The Rise of Mobile Computing for Group Decision Support Systems

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The Rise of Mobile Computing for Group Decision Support Systems: A Comparative Evaluation of Mobile and Desktop

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Abstract

The use of desktop technologies, opposed to their mobile counterparts, is still predominant in the business domain and daily corporate activities. For complex business tasks, the usability of mobile applications is still perceived as inferior. Nevertheless, mobile computing could support work activities in different ways. This research seeks to explore whether mobile applications, especially sophisticated real-time groupware such as Group Decision Support Systems can match or even outperform their desktop-based counterparts regarding task performance and user satisfaction. To provide a more comprehensive comparison, two widely used web metric frameworks, HEART and PULSE (the former focusing on human behaviour and the latter focusing on technology), have been used to evaluate and compare a web-based mobile group decision support app with its desktop counterpart on a chair-led multi-step decision-making process in lab settings and real-world contexts. Moreover, data from web tracking tools and system logs of these two apps have been analyzed to deepen the level of analysis. Therefore, an innovative methodology for usability research combining lab experiments with long-term web observations is proposed. The results have shown that users interacting with the mobile version of the system had a steeper learning curve than users interacting with the desktop one. After a short practice period, participants using the mobile version of the groupware could perform as efficiently as participants using its desktop counterpart. Not only both the mobile and the desktop version of the app were used effectively for the group decision tasks chosen for this study, but also the two versions of the application were rated similarly in terms of user satisfaction. Furthermore, the mobile version had a faster adoption, better engagement, and better retention than its desktop counterpart. Despite an additional groupware middleware layer and a sophisticated user interface rendering layer, both groupware versions have yielded a user-to-user response time sufficient for real-time group interactions. These results convey important implications; as society is quickly moving towards mobile computing, web-based mobile technologies can now support multi-step group decision-making tasks.

Keywords: Mobile groupware, Desktop groupware, Group decision support system, Usability testing, Web metrics, Web tracking

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1. Introduction

The fast adoption and rising engagement of social media on mobile phones have broadened people's mind concerning what relatively small mobile devices can do. Mobile applications, especially mobile social software, have been widely used for several purposes, from staying connected to family and friends to engaging in business activities. Recent research has provided promising usability results on various single-user mobile apps and social media mobile apps for simple activities such as information sharing and communication purposes (Jabeur et al., 2013; Kortum and Sorber, 2015). However, there are other more complex activities that modern mobile technologies can enable. In addition to information sharing and communication, *groupware* offers a shared workspace, a set of task-specific tools, and coordination devices for enabling people to work together. These technologies offer a broad range of possibilities, from scheduling activities, assigning tasks and managing teams of people, to complex group-decision making tasks and decision analysis. The present research focuses on a particular type of groupware called Group Decision Support Systems (GDSS) – e.g. ThinkTank, developed by GroupSystem (Briggs et al., 2001) and MeetingWorks, developed by Advisor Pathways (Zaraté et al., 2013). GDSS is a family of information systems used to support management teams to structure ill-defined problems and to analyze and take group decisions. They enhance managerial decision-making processes by providing management teams with the technology needed to generate and organize ideas in a collaborative environment, identify priorities and facilitate conflict resolution (Downing, 2014; Insua and French, 2010). GDSS can be used for several activities; for instance, they are used in *virtual focus group marketing* and *interactive group consultancy* activities. In virtual focus groups, they are used to collect customer feedback and suggestions regarding a company's product, in an organized brainstorming process led by a facilitator from the company's marketing division. In interactive group consultancy activities, they are used to conduct multi-criteria decision analysis (MCDA) and problem structuring processes. In the past, such activities were conducted in-house in a face to face setting. However, with the widespread use of new technologies, especially smartphones and social media systems, such activities can be performed remotely with technologies that users are already familiar with (as demonstrated by the application scenarios of the MobileMeeting system reported in this work).

For supporting the activities mentioned above, groupware needs to have a shared workspace, a coordination device for enabling team members to work together and a set of task-specific tools. Such tools are task related. For instance, to support multi-criteria decision analyses, a GDSS needs 4 task-specific tools, one for each of step: (1) a tool for the brainstorming of alternatives; (2) a tool for the brainstorming of criteria used to evaluate the alternatives; (3) a tool for the weighting of the criteria; (4) a tool for voting. As this is a group process, in addition to these basic MCDA tools, the system needs a communication and a coordination tool to enable the session chair (i.e. group process facilitator) to manage the process and to guide the team members throughout the process (Kolfschoten et al., 2012).

Although GDSS for desktop computers are already in use in commercial organizations (French et al., 2009), the mobile versions of such groupware have not been widely integrated into business activities. Conversely, many other business applications, such as mobile passenger information systems (Beul-Leusmann et al., 2014), mobile computing devices in higher education (Gikas and Grant, 2013), mobile health application tools (Jakobsen et al., 2015; Sama et al., 2014), and applications for enhancing group awareness (Saari et al., 2009) have been already implemented for mobile computing, and there might be several advantages of using GDSS on mobile devices as well. Furthermore, considering the massive increase in popularity of mobile devices and social media, the study of the use of mobile applications to directly support business activities is extremely important and has several implications. People use mobile devices on the move, many times a day and with a deep level of engagement. Additionally, groupware such as GDSS can be integrated into social media which are already extensively used on mobile devices. As a result, people could access activities such as group-decision tasks and virtual focus groups from entry points embedded in a social media context. In turn, this would allow more people to participate in such activities and enhance the decision-making experience. Compared with the abundant usability studies on desktop-based groupware, the usability of such mobile groupware has not been adequately investigated. To our knowledge, evaluative studies comparing more sophisticated real-time desktop groupware with their mobile versions, in both lab settings and complex real-life contexts (e.g. group decision tasks), are still missing.

Historically, due to some smartphones limitations such as a small screen size, limited CPU power and inferior wireless networking reliability, the design and implementation of sophisticated real-time groupware on mobile devices presented several challenges. (Roth, 2002) initially highlighted seven main issues regarding mobile groupware development such as communication, architecture, coordination, data distribution, data consistency, usability, security/privacy and software realization issues. At present, some of these challenges remain the focus of mobile technology design. Such limitations and challenges led to the common assumption that desktop applications, which have the advantage of a larger screen size, more reliable network connectivity, and superior CPU power may outperform mobile applications, especially for business-related tasks. Due to the recent advancements in mobile computing, the position above has been challenged. In fact, some research streams support the idea that most of the technical challenges faced in mobile groupware development have been addressed. Mobile Groupware is becoming more powerful, and users are becoming increasingly competent through constant interaction with such technologies. Some gaps, however, remain, especially the idea that such a technological drift may not have affected some areas of computing involving complex business activities. It follows that this research seeks to explore whether complex real-time groupware developed for mobile devices can be equally efficient or even outperform their desktop counterparts. Moreover, it tries to investigate the advantages and disadvantages of mobile groupware compared to desktop groupware, not only from a technical perspective but also from a cultural and social viewpoint providing insights into the interactions between such technologies and the current user.

For this purpose, two widely used web metric frameworks, one focusing on human behavior and another focusing on technology, have been adopted in the present research to compare two real-time GDSS on several multi-step decision-making tasks. A controlled experiment and several observational investigations in real-world settings have been conducted. In addition to some post-session questionnaire surveys and measures of performance, a web tracking tool - Google Analytics (Clifton, 2012) - and systems logs were used for collecting the data for our chosen usability and web metrics. Based on the data collected and the metrics adopted, a pair-wise comparison and a relational analysis between these two apps have been performed.

The rest of the paper is organized as follows: Section 2 presents the literature review, introduces the topic progressively, highlights the scientific relevance of this research, justifies the approaches used and underlines their implications. Section 3 describes the research methods adopted in this study, including a controlled lab experiment and qualitative research conducted in real-world settings along with post-session questionnaire surveys and interviews. Section 4 presents and discusses the research results. A comparison to closely related research is presented to highlight the novelty of this work and enrich the discussion. In section 5 a summary of the main conclusions, some implications emerging from the results and some limitations inherent in the nature of the research are presented, along with some recommendations for further work.

2. Related Work

In the last decade, innovative Web technologies have introduced new forms of communication and behaviors such as social networking and information sharing in the cyberspace (Boyd and Ellison, 2010). A multiplicity of popular social networks has emerged such as Facebook, Twitter and WeChat, to name a few, in order to satisfy people’s natural needs for social life, communication, sharing and discussion (Boyd and Ellison, 2010; Wang et al., 2007). Moreover, with the advent of Web 2.0, websites that facilitate and encourage users to participate and create their own content as distributors to other like-minded users display a fundamental transformation in the way people interact with Web content, services, and other users. Indeed, this phenomenon has shaped the evolution of a new virtual online community supported by groupware applications (Kietzmann et al., 2011; Murugesan, 2007). The goal of these applications is to provide an appropriate environment for people to connect with each other in a flexible manner and to enhance efficiency and flexibility of cooperative activities, enabling groups to become independent of time and space (Ellis et al., 1991). As groupware technologies such as e-collaborative systems could be extremely versatile and powerful and could be adapted to different activities and different business sectors, they were developed further into more sophisticated tools used in complex business activities (Schmidt and Bannon, 2013). Some early examples of such technologies were used for supporting remote meetings and for basic team-work activities (Streitz et al., 1994; Warkentin et al., 1997). Nowadays however, there are different requirements and more complex activities need to be supported by information systems. Collaborative working activities such as group decision-making, conferencing and brainstorming not only can be performed by using electronic systems, but they may also be ameliorated by such technologies. For instance, brainstorming may be improved by using electronic groupware systems as e-collaboration can optimize the collection of ideas and reduce the effect of biases such as groupthink (Michinov, 2012). Therefore, e-collaboration systems (e.g. Ventana Corporation's Group System ThinkTank 4.0[3]) have been extensively implemented for commercial uses to support decision-making processes, improve productivity and develop new competitive products in virtual focus groups (Michinov, 2012). Some of the advantages of e-collaboration systems over face-to-face brainstorming, such as flexibility, efficiency and bias reduction may also be mitigated by the advent of innovative mobile technologies as mobile devices may be preferred, for some activities, to desktop computers. Data collected on-line show that in the US and the UK people spend on average about 30% more of their time online on mobile devices than they spend on desktop computers[4]. In recent years, mobile phones and tablets have become increasingly powerful, leading to an increase in people's use of such devices not only for recreational purposes, but also for business-related activities. Tasks that were once bound to stationary computers can now widely be performed on mobile devices regardless of the location of the user (Dinh et al., 2013).

Among the many limitations of mobile technologies, limited screen size and limited interfaces for input activities such as text creation have been reported as being the most problematic issues. Early studies have shown that mobile devices were perceived as inconvenient to use for actions such as Web browsing and input of a large amount of text, in comparison to a desktop computer and laptop. In these studies, lack of a large keyboard (Schrott and Glückler, 2004) and limited screen size (Shrestha, 2007) have been reported as the major limitations of mobile technologies. Moreover, (Karlson et al., 2010) found that when mobile users experienced problems while performing a task, they immediately moved to a desktop computer or laptop to complete the remaining parts of the task. In addition, the ones who *did* complete the task on mobile devices became far more frustrated compared to those who moved to desktop computers (Karlson et al., 2010). This may be even more

[3]ThinkTank 4.0, http://www.groupsystems.com
[4] Surveys of Nielson and SmartInsights, http://www.nielsen.com and http://www.smartinsights.com/mobile-marketing/mobile-marketing-analytics/mobile-marketing-statistics/

problematic for collaborative work. As Caballé and colleagues highlighted, mobile technologies that are specifically applied to collaborative activities are still in their infancy (Caballé et al., 2010). Subsequently, some attempts were also made to integrate mobile and desktop technologies in collaborative environments. For instance, to obtain a large screen size and extend the collaborative workplace without space-time restrictions a study adopted table-top computers controlled remotely by mobile devices (Lee et al., 2011). However, this solution still requires the use of large devices bounded to mobility constraints. Kolici performed a use-case analysis on some mobile applications for some small and medium enterprises, including their use in mobile teamwork (Kolici et al., 2013). Several issues concerning event-based notification, coordination as well as integration services in such applications have been identified, suggesting that mobile technologies need to be ameliorated to address the current business needs, but also highlighting the importance of mobile computing for business and enterprises (Kolici et al., 2013).

Although new groupware systems for mobile devices are yet to prove themselves, they might be equally effective and, in some cases, ameliorate the current experience people have when using similar systems on desktop computers. Early studies have highlighted that as long as the software used is easy to understand and simple in its design, users will become accustomed to its use on mobile devices and they will prefer receiving and processing information through such devices rather than through stationary computers (Maurer et al., 2010). Furthermore, Herskovic and colleagues stressed that for mobile groupware to be useful, they should have the ability for users to work simultaneously and be 'reachable' (i.e. it should always provide a real-time communication channel that allows users to communicate and expect a response in real-time) (Herskovic et al., 2011). Hung and colleagues stated that mobile users might obtain more satisfaction than PC users, as long as the usability and flow (control, clear goals, feedback, etc.) of the software are powerful enough (Hung et al., 2012). This however, may not be the case in business-related situations using specific groupware such as GDSS.

In recent years the capabilities of smartphones and tablet technologies have improved dramatically, leading to growth in their market. Nevertheless, the different usability between mobile devices and desktop devices may pose the question of whether people use groupware on mobile devices with the same confidence and ease that they have when they use desktop computers, especially for e-collaboration business tasks. On the one hand, technical issues are leading to a different user experience when using mobile systems. On the other hand, the benefits of mobile computing highlighted above are also mitigated by contextual factors. Tsiaousis and Giaglis proposed a theoretical framework to analyze the adverse effects of the environment on the usability of mobile websites (Tsiaousis and Giaglis, 2014). After conducting a real-world study (i.e. the use of such technology in public places), they suggested that environmental distractions may have significant effects on user performance. However, this did not seem to affect user satisfaction, suggesting that the constraints linked to mobile devices in dynamic contexts still need to be addressed. This stream of research highlights the importance of taking into account the complexity inherent in mobile computing, including the users' interaction with the environment, when designing scientific studies. Conversely, some research showed that usability professionals tend to focus on usability at an individual level rather than concentrating on environmental and organizational factors. Professionals appear to be more concerned with goal-related performance and users' cognitions rather than with users' satisfaction, perceptions and environmental dynamics (Hertzum and Clemmensen, 2012). Furthermore, many HCI research investigations are still lab-based and do not involve multiple approaches to the study of usability (Nazir et al., 2014). Thus, as the results from the research above showed, these studies may be limited by the artificial environment encountered when testing in the laboratory. This is why, in the present study, a wider approach involving lab experiments, naturalistic studies, web-tracking tools and system logs analysis is undertaken.

To summarize, mobile computing is taking over and research on the use of mobile devices to support complex business activities appears to be a significant contribution to technological advancement. There is a scarcity of empirical research on the use of mobile groupware for collaborative work in complex business situations (e.g. virtual focus group marketing). Recent studies have shown an improvement in mobile groupware and social-media applications usability for simple activities such as information sharing and communication purposes. As mobile groupware are becoming more flexible and powerful than they once were, the models that describe them should be renovated and evaluated. From a technical perspective, web page objects have a similar size in both mobile and desktop versions, though they exhibit a different composition by types of objects in greater details. However, there are still some queries that need to be addressed. For instance, regarding usability concerns bounded to contextual factors, a large screen size and a more effective input text-interface may be crucial in business related tasks such as group decision-making in organizations.

In light of the above arguments and evidence from past research about the emergence and development of mobile platforms as well as a better integration of mobile devices into business social-activities, several questions arise. The present study tries to investigate whether mobile groupware can be as efficient as, or even outperform applications designed for desktop computers. Predominantly, it focuses on particular types of groupware developed for specific collaborative business activities (e.g. group decision-making), and it tries to suggest potential solutions for some of the challenges faced in mobile computing design. The following are the three main research questions: (1) Do people prefer mobile or desktop systems for operating in complex business contexts? More specifically, are mobile technologies perceived to be better or worse than desktop technologies for collaborative work such as group decision making and brainstorming? (2) Has people's performance improved by switching to mobile groupware and is there a consistency between people's perception (and preferences) and how do they perform when interacting with mobile and desktop GDSS? (3) Are there any difference at a higher cognitive level (e.g. learning) and, potentially, at a social level (e.g. perception of technological trends in modern society and attitudes toward modern technologies used for supporting business activities) between mobile groupware-human interaction and desktop groupware-human interaction in complex business activities?

The present research seeks to shed light on these unexplored issues by the support of empirical evidence using two specific applications, PowerMeeting and MobileMeeting (see the Methods section below), which are GDSS that satisfy the requirements for testing the research hypothesis. The three hypotheses emerging from the research questions are:

- H1: There will be a difference, in user satisfaction (measured by self-reported usability metrics), among users who completed the tasks using desktop groupware (PowerMeeting) and users who completed the tasks using mobile groupware (MobileMeeting).
- H2: There will be a difference in task efficiency measured by task completion time (H2.1) or/and the number of steps taken to complete the task (H2.2) between users who completed the tasks using desktop groupware (PowerMeeting) and users who completed the tasks using mobile groupware (MobileMeeting).
- H3: There will be a difference in terms of learnability, measured by the task completion time improved over time with more practicing (H3.1) or by the number of steps taken to complete the task improved due to previous experience with similar groupware (H3.2), between users who performed the task using the desktop version of the groupware (PowerMeeting) and users who performed the task using the mobile version of the groupware (MobileMeeting).

3. Methods

To investigate the hypotheses, three different studies were conducted progressively. Firstly, a **controlled experiment** in an artificial environment was designed to conduct an initial investigation on how users would perform using both applications (**MobileMeeting** and **PowerMeeting**) and some related differences between these applications regarding user satisfaction and performance (i.e. effectiveness and efficiency). This research made use of some rigorous quantitative methods and statistical analysis to assess and compare the usability of the two applications. The experiment was designed taking into account the guidelines on usability testing for mobile systems set by (Kjeldskov and Stage, 2004). Secondly, an **observational study** in real-world scenarios was conducted with one group of users using both versions of the system (mobile and desktop) and, as mobile computing was the main focus of the present investigation, several other groups used MobileMeeting only (the mobile version of the app). Finally, **Web analytics** with web tracking data from Google Analytics and the systems logs were also collected to extend the analysis further as explained below. Post-session questionnaire surveys were used in both the controlled experiment and the observational user studies.

Rationale for the dual-approach

In this research, the observational study is complementary to the controlled experiment. In the lab experiment, to eliminate variations in thinking-time based on individual differences to obtain comparable data, a set of precise instructions for each step of the task were provided to each participant in a task-sheet describing the mechanical procedure with accuracy. Thus, participants were aware of all the steps (including their particular inputs) required to complete the task in details and this procedure involved a mechanical and artificial measurement of users' efficiency. Therefore, to obtain ecologically valid results, qualitative data from real-world scenarios were also collected. In this stage, measures of groupware effectiveness and user feedback were gathered to find some important explanations for the results emerging from the artificial experiment and the longitudinal data obtained from Google Analytics. More precisely, the second study in real-world settings was needed to assess the systems effectiveness as the mechanical nature of lab experiments was only able to evaluate the efficacy of the systems.

3.1 Web Metrics Frameworks

The lab testing, the observational studies in the real-world scenarios and the analysis of the longitudinal data collected from Google Analytics were designed using the metrics described in the HEART and PULSE web metrics frameworks (Rodden et al., 2010). HEART is a user-centered web metrics framework focusing on users' attitude and behavior. It is developed by Google engineers to measure user experience on a large scale (Rodden et al., 2010). As this work aims to perform a comprehensive evaluation, the intentions behind all the five elements of the HEART framework and the two technology aspects in the PULSE framework were taken as sub-goals of our evaluative studies. We have applied the Goals-Signals-Metrics process as outlined by (Rodden et al., 2010) to map the high-level assessment categories to particular web metrics. These five HEART metrics categories, their corresponding metrics, and the data sources used in the present investigation are described as follows:

- Happiness refers to the subjective and attitudinal aspects of user experience, such as visual appeal and perceived ease of use. It was measured through (standardized) post-session psychometric questionnaires developed for assessing the construct of usability;
- Engagement refers to the level of users' involvement with an application. Concrete web metrics in this category included average session duration and frequency of use. These data were obtained from web tracking tools (Google Analytics);
- Adoption refers to the number of new users who started using an application during a given time period. The web metrics used in this category included the number of new users and the percentage of new users. These data were also obtained from Google Analytics;

- Retention refers to the number of users from a given time period are still present in some later time period. The web metrics provide such signals include retention rate and monthly active users. The data for these metrics were also obtained from Google Analytics.
- Task success refers to traditional behavioral metrics of user experience, such as effectiveness (e.g. the percentage of tasks that were completed) and efficiency (e.g. the time and the number of steps taken to accomplish a task). These data were obtained from a controlled experiment and the analysis of users' feedback in a study based on real-world settings.

In addition to the HEART framework, Rodden and colleagues also described another framework (with different, but complementary, metrics to assess Web applications) called PULSE, which stands for Page views, Uptime, Latency, Seven-day active users and Earnings (Rodden et al., 2010). These metrics are business-centered and focusing on technology. As these are either very low-level or indirect metrics of user experience, making them problematic when they are used for evaluating the impact of user interface changes (Rodden et al., 2010). In fact, HEART metrics were developed specifically to address this weakness. However, the technical performance of a website is not covered by HEART. Complimentary to the HEART metrics, we used the Uptime and Latency metrics (from the PULSE framework) to measure the technical strengths of the two systems. Uptime measures the service reliability, i.e. how long the system remains stable online; while Latency measures the technical performance of a website, using metrics describing response time (i.e. round-trip time for real-time groupware, see section 4.2.4 for details). These two web metrics were obtained from the system logs of the two applications.

3.2 PowerMeeting, MobileMeeting, and the Group Decision Tasks

Two research prototype systems, PowerMeeting and MobileMeeting[5] were used as a test-bed to address the research questions and test the hypotheses. PowerMeeting has been online for many years, and MobileMeeting has been online since November 2014. The first author has developed both apps which have been used in many teaching and research-related group activities. These apps were modified during the past years through a series of iterations and, while being still prototypes, the versions of the systems used in this study are more advanced and stable than the initial ones. The rationale for choosing these systems rather than commercial products available in the markets was that the authors had full control over the systems and could connect them to Google Analytics and access their systems logs for the longitudinal analysis. Commercial systems such as ThinkTank could only be used by the authors as service users (given the license we had at the time). Indeed, in the case of ThinkTank, the authors could neither track such system using Google Analytics nor access its server logs for the planned long-term observation.

[5]PowerMeeting and MobileMeeting website, www.powermeeting.co.uk

These two systems are synchronous groupware applications. Synchronous Groupware refers to the concept of operating in real-time allowing multiple participants to collaborate in groups at the same time. Such Groupware enables remote interactions via a shared workspace and group communication channels for geographically separated group members to coordinate their group activities.

PowerMeeting allows participants to plan and perform their group tasks with access to a wide range of groupware tools in a well-coordinated environment. Likewise, MobileMeeting is designed for people to have virtual meetings using their mobile devices. This latter application combines popular social media with task-specific groupware tools to support team building, decision-making, and project coordination. Like other social media systems, users of MobileMeeting can add contacts, chat and share information with their contacts. One of the major differences to current popular social media systems is that groups, in both the groupware applications, are created together with a shared workspace consisting of shared content and many task-specific groupware tools. As the development of MobileMeeting is based on PowerMeeting, it shares main key features of its desktop counterpart. Both apps are built using Google Web Toolkit (GWT) (Perry, 2007) and a groupware framework developed in our previous work (Wang, 2008; Wang et al., 2009; Wang and French, 2008). One of the objectives of the mobile version was to look and behave like a native mobile app. Therefore, in addition to the standard GWT, mobile GWT[6] was also used to develop the application. These toolkits enable the automatic adjustment of the size of the interface to fit the screen of mobile phones (or tablets) in use, maintain the navigation history, and support the back button navigation that the web and mobile users have got used to. One of the most significant advantages of the web-app approach is that these apps can run on any mobile device within a standard web browser without the need for downloading and installation. In the following paragraphs, the characteristics of the applications are presented in greater detail with the help of some screenshots displaying how users actually see these applications on mobile and desktop devices.

The key features of these two applications are: (1) a shared workspace, (2) a set of task-specific groupware tools which enable several activities such as brainstorming, voting, multi-criteria decision-making (MCDA), task planning and tracking, documents sharing, group blogging, to name a few, (3) a chair-led group process captured in an agenda list and the tool-specific steps describing the different stages of a group decision-making process (e.g. brainstorming, categorisation, and voting, etc.), and (4) textual and vocal communication tools to coordinate fine-grained group actions throughout the process. As both applications are real-time groupware, any change made by a group member will immediately be visible to all the other members. Due to the need to coordinate group activities in a shared workspace, groupware user interfaces of GDSS are normally more complicated than those of single-user applications. In addition to some shared artifacts, group awareness, workspace awareness,

[6]mobile GWT, http://www.m-gwt.com/

and activity awareness information need to be provided in order to complete a meaningful decision-making process. Textual (or voice) chatting about a shared content need to be visible (or audible) in real-time in a shared workspace. The user-interface areas were provided for an agenda lists and a shared workspace along with participants' online status, change notification badges, and group chat. In the following paragraphs, the interface layout will be introduced together with some screenshots that capture some examples of chair-led, multi-step, MCDA tasks which were performed by the participants during the experiment.

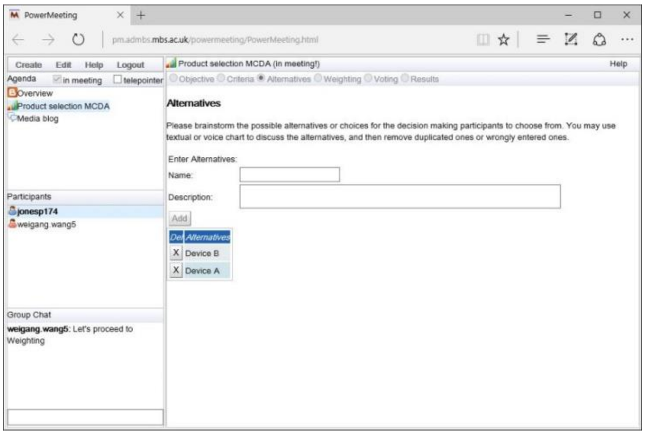

Figure 1. PowerMeeting user interface layout

Figure 1 shows the layout of the user interface for PowerMeeting. The Agenda, Participants, and Group Chat are located on the left side of the screen. The shared workspace is located on the right side of the screen. This instance presents the groupware user-interface for a MCDA (Stewart et al., 2013). The MCDA tool is activated by the session chair of a working group, and becomes visible in the workspace by selecting the second agenda item (as shown in a highlighted blue-colored background) in the agenda list. More specifically, the picture shows the third step of the MCDA task,

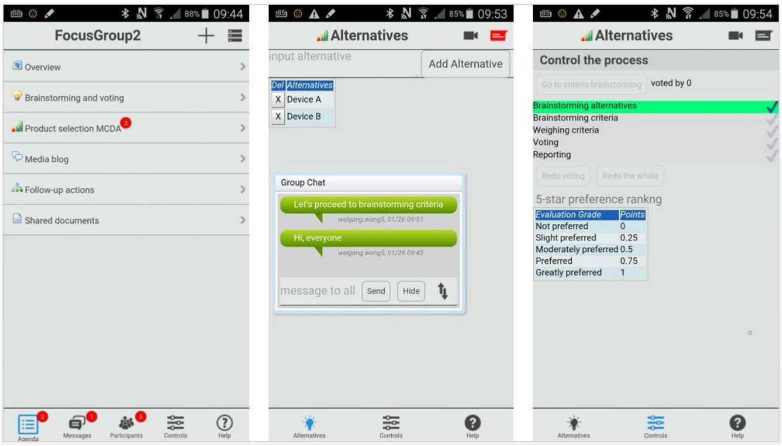

Figure 2. MobileMeeting user interface (from left to right: agenda list, Alternatives step in MDCA, control panel)

the creation of alternatives. The progression of the steps is controlled by the session chair. It is worth noting that the user interface layout for conducting the MCDA in PowerMeeting is similar to the one for MobileMeeting which is shown in Figure 2. In the mobile version, the aforementioned four interface components are placed in four tab panels (see the left screen in Figure 2, with the agenda tab as the default selection). Similarly to PowerMeeting, when a groupware activity agenda item is selected, its corresponding groupware user interface is displayed - see the middle-screen in Figure 2. This figure shows the step to brainstorming alternatives. As shown in the picture, the icon for 'Group Chat' is highlighted (in red color) as a notification of an incoming message. Then, when the icon is selected, the Group Chat dialog box appears with the content of the message. When the message comes from the session chair the box appears automatically without the need of clicking the dedicated icon. When the 'Control Tab' is selected, the control panel is shown in the workspace. This indicates the step at which the MCDA process currently is (i.e. the highlighted one in the picture) and what the following steps are. Only the session chair can control the progression of the steps; whereas 'ordinary' participants can only check the process-awareness information and contribute to the session accordingly.

The number displayed in the red colored badges attached to the agenda items and the tab labels represents change notifications (see left screen in Figure 2). The badges on the agenda items show how many changes were made to the content of each groupware tools; whereas the badges on the Agenda Tab show the total number of changes made on every groupware tool. The badges on the Message tab indicate how many unread messages are present. Finally, the badges on the Participants tab show how many people are currently online in the cooperative session.

According to Clark's theory on language use, for people to understand each other, they need to establish a "common ground" between them (Clark and Brennan, 1991). This common ground can be developed in a grounding process, in which both the content and the communication process need to be coordinated to reach and evolve the common ground gradually (Clark and Brennan, 1991). Gutwin and Greenberg have identified a set of mechanics of collaboration for people to work together in a shared workspace. These include communication, coordination, planning, monitoring, assistance, and protection (Gutwin and Greenberg, 2000). Based on these theories and needed mechanics, when people working together using groupware tools, they need to be aware of what is going on inside the group (e.g. who are the group members and who are online at the moment), within the group process (e.g., what is current task step in the process), about other group members' actions (what they are doing) in the shared workspace.

As are many groupware systems, the user interface design of PowerMeeting and MobileMeeting is also based on these theories. PowerMeeting has placed all the four user interface components carrying such information (i.e. agenda for process awareness, group chat for direct communication, participant list for group awareness, and content panel for shared artifacts of particular group activities and tools) in different areas of a relatively large display space. In this way, a complete overall view is provided as a glance. Due to the screen size limitation, mobile user interface designs must scale to handle the wide range of different-sized displays without appearing cramped at the low end or stretched at the high end. The MobileMeeting interface design has grouped the four components mentioned above on four associated tabs. Tabs are one of the most used components of mobile UIs. They allow users to quickly move between a small numbers of associated (sub) views that belong to the same parent view. As only one tab panel is visible at a time on a mobile phone, to get a complete overview, users have to switch between the sub-views. For providing various awareness information and avoiding frequent switching, notification badges are attached to each tab icon. People only need to move to a tab panel when the change notification information concerned at the time appeared on the badge attached to the tab icon. In effect, the desktop design provides an “overview" (with a focus on the content panel) while mobile design enforces “focus" on a sub-view (with overall awareness information distributed on the tab badges). Such layout difference introduce different interaction patterns. How these two compare is one of the research questions we are trying to explore in this study.

3.3. Method for the Lab Experiment

The initial part of the study consisted of a lab experiment which main aimed at assessing the efficiency of the systems. The second part, described in section 3.5, was an extension of the lab experiment and it was adopted to assess systems effectiveness in real-world settings.

In this experiment, “Happiness” was measured as perceived usefulness, satisfaction, ease of use and learnability using three standardized usability questionnaires (see questionnaires description below). The participants’ performance on both systems as reflected in the category “Task success” of the HEART framework was measured as time-on-task (i.e. the time taken to complete the decision-making process) and steps-on-task (i.e. the number of steps taken to complete the decision process). A step, in this experiment, was recorded as a click on the user interface leading to a different state in the interface of the system. All participants’ performance was video recorded (after signing a written consent form) using a video camera. The experiment adopted a within-subject design where participants had to complete the task following a script with a detailed step-by-step procedure using both applications - for experimental scripts see Appendix A. An analysis of covariance (ANCOVA) method was used to evaluate the user experience against the different measures of usability and performance. The first factor (IV1) was a within-factor defining the type of applications which had two levels (PowerMeeting and MobileMeeting). The second factor was defined as a covariate which was represented by the experience and exposure that participants had with both (1) PowerMeeting and MobileMeeting and (2) commercial groupware in general. As a result, the covariates taken into account were called “NumberOfTimes”, indicating the number of times participants used PowerMeeting and MobileMeeting, and “OftenUse”, indicating how often on a scale from 1 to 5 participants use commercial groupware in their daily life (1 for seldom, 5 for very often). There were five dependent variables (DVs). The first three DVs measured participants' satisfaction and the last two DVs measured participants' performance during the task in both PowerMeeting and MobileMeeting. The psychometric questionnaires used in the lab-experiment were:

- DV1: System Usability Scale (Brooke, 1996).
- DV2: Perceived Usefulness and Ease of Use scale (Davis, 1989).
- DV3: After Scenario questionnaire (Lewis, 1995).

Participants' performance on the two applications was measured as follow:

- DV4: Number of steps taken to complete the task.
- DV5: Amount of time spent to complete the task (in seconds).

3.3.1 Participants and Stimuli

The participants for this study were a convenience sample taken from a population of students in Manchester Business School (MBS) who volunteered for the experiment in return for Amazon.com vouchers. In total, 30 students participated in the experiment, 17 females and 13 males, aged between 20 and 28. 27 previously studied business related subjects and 2 studied IT related subjects. The experiment took place in a computer lab within MBS where participants used desktop computers (for the "PowerMeeting condition") and personal smartphones (for the "MobileMeeting condition") to complete the tasks. The Chrome web browser was the default choice which eliminated potential browser-specific systematic errors. In addition, verbal communication was not allowed to avoid potential confounders emerging from social behavior.

3.3.2 Procedure

Participants were told that a fictional company had to develop two products, two wearable electronic devices, but did not have enough capital to commercialize both of them. They were also told that they were a team of external consultants called upon to advise the top management team on the selection of the product that needed to be launched onto the market. Participants had to perform a group MCDA to achieve this goal (i.e. the selection of one product out of two). They had to complete the same tasks on both applications (PowerMeeting and MobileMeeting) in two different sessions. The order in which the applications were used (i.e. PowerMeeting first and then MobileMeeting or vice versa) was counterbalanced to control for carryover effect which could emerge from a fixed order.

The 30 students were divided into ten groups. The groups were formed randomly using a scheduling and self-enrol system (i.e. doodle.com). Due to the availability of the participants, there were two groups (i.e., group 1 and 10) with 5 participants, four groups with 3 participants, and three groups with 2 participants. The session chair role was decided by the participants in each group. To cancel the carryover effect, the odd numbered groups used the MobileMeeting first; while even numbered groups used PowerMeeting first. The screen video recordings for each participant were taken during the tasks execution on both applications to record completion time and number of steps taken to complete the tasks. After the tasks had been completed, participants had to complete the three psychometric questionnaires described in the previous section along with some open questions related to the usability of the two systems (see Appendix A for the task sheets).

3.3.3. Post-session questionnaires and questionnaire analysis

The System Usability Scale (Brooke, 1996), the After Scenario Questionnaire (Lewis, 1995) and the Perceived Usefulness and Ease of Use Questionnaire (Davis, 1989) were adopted in this study as measures of usability (see Appendix A). The reason to adopt available questionnaires rather than building one specifically for this research was that the questionnaires chosen were previously tested for validity and reliability and had been extensively used in many usability studies in contexts similar to the one used in the present research.

The System Usability Scale (SUS) questionnaire consists of a 10-items and gives a global overview of a subjective assessment of usability. It is a general index of usability without distinction between different usability sub-dimensions; and therefore it addresses usability as a domain-general concept (Brooke, 1996). Conversely, the Perceived Usefulness and Ease to Use questionnaire (PUEU) uses a 12-item and 7-point Likert scale (from 1 to 7) to measure two sub-dimensions of usability: the subjective usefulness of the application tested and how easy it is to use the application. Specifically, ‘perceived usefulness’ refers to the degree to which the user finds that the use of the applications can improve and add value to the user’s daily business activities, or hypothetical business activities. ‘Perceived ease of use’ refers to the degree of “easiness” perceived by the users interacting with the applications when completing a meaningful task (Davis, 1989). Finally, the After Scenario Questionnaire (ASQ) consists of three questions, measured by a 7-point Likert’ scale, which give a subjective assessment of usability related to a specific task. Therefore, this scale seeks to measure domain-specific usability related to the context of the tasks (Lewis, 1995). The total SUS score ranges from 0 to 100, the ASQ score from 3 to 21, and the PUEU score from 12 to 84.

3.4. Google Analytics and system logs

‘Engagement’, ‘Adoption’ and ‘Retention’, to be meaningful, need to be measured over a long period through the collection of longitudinal data. To compare the two applications against these categories of the HEART framework, a set of web metrics (as described previously in the first part of section 3) were identified. Both PowerMeeting and MobileMeeting have been tracked by Google

Analytics and the data collected for both applications represents a 14-month period (from the 15th of October 2014 to the 15th of December 2015). Furthermore, both PowerMeeting and MobileMeeting have system logs which track some aspects such as the "Uptime" of the system servers and the "Latency" of the transactions that cannot be obtained from Web tracking tools. These data were analyzed and discussed to add further insights into the discussion. The long-term observations described here concern the behavior of the anonymous and open group of users from the internet who happen to access our tools during the period mentioned above.

3.5. Applications in naturalistic settings

This part of the study adopted real-world scenarios to move away from the artificial settings of the lab-based experiment, addressing the research questions from a more ecologically-valid perspective. This study adopted a qualitative analysis of several interviews and written reports.

3.5.1. MCDA for product selection using both PowerMeeting and MobileMeeting

The group task adopted in this part was an MCDA, similar to the one used in the lab experiment. The main difference was that no formal instructions were provided on the step-by-step procedure to complete the decision process. Therefore, the group members could select the topic of their group decision task themselves and complete the decision process according to their own time and locations. Six participants were divided into two three-member groups. Each group performed the task twice, and the order with which the applications were used was opposite so as to counterbalance the potential carryover effects. After completing the group tasks on both systems, semi-structured interviews were conducted with each participant. The interview questions focused on the effectiveness of the users' tasks while using the systems, the effectiveness of group communication and coordination, as well as the strengths and weaknesses of the applications. The six participants of this study include 3 female and 3 males, aged between 22 and 26, with a business-related academic background.

3.5.2. Virtual focus group activities using MobileMeeting

The business scenario for this group task was based on a virtual focus group marketing campaign for consumer research. Participants were told that they had to conduct a social-media market campaign to invite potential customers from around the world to participate in a virtual focus group activity to discuss and comment on a new concept product to be launched by a fictional company. This task had to be conducted entirely on MobileMeeting using its 'brainstorming' and 'voting' tools. Led by a session chair, participants moved through a multi-step group process consisting of four stages:

1. Brainstorming: They had to generate ideas about which aspects of the product they liked, disliked, and suggestions to improve the product;
2. Consolidation and categorization: They had to look for redundancy and remove any duplicate idea. They also had to group these ideas into different categories such as ‘pros’, ‘cons’, or ‘suggestions’;
3. Voting: Participants had to vote the ideas;
4. Reporting: Based on participants’ votes, a ranked list of ideas in each category was created.

For this study, 56 students from Manchester Business School were randomly divided into ten groups, with 5 to 6 members in each group. As described above, each group had to organize a social media marketing campaign to engage potential customers to participate in virtual focus groups in a MobileMeeting shared workspace (i.e. a cooperative session) created by the group members. In addition, to advertise the product and to attract more people to participate the activity, they had to distribute the social media posts on the product together with a tagged link pointing to the shared workspace in MobileMeeting on two popular social media systems of their choice (e.g. Facebook, Twitter, WeChat, Google+, LinkedIn, WhatsApp, to name a few). The tags added to the link (URL) pointing to the system home page include the shared-workspace session id and three campaign-related tags (which were generated from the URL Builder of Google Analytics to identify specific campaigns run by specific student groups and on specific platforms). When the tagged links were followed by the potential customers, not only the potential customers could directly move into the shared workspace, but also Google Analytics automatically recorded the click-streams.

In this experiment, the students' aim was to involve as many respondents as possible to participate in the virtual focus group activities conducted via MobileMeeting; whereas the purpose of the virtual focus group itself was to produce ranked lists of ideas generated by the potential customers. From a research perspective, however, the purpose of this study was to investigate whether mobile GDSS could be effectively integrated into popular social-media applications and whether such integration could potentially promote the adoption of these systems into business activities of this kind. The deliverable to be submitted for this student project was a written report analyzing and discussing students’ social media marketing and virtual focus group activities.

4. Results and Discussions

The results and analyses of the three parts of our study are presented in the following sub-sections.

4.1. Results of the experiment and discussions

An ANCOVA analysis was conducted to assess whether there was a significant difference between the two applications against all the DVs measured in the experiment. The data collected from the SUS show that usability was slightly higher for PowerMeeting ($\bar{x}$ = 64.50, σ = 16.772) than it was for MobileMeeting ($\bar{x}$ = 56.367, σ = 19.928). However, this difference was not statistically significant - $F(1, 27) = 0.307$, $p = 0.584$. A similar result was found in the analysis of the data collected from the PUEU questionnaire, where the mean value for PowerMeeting ($\bar{x}$ = 61.30, σ = 12.366) was slightly higher than the mean value for MobileMeeting ($\bar{x}$ = 53.37, σ = 14.464). However, this difference was not statistically significant - $F(1, 27) = 1.803$, $p = 0.191$. Likewise, the ASQ mean value was slightly higher for PowerMeeting ($\bar{x}$ = 15.77, σ = 4.125) than it was for MobileMeeting ($\bar{x}$ = 14.50, σ = 3.937). Once again, this difference was not statistically significant - $F(1,27) = 1.446$, $p = 0.24$. These results do not support Hypothesis 1 as users interacting with the two versions of the systems (mobile and desktop) reported a similar level of satisfaction when performing the tasks.

An ANCOVA test was also conducted to compare the two applications against the measures of performance (i.e. the completion time and the number of steps taken to complete the tasks). Participants appeared to be faster when performing the tasks with PowerMetting ($\bar{x}$ = 108.37, σ = 17.893) than they were when performing the task with MobileMeeting ($\bar{x}$ = 127.27, σ = 25.753). This difference was not statistically significant - $F(1,27) < 0.001$, $p = 0.987$. This result does not support Hypothesis 2.1 as the time taken to complete the task was similar for both versions of the system.

A significant difference between the two applications was found in the measure of ‘number of steps’ participant took to complete the tasks. Participants took less steps to complete the tasks when using PowerMeeting ($\bar{x}$ = 33.20, σ = 4.752) than they took when using MobileMetting ($\bar{x}$ = 42.67, σ = 9.639). This difference was statistically significant as $F(1,27) = 24.175b$, $p < 0.001$. This result supports Hypothesis 2.2.

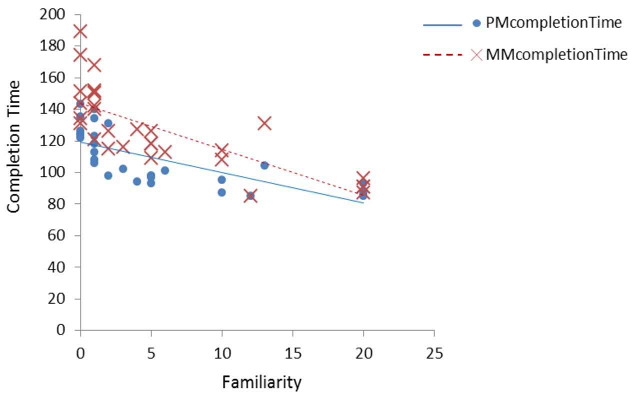

Figure 3. Relationship between familiarity and time-on-task

However, there was a significant interaction between the type of application used to perform the tasks and users’ familiarity with the applications - $F(1,27) = 8.252$, $p = 0.008$. Specifically, familiarity with the applications (as measured by having used the apps 0, 5, 10, 20, 25 times) seems to have improved participants' performance mainly when they used MobileMeeting, where people who were more familiar with the applications were significantly faster than people who were not familiar with the applications. Although this effect was also found in PowerMeeting, the magnitude of this it was relatively small when compared to the effect seen on the mobile version of the system - see Figure 3 below. This result supports Hypothesis 3.1.

Furthermore, there was an interaction between the type of application used and how often users engage with similar groupware applications in daily life - F(1,27) = 6.522b, p = 0.017. Specifically, as shown in Figure 4, experience with other similar groupware applications (as measured by how often they used similar software, from 1 never to 5 often) seems to improve performance when the participants used MobileMeeting greatly. The magnitude of this effect was significantly smaller when participants used PowerMeeting – see Figure 4. This result supports Hypothesis 3.2.

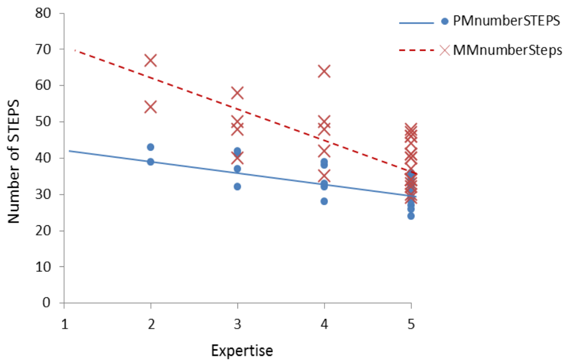

Figure 4. Relationship between expertise and steps-on-task

Discussion of the lab-experiment

As shown in the analysis above, the two systems appear to be somewhat similar regarding the overall level of usability. No significance difference was found between the two applications against the three usability scales adopted here for the assessment of the category Happiness of the HEART framework, suggesting that the desktop version of the GDSS adopted in the study and its mobile version have similar user satisfaction levels. The analysis shows that people complete the same task with significantly less steps with the desktop version of the system than they do with the mobile one. However, such large different is noticed only when they are not familiar with the two applications or when they have limited experience using groupware. This difference may be explained by the difference between their user interface designs. The complete overview offered by the desktop version makes it easier for users to understand the roles of the groupware components and the relationship between them. As the mobile version forces the focus on one of the, without a clear mental model of the groupware and its associated components, new users may not be clear on the role of the components and when to use each of the tab panels. As a result, they ended up with frequently switching the views between the tab panels and therefore added many unnecessary steps to perform the task. The results of a second study in real-world settings as described in Section 4.3 has provided some evidence on such an explanation. Once familiarity with the specific applications and experience with similar groupware are increasing, the difference in performance becomes unnoticeable. This suggests that mobile groupware used for complex tasks may have a higher learning curve, but also a higher learnability (i.e. a quicker and more noticeable performance improvement) than their desktop version. This is in line with some previous research described in the literature review for collaborative apps highlighting that mobile computing is taking over and, although they were once perceived as inferior regarding performance, their functionality has improved dramatically. Furthermore, people are more and more familiar with the new trends in mobile computing and mobile use for complex activities. Further research comparing a larger number of applications would be needed to validate such a generalization.

4.2.Results from Google analytics and system logs

The data collected to assess the applications against the metrics describing 'Engagement', 'Adoption', and 'Retention' of the HEART framework were obtained from the web tracking tools of Google Analytics; whereas the data collected to assess the applications against the metrics describing 'Uptime' and 'Latency' of the PULSE framework were obtained from the server logs of the two systems.

4.2.1. Engagement

"Engagement" reflects the user's level of engagement with a particular Web application. Behavioral proxies of engagement include frequency, intensity, or depth of interaction over a period. As "Engagement" is measured by how much time new and returning visitors are spending on a website, the number of sessions (visits) and the average session duration per visit were chosen as Web metrics. In the 14-month period, PowerMeeting had 818 visits, while MobileMeeting had 8455 visits. The average session duration for PowerMeeting was 5 minutes and 1 second, while the average session duration for MobileMeeting was 4 minutes and 18 seconds. About 18% of PowerMeeting users used the desktop app three to eight times, while 28% of MobileMeeting users used the mobile app three to eight times. About 4% of PowerMeeting users used the desktop app more than nine times, while about 23% of MobileMeeting users used the mobile app more than nine times. From the above data, it can be noted that the mobile version of the system was visited more frequently. There were, on average, a higher percentage of users who used the mobile version of the app more frequently than the desktop version. The intensity or depth of interaction, as reflected by the average session duration between the two apps, was similar for both systems. Moreover, by comparing the numbers of recent transactions fired by the two systems, it can be noted that the number of MobileMeeting transactions produced in three months is larger than that generated by PowerMeeting in over two years (See Section 4.2.4). This suggests that user engagement with MobileMeeting is much higher than that observed with PowerMeeting.

4.2.2. Adoption

"Adoption" metrics describe the number of new users who started using a product during a period. During the 14-month period, PowerMeeting had added 318 users, while MobileMeeting had added 1080 users. When assessing the user adoption, one should think about a) the novelty of the application; and b) the possible competition. As PowerMeeting is available for a longer time, so many interested users might already have seen it before and only now look at the new MobileMeeting. There are several desktop Web-based Group Decision Support (WGDS) systems available online; mobile solutions, however, are rather new. MobileMeeting reflects new trends in user-interactions with new technologies which are moving more and more from desktop to mobile computing. These may help to explain why the mobile app had a higher "adoption" than its desktop counterpart.

4.2.3. Retention

"Retention" metrics give the number of users who remain active in a given period. In Google Analytics, New visitors of a website are those who visited the site only once; while returning visitors are those who visited the system at least twice during a given period. During this 14 month period, PowerMeeting had 204 returning users, but these represent a smaller portion (39%) of the users (See Figure 5). Most of the users (61%) during the period only tried the system once. This immediately raises the goal to encourage visitors to return to the system. MobileMeeting had 1979 returning users who were over two-thirds of all the users in that period (see Figure 5). This is a proportion that indicates both a good retention rate (65%) and a good level of new user growth (35%). The number of monthly active users (MAU) in the final month in this period was 45 for PowerMeeting and 1082 for MobileMeeting. It appears that the mobile application had a better retention than its desktop counterpart.

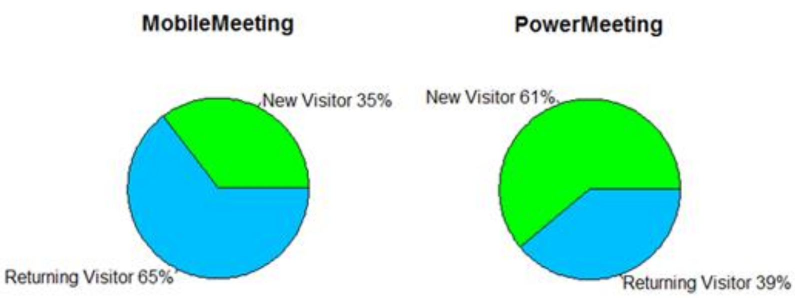

Figure 5. Percentage of new to return users

To summarize, although PowerMeeting had been online for longer than MobileMeeting, the results provided above showed that MobileMeeting scored better than PowerMeeting in the measure of Engagement, Adoption and Retention. This can be explained, at least partially, by the new trends that favour mobile over desktop computing.

4.2.4. Uptime and latency

"Uptime" metrics measure the reliability and availability of a website, whereas "Latency" metrics measure the response time performance of a website. Data from the system logs of both PowerMeeting and MobileMeeting show that both systems have been up and running most of the time, the only exceptions were those brief periods when the server machine was off for regular IT service maintenance. When the server machine starts, the servers of both systems start automatically. Therefore, both systems performed equally well on the "Uptime" web metrics.

The "Latency" or response time in groupware can be measured as the user-to-user response, i.e. the waiting time needed to move from the change made by one user to the modification seen by a remote collaborator. In real-time groupware, such change operations are managed using update transactions. Technically, this user-to-user response time has been measured as roundtrip time: i.e. from the time a transaction is sent to the system server to the time a confirmation is received from the server. This 'half-of-the-trip' confirmation time would be similar to the time needed to deliver a transaction to another user. In addition to the transmission time needed to deliver a transaction through the Internet, latency also includes the time used (or delay caused) by the graphical user interface rendering and the processing time used by the groupware middle layer for replication management (for replicating data or sending update transactions to each user's site), concurrency control (for avoiding loss of work due to conflict changes made by different users) and persistency management (for saving the changes in the database on the server side). Due to the complexity of real-time groupware, such delays are usually heavier than the delays experienced in simple groupware websites without such layers. As on the Internet some unexpected delays could happen from time to time which may be linked to a poor stability of wireless network, we use a set of descriptive statistics to measure the response times of all update transactions over a time period, rather than measuring the response time on some random instances in that period.

From the PowerMeeting log (from 27 March 2013 to 03 September 2015), 11991 transactions were recorded. The roundtrip time mean was 161 milliseconds (ms), the median was 53 ms and the total range was from 0 to 24086 ms. Specifically, the 25^{th} and 75^{th} percentile were 23 ms and 109 ms, whereas the 90^{th} percentile was 250 ms and the 95^{th} percentile was 502 ms. As a result, most of the time (i.e. 75% of the time) the response-time recorded ranged between 0 and 109 ms, and time longer than half-a-second happened in about 5% of interactions. From the MobileMeeting log, which recorded the data from 22 June to 26 August 2015, 15290 transactions were recorded. The roundtrip time mean was 277 ms, the median was 55 ms and the total range was from 0 to 26835 ms. Specifically, the 25th percentile was 0 ms and the 75th percentile was 194 ms, whereas the 90^{th} percentile was 610 ms and the 95^{th} percentile was 1060 ms. As a result, 75% of the time the response-time recorded ranged from 0 to 194 ms, and time longer than a second only happened about 5% of the time. From these results, it can be noted that PowerMeeting had a slightly better response time than that of MobileMeeting. This, probably, was mainly due to the more reliable and speedy wired-network used by desktop computers. Mobile devices make use of wireless networks which are known to be inferior when compared to more stable wired connections. However, even under wireless-networking conditions, most of the times MobileMeeting's response time was within a 200 ms threshold and rarely exceeded one second. The interpretation and implications of these results are discussed below in details.

According (Card et al., 1991; Miller, 1968; Nielsen, 1994), a response time of 100 ms gives the user a feeling of immediate response – i.e. within this duration the transaction outcome appears to be caused by the user, not by a computer or a collaborator. Nielsen also noticed that a response time of 1 second can still keep the user's 'flow of thought' seamless as he/she can sense a delay, but still feels in control of the overall experience. A response time of up to 10 seconds still can keep the user's attention but is undesirable. However, beyond this threshold attention is lost and user's engagement with the technology is greatly reduced. Moreover, these thresholds and their effects refer to single-user-system interaction. For real-time groupware, a faster and synchronized remote interaction is expected. In this case, a 10-second delay, which was acceptable for accessing an informative website, may be very distracting and detrimental for collaborative work. A sub-second response time is required. It follows that the two systems used in the present study provide an efficient user-user response time that was well below the acceptable threshold for an effective interaction. Overall, it can be concluded that nowadays real-time groupware built on the standard web HTTP protocol can be practically deployed for real-world applications even under wireless networking.

4.3. Results of the groupware applications in real-world settings

The results from the lab experiment described in section 4.1 were obtained in a mechanistic procedure; therefore they may lack ecological validity. Here we present the results obtained from a second study conducted in real-world settings, consisting of two distinctive but related parts, whose design and implementation emerged from the results obtained previously in the lab experiment. This generated qualitative data which was used to capture the depth of the interaction between the users and the system. Indeed, this part of the research had fewer constraints than the lab experiment. One of these constraints was that the groups had to complete the tasks within a given deadline, but they could work on their preferred time, and at their preferred location. Contrary to the lab experiment, the process micro-management and timing were not over-imposed. All the groups completed the tasks before the deadline and most of the members of the groups worked asynchronously, as reported in the deliverable submitted. The results of the two parts of this study are reported below in detail.

4.3.1. **Feedback from the MCDA for the product selection tasks**

For both of the two groups, all the steps of the MCDA were completed along with a list of alternatives ranked according to the analysis conducted by the groups. The tasks performed in each system were led by a session chair. Both groups used the chat tools to coordinate their actions and the blogging tools to discuss and exchange information. Most of the participants (5/6) reported that mobile technologies can increase the flexibility in performing group decision tasks. Specifically, they highlighted that MobileMeeting can be used while in motion. This, according to participants' feedback, is a great advantage for collaborative work of this kind. All of the participants suggested that the integration of social media functions into PowerMeeting and MobileMeeting added value to group collaborations. As they performed their tasks asynchronously over multiple days, the social media interaction helped them to coordinate the group process and to deliberate on the criteria in the MCDA. They also mentioned that MobileMeeting disconnected automatically more often than PowerMeeting, especially when they were working in places where the wireless networking signal was not very strong. A limited screen size, poor wireless connection stability, and an inferior battery capacity were the key constraints reported for the mobile version of the system.

4.3.2. **Feedback from the virtual focus group activities**

Each group had chosen a new concept product for their online marketing activity (e.g. a bendable smart device, an iWatch, etc.). The session chair was in charge of the virtual focus group activities; whereas two social-media campaign coordinators, chosen by the group members, were responsible for the campaigns. The social media coordinators created an account in each of their chosen social media platforms; whereas the session chairs created the sessions (workspace) on MobileMeeting for their virtual focus group activities. The session chairs also created workspace links with session id and campaign parameters which were given to the social media coordinators. The coordinators had to embed these tagged links in their posts in two chosen social media systems. All groups' members scheduled their activities over a two-week period. The first week was used for tasks preparation and pilot testing, and the second week was used to advertise the virtual focus group activities and invite people around the world to participate the virtual focus group activities for collecting and ranking ideas about the new concept product. All ten groups completed the virtual focus group activities successfully within two weeks, generating a large amount of feedback and ideas given by the participants who contributed to the tasks. The ten groups were able to invite a total number of 736 people from several social-media applications to the virtual focus group activities conducted via MobileMeeting. These 736 users visited the mobile GDSS 2165 times. This implies that many of those users visited MobileMeeting more than once.

Table 1 shows the two social media systems chosen by the groups and the number of users who participated in the brainstorming and voting tasks in each group. As shown in Table 1, Facebook was chosen by almost all groups. Moreover, due to a large percentage of Chinese students in the class, WeChat was also used by the majority of the groups. Twitter and Weibo were selected only by two groups. Instagram was selected by only one group. The data in the table were collected from Google Analytics in its ‘All Campaigns’ page within the ‘User Acquisition’ section. The group activities were performed between the 15th of November and the end of the November 2015 and the data shown in Table 1 were captured in that period.

Table 1. MobileMeeting Users who engaged in the virtual focus group tasks

Group	Social Media System 1			Social Media System 2		
	Name	Users	Visits	Name	Users	Visits
1	Weibo	36	94	Facebook	30	107
2	WeChat	66	114	Facebook	26	76
3	Weibo	96	218	Facebook	30	81
4	Twitter	24	59	Facebook	44	168
5	Twitter	70	260	Facebook	10	25
6	WeChat	43	54	Facebook	16	49
7	WeChat	31	185	Facebook	21	112
8	WeChat	25	84	Instagram	17	94
9	WeChat	31	73	Facebook	36	137
10	WeChat	37	79	Facebook	47	96

In order to better coordinate the virtual focus group activities, most of the groups’ members used the chat tools embedded in the mobile GDSS and the blogging tools of the system. Other social-media applications were predominantly used for inviting (through tagged link posting) external people to participate the tasks. These links allowed potential participants to join a working session with a simple click.

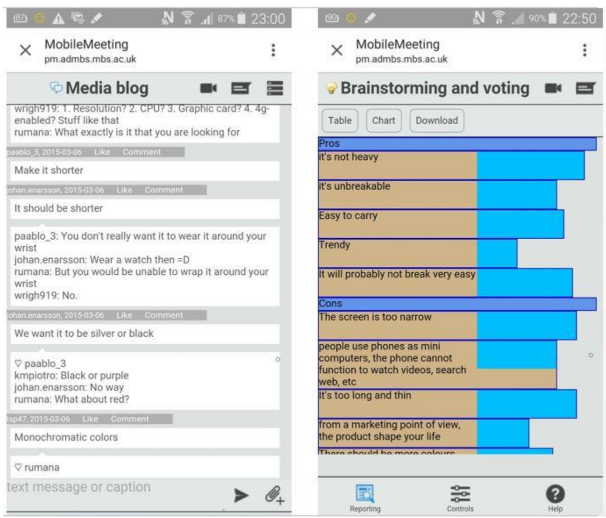

Figure 6. MobileMeeting workspace within Twitter

Figure 6 shows a MobileMeeting workspace opened in the in-app browser of Twitter itself. It can be noted that, by looking at Figure 6, the MobileMeeting user-interface fits the user-interface style of the social-media applications from which it is opened. This integrated interface functionality gave the impression that MobileMeeting tools such as Brainstorming, Voting (See the screen on the right-hand side in Figure 6) and Group Blogging (See the screen on the left-hand side in Figure 6) were part of the social media application used - in this case Twitter. A Back Button click would move the user back to the Twitter page with the tagged link. The integration above is also possible with the desktop version of the e-collaboration system. However, as the interface of PowerMeeting was developed for web browsers on desktop devices, when it is accessed using a smartphone, the components of the user interface would appear to be too small to be seen clearly by the users. The users have to enlarge, pan and move using gestures to see different parts of the user interface. This reveals that MobileMeeting can achieve a seamless integration with popular mobile social media systems on mobile devices, while PowerMeeting cannot.

The screenshot on the left-hand side of Figure 6 shows that some users were discussing a bendable watch concept product using the Media blog tool embedded in MobileMeeting. Despite users preferred to use their favorite social media systems on a mobile phone to communicate with their friends or colleagues, for communicating with group members within the task they used the chatting or blogging tools within MobileMeeting. This was not over imposed by the experiments. Rather, it was a self-made choice. This can be explained by the fact that the participants of the virtual focus groups were users of different social media systems who did not know each other. This heterogeneous sample of participants, with their preferred social media application, needed a common system for communication and coordination. This forced the group members to adopt a common tool (MobileMeeting) for e-collaboration activities within the group. It follows that the various social media systems provided the entry points to the MobileMeeting workspaces; while a MobileMeeting workspace was used as a ‘glue-element’ to connect users from different social media systems.

4.4.Overall Discussions

The previous sections provided a description of the results and their interpretation along with some considerations. The following focuses on highlighting the major contributions of this work and their implications. Wherever possible, the results are compared with closely related work to provide some useful means of comparison.

An innovative comprehensive evaluation framework for comparing mobile and desktop GDSS

The different focus between researchers and usability professionals leads to the development of different methodologies to the study of HCI interaction, such as usability testing in the lab, online testing in large scale, expert walk through, web tracking, questionnaire survey, and interview, to name a few. Interaction research is seen here as a multilevel activity. We try to combine lab experiments and studies in real world settings with longitudinal data analysis emerging from long-term Web observations. Our primary goal was to test the research hypothesis. Nevertheless, a second goal was to develop a method integrating different approaches using existing frameworks (e.g. HEART and PULSE) not only to assess systems performance but also to capture the depth of user-system interaction. This can be valuable for both professionals and academic researchers who may need to tackle HCI research from different angles. This study and its results set solid bases, ideas and an integrated evaluation framework which are useful for future research in mobile computing for collaborative work.

The mobile group decision support system can match its desktop counterpart

This research compared two versions of a group decision-support system to uncover whether mobile technologies can be as efficient and effective as desktop ones for complex collaborative business activities. Results from a lab experiment showed that, after a short period of practice, the mobile version of the GDSS could be almost as efficient as its desktop counterpart. This was a substantial improvement and was also in line with the recent trends in technology. In fact, nowadays similar applications have been developed for mobile devices to support complex business activities. But little, if any, research has tried to evaluate these technologies and their implications empirically. For instance, ThinkTank is one of the most popular GDSS in the world, and it is widely used in many Fortune 500 companies (French et al., 2009). Many publications have reported its successful applications in different fields and on different tasks such as collaborative requirement engineering (Azadegan et al., 2013), multi-criteria decision analysis (Porthin et al., 2013) and crisis management (French et al., 2009). In 2014, a mobile version of ThinkTank, ThinkTank Mobile, was released. However, as with its desktop version, no direct communication features are included. ThinkTank is largely used in meeting room settings and if used for remote collaboration, external communication tools (such as web conferencing tools, e.g. WebEx[7] or conference phones) are needed. So far, no comparative evaluation of the mobile version of the system has been published and, to our knowledge, the aforementioned comparative performances on complex group activities have not been reported anywhere in the literature. This work produced meaningful findings on the performance of the mobile groupware in comparison to its desktop counterpart.

Standard web technology based real-time groupware can provide an adequate user-to-user response time

As shown in the literature social interactions in business settings such as group brainstorming and decision making appear to be best accomplished synchronously (Ellis et al., 1991). Moreover, as real-

[7] WebEx, https://www.webex.com/

time groupware systems supporting these activities should not hinder the group's cadence, two key system properties are required (Ellis et al., 1991). The two properties are a) a short local-change response time, which is the time required for a user interface to reflect the user actions; and b) a short notification time (i.e. the user-to-user response time), which is the time required for these actions to be propagated to every group member's interface (Ellis et al., 1991). Both MobileMeeting and PowerMeeting are Web-based applications and were developed on the same real-time groupware middleware (for data replication, concurrency control, and persistence management) that are built on the same AJAX-based server-push mechanism and server site (Wang, 2008). The short local-change response time has been ensured by an optimistic concurrency control mechanism that allows users to operate directly on the data without obtaining locks (Ellis and Gibbs, 1989) (Wang, 2008). As shown by the analysis in section 4.2.4, the notification times (i.e., the user-to-user response time) of the two apps are well within the levels set by the usability guidelines. Our results confirm the results from Gutwin and colleagues (2011) which show that web-based systems can support real-time collaboration if the systems are well designed. However, as acknowledged by the authors, the main limitation of their research was that their results were obtained from an analysis of simulated transactions and a testing of a simple groupware. They suggested that future works should focus on more sophisticated groupware with a middleware layer and a visual rendering layer in real world applications. These issues were addressed in the present study. In fact, our results were obtained from transactions generated by real group-activities performed by groups of real people using more sophisticated group decision support systems. These results strengthened Gutwin and colleagues' conclusions and added ecological validity to their findings. Our results indicate that the delay experienced in web-based networking, added to the potential delay caused by the rendering engine and the groupware middleware, is rather low as both the mobile and desktop versions of group decision support systems could still provide a good response time for real-world collaboration.

The strengths and weaknesses of the mobile and the desktop applications

Regarding the groupware usability, the experiment results indicate that the desktop app still (slightly) outperforms the mobile app, especially at initial attempts. The users' feedback revealed that for real-time group tasks and for editing documents, participants still preferred the desktop version of the system over the mobile one as it has a bigger screen with an interface layout showing all the major graphical user interface panels simultaneously and an input system based on a full-sized physical keyboard. Moreover, participants complained that MobileMeeting had more networking disconnections than PowerMeeting, especially when they were working in places where the wireless networking signal was not very strong. On the positive side of mobile computing, most of the participants reported that mobile technologies increased the flexibility of their work especially when they were working on group decision tasks. Moreover, the data collected from the web tracking tool showed that the mobile version of the app had a faster adoption, better engagement, and better retention than its desktop counterpart. This might be a reflection of the recent shift towards mobile technologies in our society and the fact that people are more and more exposed to such technologies like never before.

The usefulness of the integration of mobile groupware with popular mobile social media

Previous studies investigating the integration of social media into the user-interface of specific systems, such as e-collaboration systems, showed that such integration might improve usability, enhance collaboration and ameliorate accessibility to social media content (Cui and Honkala, 2013; Franken et al., 2014; Prinz and Kolvenbach, 2012). In the present study, the enhanced usefulness of the social media functionalities implemented in MobileMeeting to support communication and coordination in session-chair-led group processes has been reported by many users. We have also investigated how to integrate groupware into existing social media platforms. Especially, the integration of MobileMeeting into popular social-media systems through the embedding of tagged URLs that point to MobileMeeting groupware tools, or specific MobileMeeting workspaces, was appreciated by most of the users in the collaborative tasks. This was probably emphasized by the fact that the groupware user interface was totally integrated into the user interface of the popular social media system selected by the user. This created the experience of having the two interfaces becoming an integral part of a unique system. In such a seamless integration, a social media system can provide a context and entry points for collaboration; whereas the groupware extends the social media system functionality to a collaboration support environment with shared workspace and task-specific groupware tools. Thus, the familiarity and popularity of social media environments can promote the adoption of mobile groupware. This however needs further investigation as the mechanisms underpinning the reason why this integration enhances the adoption of mobile groupware are not clear.

5. Conclusions

The paper presents an extended comparative evaluation of a mobile vs. desktop version of a group decision support tool. The goal of the evaluation is to assess whether the usability of mobile systems is (already) suitable for complex business tasks. An innovative and comprehensive evaluation has been performed and it is based on lab experiments, observation of group work in real-world application scenarios and extends the results by evaluation of long-term weblogs. The results of the evaluation suggest that

- The mobile version can match its desktop-based counterpart regarding user satisfaction and performance (after a short period of practicing); and it has a much faster adoption, better engagement, and better retention than its desktop counterpart.

- Users have appreciated the smooth integration of the mobile group decision-support system with popular social media systems as a useful feature for group decision support.
- Sophisticated real-time groupware built on the standard web HTTP protocol can be practically deployed for real-world applications with adequate user-to-user response time even under wireless networking connection.
- These results imply that web-based mobile technologies can now support multi-step group decision-making tasks.

In spite of these promising results, there are some limitations. The participants of this research were university students who were motivated mainly by rewards such as vouchers. Students may lack not only the motivation but also the necessary experience in business-related contexts to be a representative population. The sample size, comprised of 30 participants in the controlled experiment and 56 participants in the group projects, is not particularly small for usability studies conducted in university facilities, but this may be a small sample for online testing which is generally performed by professional companies. Moreover, the results emerging from domain-specific decision tasks such as the ones adopted in the present research may not be generalizable to other collaborative activities. Further research is needed to investigate whether similar results can be obtained in different contexts and with samples drawn from different populations. Furthermore, as one the main feedback received by the participants of the study was the appreciation of the two-way approach of integrating groupware with social media, future research could focus on the integration of other social media functionalities into groupware and the integration of groupware shared workspaces into existing popular social media systems. Specifically, further research may focus on testing different types of collaborative tasks using the mobile app's shared workspaces that are embedded within the popular social media systems.

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Appendix A.

A.1. Questionnaires

A.1.1. The System Usability Scale Questionnaire (SUS)

This is based on (Brooke, 1996), accessible at http://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html.

A.1.2. After Scenario Questionnaire (ASQ)

This is based on (Lewis, 1995), accessible at http://garyperlman.com/quest/quest.cgi?form=ASQ

A.1.3. Perceived Usefulness and Ease of Use Questionnaire (PUEU)

This is based on (Davis, 1989), accessible at http://garyperlman.com/quest/quest.cgi?form=PUEU

A.1.4. General Comments

1. How many times have you used PowerMeeting/ MobileMeeting?
2. What are, in your opinion, the most useful and the least useful features of the App?
3. What are, in your opinion, the most complicated and the least complicated features of the App?

A.2. Preliminary questions for the controlled experiment

After the task, you are required to fill in a simple questionnaire here below. This will contain some personal information that will not be shared. They will be used just for the purpose of this study and kept just by the experimenter. Private information will not be used in any way, and will not be shared with third parties.

Furthermore, your private information will not be linked to your name, just to a participant number, so that your privacy will be respected. It will also contain questions related to the task and the applications you just used. Please answer honestly and to the best of your knowledge. Thank you for your collaboration.

1. Participant ID
2. Role
    a) Participant
    b) Session Chair
3. What is your gender?
    a) Male
    b) Female
4. Which age group are you in?
    a) Under 18 years old
    b) 18-23 years old
    c) 24-28 years old
    d) Over 28 years old
5. What is your academic background?
    a) Business related
    b) IT related
    c) Art/Humanities related
    d) Others
6. Have you ever used similar web application software before?
    a) Yes
    b) No
7. How often do you use groupware?

(Never) 1, 2, 3, 4, 5 (Often)

8. How many times have you used Mobile Meeting?
9. How many times have you used Power Meeting?
10. What are, in your opinion, the most useful and the least useful features of both groupware?
11. What are, in your opinion, the most complicated and the least complicated features of both groupware?

A.3. Experiment Scripts (For Chair Participant)

<u>Scenario:</u>

An IT company is considering launching a new product, a wearable device, to the market. The company has developed two different devices, product A and product B. However; the company has a limited budget. Therefore it can launch just one of them. Your task, as a group, is to advise the company on which product to launch. You are the potential end consumers of the product. So you need to evaluate both choices basing your judgment on some key features that you chose, give a ranking of importance of these features and vote the products against these features. You need to submit your votes and at the end of the voting session you need to report the results to the company.

- Participant Id:
- Group id:
- Chair: yes

MobileMeeting Task Procedure

Setup Phase

1. Logging into MobileMeeting
   - Go to the link https://sites.google.com/site/meetinginbrowsers/ and click on the MobileMeeting link in the first paragraph of the Introduction; log in to MobileMeeting (if you use the first time, you need to register with the system before login)
2. Creating a New Session
   - Create a new session named “2015groupX”, where X is the number of your group given to you by the instructor, with password (groupX), and (tell) the session name and session password to your group members.

Decision Process

1. Using MCDA Feature

1.1 Brainstorming Alternative - Add the following two devices as alternatives – “Device A” and “Device B”. Then using the Controls Tab to proceed Brainstorming Criteria; Send a message to inform all the participant to proceed to brainstorm criteria phase (e.g. “start brainstorming criteria”);

1.2 Brainstorming Criteria – Input the criteria “Spec”. When all the 5 criteria listed below appear, proceed to the weighting criteria phase; Send a message to inform all the participant to proceed to the weighting phase (e.g. “rank the criteria”);

1.3 Weighting criteria – Where assign weights to each criterion. Spec – 3, Design – 4, Functionality – 5, User-friendly – 2, Reliability - 1. Waiting for a while for others to complete these, then proceed to Voting phase; Send a message to inform all the participant to proceed to the voting phase (e.g. “go voting”);

1.4 Voting stage – Input the following votes and then submits these votes. Send a message to inform all the participant to proceed to the reporting phase (e.g. “go to see results”);

Criteria	Device A	Device B
Spec	3	3
Design	3	4
Functionality	4	3
User friendly	3	2
Reliability	4	5

See if all five people have voted, then go to the next stage now- Reporting

1.5 Reporting – Note down the voting results by creating a summary.

2. Sign out of the application.

3. Fill out the questionnaires using your Participant ID, Group ID, and your Role

PowerMeeting Task Procedure

Setup Phase

1. Logging into PowerMeeting

- Go to the link https://sites.google.com/site/meetinginbrowsers/ and click the PowerMeeting link in the Demonstration panel on the left-hand side, and login to PowerMeeting (if this is the first time you use the system, you need to register with the system first) by selecting "New Session" create a new session, give the name "2015groupX", where X is the number of your group given to you by the instructor, with password (groupX), and (tell) the session name and session password to your group members.

- In the session, create an MCDA agenda item with name "Which Product to Launch" ; after that select "in meeting" and only then proceed.

Decision Process

1. Using MCDA Feature (please use the textual chat tool to inform the participants the progress from one phase to the next)

   1.1 Move to Alternative phase – by selecting "Alternatives" option, and then add the following two devices as alternatives –"Device A" and "Device B".

   1.2 Move to Criteria phase – by selecting "Criteria" option (radio button), enter the criteria "Spec". Wait for everyone to finish and keep checking your chat to confirm if everyone has input the respective criteria's.

   1.3 Proceed to the Weighting phase – assigning weights to each criterion. Spec – 3, Design – 4, Functionality – 5, User-friendly– 2, Reliability - 1. Click the calculate button.

   1.4 Move on to the Voting phase – Initialise first, input the following votes, and then submit these votes. When all the people in the group voted, clicking the "Calculate" button to generate the results.

Criteria	Device A	Device B
Spec	3	3
Design	3	4
Functionality	4	3
User friendly	3	2
Reliability	4	5

   1.5 Go to the Reporting.

   1.6 Note down the voting results by discussing it on the chat with the other participants.

2. Sign out of the application

3. Fill out the questionnaires using your Participant ID, Group ID, and your Role

A.4. **Experiment Scripts (For Participant 1)**

Scenario:

An IT company is considering launching a new product, a wearable device, to the market. The company has developed two different devices, product A and product B. However; the company has a limited budget. Therefore it can launch just one of them. Your task, as a group, is to advise the company on which product to launch. You are the potential end consumers of the product. So you need to evaluate both choices basing your judgment on some key features that you chose, give a ranking of importance of these features and vote the products against these features. You need to submit your votes and at the end of the voting session you need to report the results to the company.

- Participant Id:
- Group id:
- Chair: no

MobileMeeting Task Procedure

Setup Phase

1. Logging into MobileMeeting

- Go to the link https://sites.google.com/site/meetinginbrowsers/ and clicking on the MobileMeeting link in the first paragraph of the Introduction panel; log in to MobileMeeting (if you use the first time, you need to register with the system before login)
- Join the existing session using the session name '2015groupX', where X is the number of your group given by the instructor, and the session password is 'groupX.'

Decision Process

1. Using MCDA Feature

1.1 Ask the chair on group chat to input the two alternatives – "Alternative A" and "Alternative B".

1.2 Once you get a message from chair to proceed, enter Brainstorming Criteria phase – Input the criteria "Design". Inform the chair that you have done this step.

1.3 Weighting criteria – Where assign weights to each criterion. Spec – 3, Design – 4, Functionality – 5, User-friendly – 2, Reliability - 1. Submit your weights then go back to session space to see if the chair has sent any message;

1.4 In Voting phase-- Input the following votes and then submits these votes. Go back to session space and send the chair a message that you have done this step;

Criteria	Device A	Device B
Spec	3	5
Design	5	4
Functionality	2	2
User friendly	4	4
Reliability	3	3

1.5 In Reporting phase – inspect the result

1.6 Note down the voting results by discussing it on chat with the participants.

2. Sign out of the application

3. Fill out the questionnaires using your Participant ID, Group ID, and your Role

PowerMeeting Task Procedure

Setup Phase

1. Logging into PowerMeeting

- Go to the link https://sites.google.com/site/meetinginbrowsers/ and click the PowerMeeting link in the Demonstration panel on the left-hand side, and log in to PowerMeeting (if this is the first time you use the system, you need to register with the system first) by joining the existing session, using the session name '2015groupX', where X is the number of your group given by the instructor, and the session password is 'groupX'
- Inside the session, select the " Which Product to Launch" agenda item

Decision Process

1. Using Multi-Criteria Decision Analysis (please use the textual chat tool to communicate with the session chair and see what to do next)

1.1 Ask the chair on group chat to input the two alternatives – "Alternative A" and "Alternative B".

1.2 In the Criteria phase -- Enter the criteria "Design". Send a message once done on chat.

1.3 Proceed to the Weighting phase -- assigning weights to each criterion. Spec – 3, Design – 4, Functionality – 5, User-friendly– 2, Reliability – 1; and submit your votes. Go back to the messages and let the session chair know once the task is done.

1.4 In the Voting -- Input the following votes, and then submit these votes. Send a message once done to session chair.

Criteria	Device A	Device B
Spec	3	5
Design	5	4
Functionality	2	2
User friendly	4	4
Reliability	3	3

1.5 In the Reporting phase -- Note down the voting results by discussing it on chat with the participants.

2. Sign out of the application
3. Fill out the questionnaires using your Participant ID, Group ID, and your Role

A.5. Experiment Scripts (For Participant 2)

Scenario:

An IT company is considering launching a new product, a wearable device, to the market. The company has developed two different devices, product A and product B. However; the company has a limited budget. Therefore it can launch just one of them. Your task, as a group, is to advise the company on which product to launch. You are the potential end consumers of the product. So you need to evaluate both choices basing your judgment on some key features that you chose, give a ranking of importance of these features and vote the products against these features. You need to submit your votes and at the end of the voting session you need to report the results to the company.

- Participant Id:

- Group id:
- Chair: no

MobileMeeting Task Procedure

Setup Phase

1. Logging into MobileMeeting

- Go to the link https://sites.google.com/site/meetinginbrowsers/ and clicking on the MobileMeeting link in the first paragraph of the Introduction panel; log in to MobileMeeting (if you use the first time, you need to register with the system before login)
- Join the existing session using the session name ‘2015groupX’, where X is the number of your group given by the instructor, and the session password is ‘groupX’.

Decision Process

1. Using MCDA Feature

    1.1 Ask the chair on group chat to input the two alternatives – “Alternative A” and “Alternative B”.

    1.2 Once you get a message from chair to proceed, enter In Brainstorming Criteria phase – Input the criteria “Functionality”. Go back to session space to see if the chair has sent any message;

    1.3 Weighting criteria – Where assign weights to each criterion. Spec – 3, Design – 4, Functionality – 5, User-friendly – 2, Reliability - 1. Submit your weights then go back to session space to see if the chair has sent any message;

    1.4 In Voting phase-- Input the following votes and then submits these votes. Go back to session space and send the chair a message that you have done this step.

Criteria	Device A	Device B
Spec	4	3
Design	2	3
Functionality	3	5
User friendly	4	2
Reliability	2	4

    1.5 In reporting phase -- Note down the voting results by discussing it on chat with the participants.

2. Sign out of the application
3. Fill out the questionnaires using your Participant ID, Group ID, and your Role

PowerMeeting Task Procedure

Setup Phase

1. Logging into PowerMeeting

- Go to the link https://sites.google.com/site/meetinginbrowsers/ and click the PowerMeeting link in the Demonstration panel on the left-hand side, and log in to PowerMeeting (if this is the first time you use the system, you need to register with the system first) by joining the existing session, using the session name ‘2015groupX’, where X is the number of your group given by the instructor, and the session password is ‘groupX’

- Inside the session, select the " Which Product to Launch" agenda item

Decision Process

1. Using Multi-Criteria Decision Analysis

    1.1 Ask the chair on group chat to input the two alternatives – "Alternative A" and "Alternative B".

    1.2 Once you get a message from chair to proceed, enter In the Criteria phase -- Enter the criteria" Functionality".

    1.3 Proceed to the Weighting phase -- assigning weights to each criterion. Spec – 3, Design – 4, Functionality – 5, User-friendly– 2, Reliability – 1; and submit your votes.

    1.4 In the Voting -- Input the following votes, and then submit these votes. Go back to session space and send the chair a message that you have done this step;

Criteria	Device A	Device B
Spec	4	3
Design	2	3
Functionality	3	5
User friendly	4	2
Reliability	2	4

    1.5 In reporting phase -- Note down the voting results by discussing it on chat with the participants.

2. Sign out of the application

3. Fill out the questionnaires using your Participant ID, Group ID, and your Role