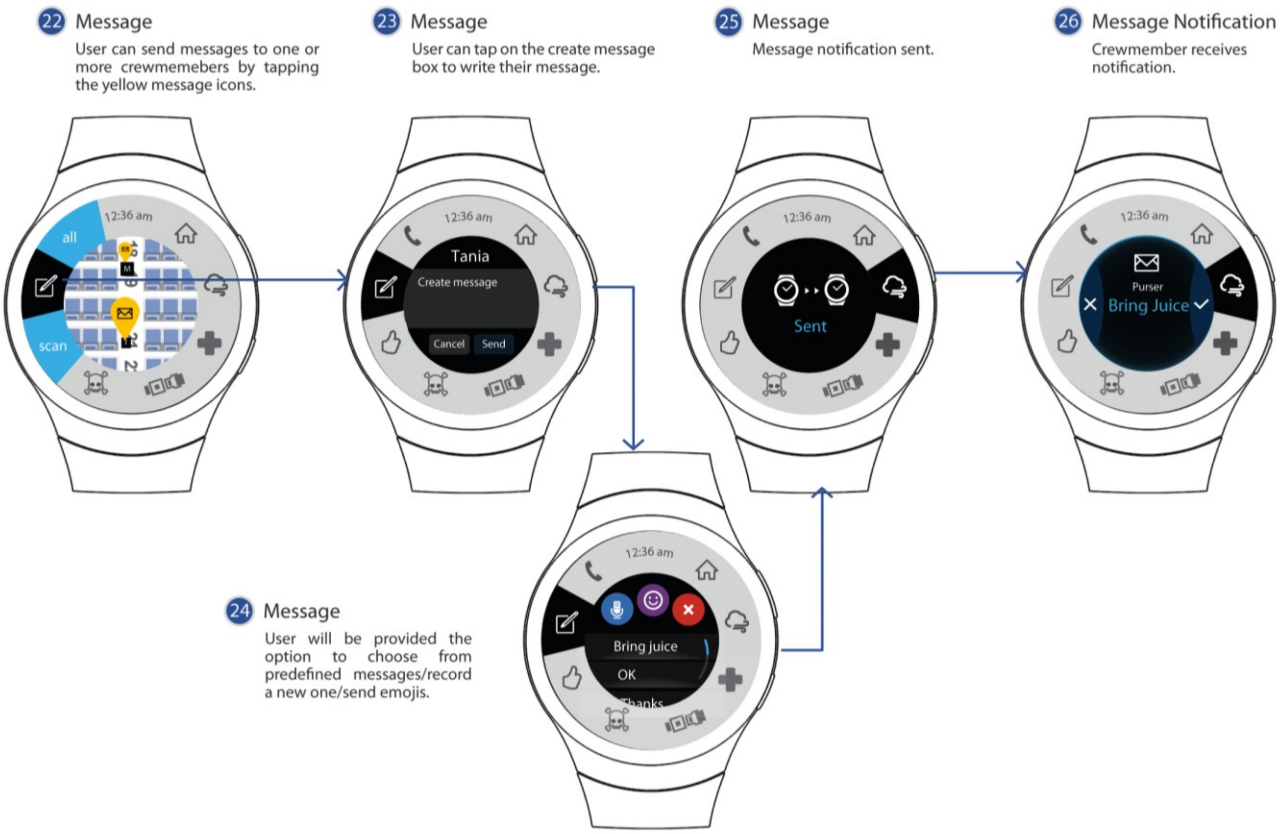


20 Cabin Ready

Cabin Ready notification sent.

21 Crew Ready Notification

Crewmember receives notific-afication to hurry up from purser.


22 Message
User can send messages to one or more crewmemebers by tapping the yellow message icons.
12:36 am
all
scan
23 Message
User can tap on the create message box to write their message.
12:36 am
Tania
Create message
Cancel
Send
25 Message
Message notification sent.
12:36 am
Sent
26 Message Notification
Crewmember receives notification.
12:36 am
Purser
Bring Juice
24 Message
User will be provided the option to choose from predefined messages/record a new one/send emojis.
12:36 am
Bring juice
OK