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EGE UNIVERSITY
Graduate School of Applied and Natural Science

AN EXPERIMENTAL STUDY ON MULTIPLAYER MOBILE GAMES FOR IN-GAME VOICE COMMUNICATION FEATURE

MSc THESIS

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Computer Engineering Department

İzmir
2019

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Computer Engineering Second Cycle Programme

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Ayham JARADAT tarafından **YÜKSEK LİSANS** tezi olarak sunulan "**An Experimental Study on Multiplayer Mobile Games for In-game Voice Communication Feature**" başlıklı bu çalışma EÜ Lisansüstü Eğitim ve Öğretim Yönetmeliği ile EÜ Fen Bilimleri Enstitüsü Eğitim ve Öğretim Yönergesi'nin ilgili hükümleri uyarınca tarafımızdan değerlendirilerek savunmaya değer bulunmuş ve 13.05.2019 tarihinde yapılan tez savunma sınavında aday oybirliği ile başarılı bulunmuştur.

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EGE ÜNİVERSİTESİ FEN BİLİMLERİ ENSTİTÜSÜ

ETİK KURALLARA UYGUNLUK BEYANI

EÜ Lisansüstü Eğitim ve Öğretim Yönetmeliğinin ilgili hükümleri uyarınca Yüksek Lisans Tezi olarak sunduğum "An Experimental Study on Multiplayer Mobile Games for In-game Voice Communication Feature" başlıklı bu tezin kendi çalışmam olduğunu, sunduğum tüm sonuç, doküman, bilgi ve belgeleri bizzat ve bu tez çalışması kapsamında elde ettiğimi, bu tez çalışmasıyla elde edilmeyen bütün bilgi ve yorumlara atıf yaptığımı ve bunları kaynaklar listesinde usulüne uygun olarak verdiğimi, tez çalışması ve yazımı sırasında patent ve telif haklarını ihlal edici bir davranışımın olmadığını, bu tezin herhangi bir bölümünü bu üniversite veya diğer bir üniversitede başka bir tez çalışması içinde sunmadığımı, bu tezin planlanmasından yazımına kadar bütün safhalarda bilimsel etik kurallarına uygun olarak davrandığımı ve aksinin ortaya çıkması durumunda her türlü yasal sonucu kabul edeceğimi beyan ederim.

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İmzası

Ayham JARADAT

ABSTRACT

AN EXPERIMENTAL STUDY ON MULTIPLAYER MOBILE GAMES FOR IN-GAME VOICE COMMUNICATION FEATURE

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MSc in Computer Engineering
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Real-time multiplayer mobile games are one of the most downloadable and successful trends of mobile games in the market. The interaction and communication between players during the game session is one of the main features that attract players and motivate them to play the game. Several PC and console multiplayer games started to integrate voice communication features in the game instead of or beside the traditional text-based communication tools. However, mobile games still use text-based communication tools, although voice communication has many benefits relative to text-based communication.

The purpose of this study is to implement a multiplayer mobile game that contains a voice communication feature and to explore the usability of voice communication feature in real-time multiplayer mobile games. The study uses the participants' reviews which were collected through several usability evaluation methods such as A/B testing, playtesting, interviews, and surveys. The obtained data is analyzed to find the best practices for implementing voice communication feature in a real-time multiplayer mobile game. The list of best practices can be used to help developers in designing and implementing voice communication systems that can positively contribute to the multiplayer mobile games experience. Moreover, the generated list of best practices can be used by usability evaluators to test and evaluate voice communication features in mobile games.

Keywords: Multiplayer mobile games, voice communication, voice chatting, usability evaluations.

ÖZET

OYUN İÇİ SESLİ İLETİŞİM ÖZELLİĞİ İÇİN ÇOK OYUNCULU MOBİL OYUNLAR ÜZERİNE DENEYSEL BİR ÇALIŞMA

JARADAT, Ayham

Yüksek Lisans Tezi, Bilgisayar Mühendisliği Anabilim Dali
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Gerçek zamanlı çok oyunculu mobil oyunlar, pazardaki mobil oyunların en indirilebilen ve başarılı trendlerinden biridir. Oyun oturumu sırasında oyuncular arasındaki etkileşim ve iletişim, oyuncuları cezbetmek ve oyunu oynamak için onları motive eden temel özelliklerden biridir. Birkaç PC ve konsol çok oyunculu oyun, geleneksel metin tabanlı iletişim araçlarının yanında veya yanında sesli iletişim özelliklerini oyuna entegre etmeye başladı. Bununla birlikte, mobil iletişim hala metin tabanlı iletişim araçlarını kullanmaktadır, ancak sesli iletişimin metin tabanlı iletişime göre birçok faydası vardır.

Bu çalışmanın amacı, bir sesli iletişim özelliği içeren ve gerçek zamanlı çok oyunculu mobil oyunlarda sesli iletişim özelliklerinin kullanılabilirliğini araştıran çok oyunculu bir mobil oyunun hayata geçirilmesidir. Çalışmada, katılımcıların A/B testi, oyun testi, röportajlar ve anketler gibi çeşitli kullanılabilirlik değerlendirme yöntemleri ile toplanan yorumları kullanıldı. Elde edilen veriler, gerçek zamanlı çok oyunculu bir mobil oyunda sesli iletişim özelliğini uygulamak için en iyi uygulamaları bulmak için analiz edilir. En iyi uygulamaların listesi, geliştiricilerin çok oyunculu mobil oyun deneyimlerine olumlu katkıda bulunabilecek sesli iletişim sistemlerinin tasarlanmasında ve uygulanmasında yardımcı olmak için kullanılabilir. Ayrıca, en iyi uygulamaların oluşturulan listesi, mobil oyunlarda sesli iletişim özelliklerini test etmek ve değerlendirmek için kullanılabilirlik değerlendiricileri tarafından kullanılabilir.

Anahtar Kelimeler: Çok oyunculu mobil oyunlar, sesli iletişim, sesli sohbet, kullanılabilirlik değerlendirmeleri.

PREFACE

Playing digital games is a well known hoppy for most young people. For me, as a computer engineer, this hoppy extended to become developing digital games. I had enough programming skills to develop mobile games. However, I did not have enough knowledge about usability. Two years ago, I got the chance to explore some aspects of the usability world when I took a relevant course in usability and human-computer interaction.

One of the best PC games I used to play is the Counter-Strike game. The beauty was not just in the game itself, but rather in the communication and interaction with the other players. Shouting and talking to my team members while playing the game were indescribable moments of joy. That's why I wanted to move this experience to a mobile game.

I started this thesis in the hope of searching and learning all of what it needs to build a mobile game that has the feature of in-game voice communication. I hope this thesis will make it easier and faster for developers and evaluators to create new exciting games that depend on the real-time voice communication between the players.

Ayham JARADAT

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1. INTRODUCTION

The mobile game market became the largest segment of the global gaming industry in 2017 (Newzoo Q2, 2017). The enhancements and advances achieved on mobile communication and smart-phone devices made it easier for developers to produce most kind of games that were only available as PC and console games. For example, real-time multiplayer mobile games are nowadays one of the most downloadable and successful types of mobile games in the market. The advance of technology is not the only factor that made this huge success of the mobile gaming industry, the creativity and new features that are added to mobile games participate in producing different games that attract the players and enhance their interaction with the game. Moreover, the variety of methods for evaluating game-play experience helped in producing good games that provide motivation and fun experience to the players (Nacke et al., 2010). However, there is still some less-focused features that can be added to the mobile games such as in-game voice communication between the players.

Voice communication between players can have many benefits relative to text-based communication for both gameplay and social experience in real-time multiplayer online games. Voice communication is faster than typing, it frees up hands for controlling character movement, and it improves communication and team coordination in real-time action games (Williams et al., 2007). These benefits are more noticeable in mobile games due to the physical characteristics of mobile devices. Although there are several online multiplayer games such as Second Life and Counter-Strike Source, that have integrated voice communications features to enable players to converse with each other (Wadley et al., 2005), most of the mobile games are still missing these features.

In multiplayer mobile games, voice communication between players during the game session is a great collaboration and interaction tool that adds more fun to the game playing experience. This is because players naturally prefer to communicate and talk with other players during a game, especially the games that depend on strategy building and planning in order to achieve victory. Moreover, the voice communication feature can help game designers and developers in creating new game trends that depend on the existence of the voice communication feature in the game where players must communicate with the other players in the game in order to win. In such games, each player sees a different partial view of the game world, and players in one team need to

communicate with each other in real time to help each other to see and recognize the full view of the game world. However, the voice communication system in multiplayer mobile games needs to be well designed and implemented both in functionality and usability perspectives in order to positively contribute to the multiplayer mobile games experience. Otherwise, the voice communication system will negatively affect the game experience and it might be a reason for players to reject the game.

The idea of voice communication in multiplayer mobile games is relatively new and very specific, there are currently no researches that have studied this particular feature in multiplayer mobile games context. However, there are several research that studied the usability heuristics and usability evaluation for online games. For example, Desurvire and Wiberg worked on refining a list of heuristics to evaluate playability for multiple of game genres and game deliveries. Their Heuristics of Playability (PLAY) list can be applied earlier in game development as well as aiding developers between formal usability research during the development cycle (Desurvire and Wiberg, 2009). Moreover, Pinelle et al. (2008) developed a set of heuristics that can be used to carry out usability inspections and evaluation of PC video games. Such Usability Heuristics can be helpful in avoiding common game usability problems, and in identifying game-specific usability problems which can easily be overlooked otherwise.

Some researchers focused on mobile games usability evaluations. The mobile devices have special physical characteristics (such as small size and limited control aspects), that need a more specific set of usability heuristics to be used as guidelines for designing and evaluating mobile games (Daud et al., 2016). Some researchers also worked on automating the process of conducting heuristic evaluation. For example, Soomro et al. (2013) designed and developed a playability heuristic evaluation system (PHES) to automate the process of conducting heuristics evaluation for mobile games. The system helps in inspecting more usability problems within time constraints and reducing manual efforts.

Multi-player games are an important type of mobile games. Currently, many digital mobile games are multi-player or have multi-player features. Korhonen and Koivisto (2007) introduced and described playability heuristics for mobile multi-player games that focus on the player-to-player interaction and competing between real players. They presented multi-player heuristics which correspond to usability issues addressed in multi-player mobile games. Furthermore, Simatic et

al. (2004) studied technical issues for mobile multiplayer games, such as communication middleware, latency, consistency, and databases with mobile phone limited resources.

Other researchers focused on the voice communication systems in multiplayer online games, for example, Gibbs et al. (2006) studied a novel voice-over-IP system designed to support player communication in online games by simulating in the game world the way utterances travel through the air in the physical world. They have found that the proximity-based constraints imposed by the voice communication system created some advantages for players in terms of their gameplay and their experience of the game as a social event. In the same manner, Carter et al. (2012) examined the design of a voice communication system and explained how its two configuration features (proximity and all-to-all) influences social interaction and gameplay by providing enjoyable gameplay experiences and user interactions. Other researchers worked on technical implementations schemes of voice communication in massively multiplayer online games. For example, Jiang and Chen (2007) proposed the concept of Area Of Interest (AOI) voice chatting, where a player can easily chat by voice with other players in his area of interest. The objective of this scheme was to improve the way players communicate with one another and to provide a more realistic virtual environment with reasonable end-to-end delay and affordable bandwidth consumption.

In this work, the focus is on the voice communication implementation and usability evaluation in mobile multiplayer games. It is important to explore voice communication feature in the context of real-time multiplayer mobile games, in order to provide developers with the best practices for implementing voice communication channels and to produce usability heuristics that can help evaluators to easily identify and detect usability problems related to the voice communication feature in mobile games.

The purpose of this research is to explore voice communication feature in real-time multiplayer mobile games -both in implementation and usability evaluation perspectives- and to derive a set of usability heuristics for evaluation voice communication features in multiplayer mobile games.

In order to achieve that, we developed the *Fire&Water* game, which is a simple Android multiplayer mobile game that includes voice communication

feature implementation. *Fire&Water* is a collaborative game which allows two players to play together in real time. Each player can see a partial view of the game world. So the players need to use the voice communication channel in the game to help each other winning the game.

We mainly used a qualitative approach to determine the best practices that can be used to implement and evaluate voice communication in real-time multiplayer mobile games. An iterative process of implementation and participants reviews analysis was used during the research. Several usability evaluation methods were used to obtain participants reviews about the voice communication feature. We used prototyping, A/B testing, playtesting, interviews, and surveys as evaluation methods.

The thesis is structured as follows: Chapter 2 gives a brief information and background about games and voice communication. Chapter 3 provides a detailed description of the game features and structure, as well as the implemented technical components. Chapter 4 provides a general overview of usability and its evaluation methods. Chapter 5 explains the performed usability evaluation and the obtained data. Chapter 6 presents a discussion and analysis of the usability evaluation results and in Chapter 7 we conclude and suggest future work.

2. BACKGROUND

This chapter presents a brief background information about games in general. Within this context, mobile games trends and types, multiplayer games and voice communication in multiplayer games are introduced.

2.1 General Overview of Mobile Games Industry

The days where gaming was just a simple way to spend time have gone a long time ago. Gaming now became a huge industry that cannot be ignored. The Global Games Market Report released by Newzoo on April 20, 2017, shows that 2.2 billion gamers across the globe are expected to generate $108.9 billion in game revenues in 2017 as shown in Figure 2.1. Mobile games with smart-phone and tablet revenues became the largest segment of the global market with $46.1 billion, covering 42% of the market (Newzoo Q2, 2017).

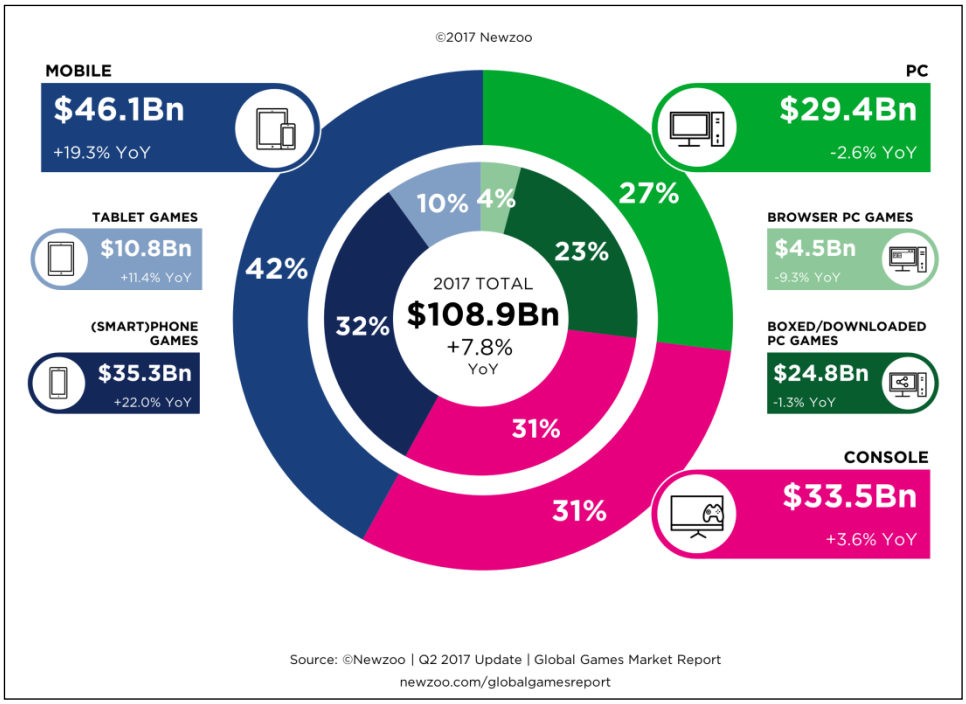


Figure 2.1 The 2017 global games market per device with year-on-year growth rates.

In more specific details for the mobile gaming market, in the first quarter of the 2017-18 year, there were 21.8 billion apps downloaded from Apple's App Store and Google Play Store. As shown in Figure 2.2, Google Play accounted for the majority of the downloads with 15.3 billion apps, leaving 6.5 billion downloads for App Store. Among these apps, games were by far the most downloaded type of app in both Google Play and the App Store. There were 6.64

billion downloaded games from Google Play, and 1.9 billion games from App Store (Sensor Tower, 2017). These games generated 75% of iOS App Store revenue, and 90% of Google Play revenue in 2016 (App Annie, 2017).

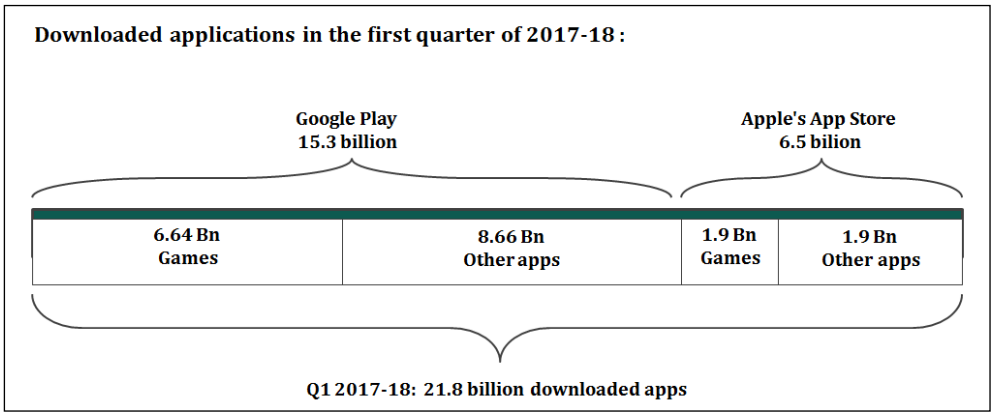


Figure 2.2 Numbers of downloaded applications in Q1 2017-18 per market and type.

2.2 Game Genres and Types

Games come in several trends based on the playability design and activities, examples of such trends are Strategy, Action, Puzzle, Casual/social, Sports, Card games and Role-playing games. Furthermore, the games types can be divided based on the number of players into two main categories: single player games and multiplayer games.

In single player games, input from only one player is expected throughout the course of the game session, these games could be games designed for only one player or they could be games played in the single-player mode. While multiplayer games include all the games that require more than one player to play the game. There are three main types of multiplayer games based on the game design as illustrated by Figure 2.3. The first and simplest one is Community-based competitive games, which are games that added some additional community features to already existing single player games such as high-score lists, tournaments, and chats. The second one is Turn-based games (slow-paced games), in these games players have to wait for their turn in order to play as in board games. The last and most complex type is Real-time games (fast-based games), in real-time games, players are free to play independently and the game is played in real time.

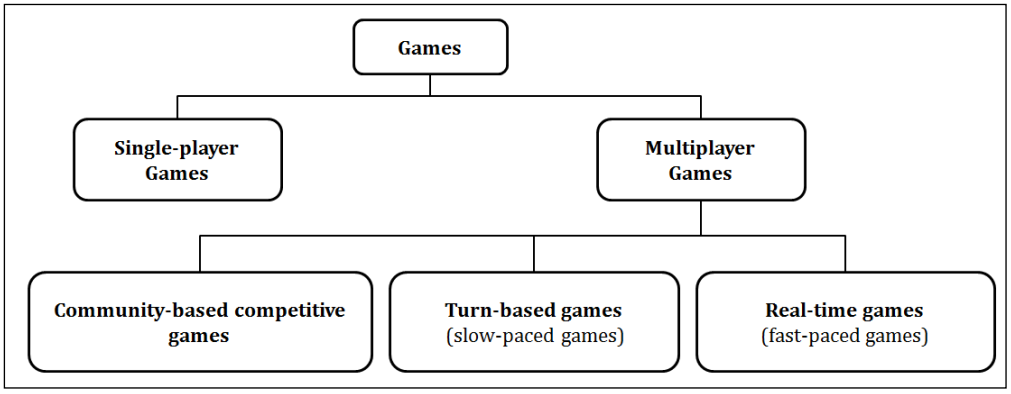


Figure 2.3 Game types based on number of player and design.

2.3 Mobile Games Design Issues

In order to design and implement a mobile game, it is very important to consider some issues related to mobile devices and other technologies behind multiplayer games. These issues are considered the factors that pave the way for success in terms of gaming experience and game quality. There are hundreds of different mobile devices available in the market. They differ in their size, shape, input methods, performance, and capabilities. Developers should consider these differences and prepare the game to work on most of these devices if not all of them. Moreover, mobile devices have constraints like small screens, limited input methods, orientation, and other main tasks to deal with. It is important that the developed game is able to work effectively across the different hardware designs and for all mobiles with older and advanced technologies. Another important issue to keep in mind is that the mobile has a limited battery, so developers should integrate some power-saving features into the game.

When designing for multiplayer games, another set of issues is added to the list, for example, developers should consider the different mobile networks that might be used by the game. Also, they should be familiar with the used network protocols and distribution topologies. Generally, developers should consider all the issues related to a sufficing player base, by keeping a low latency and high bandwidth. High latencies affect the players' views and consequently lead to a high degree of inconsistency and unfair advantages to some players. Moreover, the players should not have to wait in a lobby for other players for a long period of time. In some cases, developers should consider having a bot to fill the gap of other players. Developers should avoid unnecessary registration and long waiting time. Lastly, the game should be scalable regarding the number of players in the game (Badar and Nikhil, 2013).

2.4 Evaluation of Gameplay and Playability Experiences

Gameplay and playability are two frequently used concepts which do not have strict definitions. This section illustrates these two concepts and provides some methods that are used for evaluating the gameplay and playability experiences in a game. *Gameplay* is the gaming process created during the player-game interaction (Nacke and Lindley, 2008). In other words, gameplay is the model developed through the game rules, interaction with the player, challenges, and skills needed to overcome these challenges. Generally, the development process used to create the gameplay is based on four main modules (Ülger, 2013):

- The story of the game.
- The rules of the game.
- The graphical user interface (GUI) elements.
- The audio elements

In a similar manner, *Playability* determines the quality of a game, including the quality of user experience and how much fun, motivation and entertainment the game provides. Playability is defined as the degree to which a game is fun to play and usable, with an emphasis on the interaction style and plot-quality of the game. Sanchez et al. (2009) presented seven categories to measure playability, which are satisfaction, learnability, effectiveness, immersion, motivation, emotion and socialization.

Evaluating gameplay and playability experiences is a significant contribution to the success of any game. For game evaluation, classic usability testing is not sufficient, since its standard metrics (e.g., effectiveness in task completion or efficiency in error rate) are not directly applicable to all aspects of digital games. Traditional usability metrics are still relevant, but they need to be adapted to digital games and supplemented with a physiological and metrical assessment of gameplay experience. The digital game development process is usually iterative and product-focused. Thus, testing of game systems has classically been carried out by quality assurance groups with a focus on finding bugs in the software and has been synonymous with assuring technical quality of the digital game. Playtesting with user-focus on the player has long been performed with a high degree of informalism (e.g. recruiting testers from within the game development studio). These days playtesting adopt strategies from Human-Computer Interaction (HCI) and usability for developing inclusive player-game evaluation instrumentation.

There are three methodological categories for experiences that surround digital games:

- The quality of the product (game system experience),
- The quality of human-product interaction (individual player experience),
- The quality of this interaction in a given social, temporal, spatial or another context.

There are several approaches that can assess these three categories. For example, unit testing, stress testing, compatibility testing, and bug tracking are used to assess the game system experience. On the other hand, eye tracking, game metrics behavior assessment, qualitative interviews, and questionnaires are used to assess the individual player experience. Lastly, ethnography, cultural debugging, playability heuristics, and multiplayer game metrics can be used to assess the player context experience (Nacke et al., 2010).

The heuristic evaluation technique has been favored in a recent work on game evaluation because it is flexible, it does not make assumptions about task structure, and it can be used in either formal or informal inspections. In the heuristic evaluation, evaluators explore the interface while looking for problems based on a set of usability principles called heuristics. They look for instances where there is a mismatch between the principles and the design, and record mismatches when they are real usability problems (Soomro et al., 2013).

2.5 Voice Communication in Multiplayer Games

Traditional communication tool in multiplayer games is typing text messages. Voice communication technologies are considered as an alternative to text messages communication in multiplayer games. Voice communication between players can have many benefits relative to text-based communication for gameplay and social experience in fast-paced multiplayer online games. Voice communication systems need to be carefully designed in order to positively contribute to the gameplay and social experience of online multiplayer games (Halloran et al., 2004). Many players of multiplayer games have appropriated a variety of third-party Voice-over-IP (VoIP) applications so that they can talk with other players. Examples of such applications are: TeamSpeak, Ventrillo, Skype, Mumble and RogerWilco (Gibbs et al., 2006). Several online multiplayer games have integrated voice communications features that enable geographically-

distributed players to converse with one another. Examples of these games are Second Life, Counter-Strike Source, Microsoft's Xbox Live game network, Dungeons and Dragons Online (DDO), and Battlefield II (Wadley et al., 2005).

Voice communication in multiplayer games is a natural way for people to communicate. It is faster than typing, and does not interfere with the use of a keyboard or game controllers which frees up hands for controlling character movement or fighting (Carter et al., 2012). Moreover, voice communication can improve communication and team coordination in a fast-paced action game, which enhances the social experience of gameplay and introduces a new kind of social interaction to online gaming (Williams et al., 2007).

On the other hand, adding voice communication in multiplayer games faces lots of challenges that need to be considered. For example, voice transmissions, unlike text, can be received not just by those playing the game but by people co-located with players (in the real world) such as family members and co-workers. Conversely, sound from the player's surroundings can be transmitted into the game, leading to unintended breaches of privacy and other problems. Also, voice makes a player's gender, age, ethnicity, nationality, and education level clear, so some users may prefer not to use voice communication. Moreover, voice communication channels are easy to abuse, which may cause players to refuse to use voice with strangers (Wadley, 2007). On the technical side, voice transmission induces a high amount of network traffic, and mixing audio streams requires huge computational power. The data rates produced by a single voice channel can be a multiple of the entire game traffic (Triebel et al., 2009).

To recap, the usability and sociability of voice is situation dependent. Shared voice works best when used by a small group of players who already know each other prior to use, and are playing a fast-paced team game in which players must coordinate tactics efficiently. When too many people use one voice channel it is prone to congestion and confusion.

The implementation and configuration of voice communication in multiplayer games can differ from game to game based on the gameplay experience provided. There are several metaphors that are used for voice channel design in different games. The most famous two metaphors are "two-way radio" and " sound-in-air'" metaphors.

In “two-way radio” metaphor, utterances are broadcast to all other players (or all team members) and can be heard equally well by all recipients, irrespective of their in-game situation. This system operates as if the avatar of every player was carrying a walkie-talkie radio set. When one player speaks, all players who are tuned to the correct channel are able to hear. The ability to listen to another player is not affected by position within the game or any conditions other than having access to the channel being used as illustrated by Figure 2.4. Teams of players in first-person shooters such as Counter-strike can be understood as using a communication system that operates according to this metaphor (Gibbs et al., 2006). Games with built-in voice communication facilities such as Battlefield II and Dungeon and Dragons Online (DDO) can also be understood as implementing a similar voice communication metaphor. Voice systems configured to operate like two-way-radios are well suited to supporting the communication needs of small teams of players negotiating a large virtual space. The availability of channels allows communication to be restricted only to members of a team. The two-way radio is an efficient way to coordinate a small but geographically-dispersed group in real time (Triebel et al., 2009).

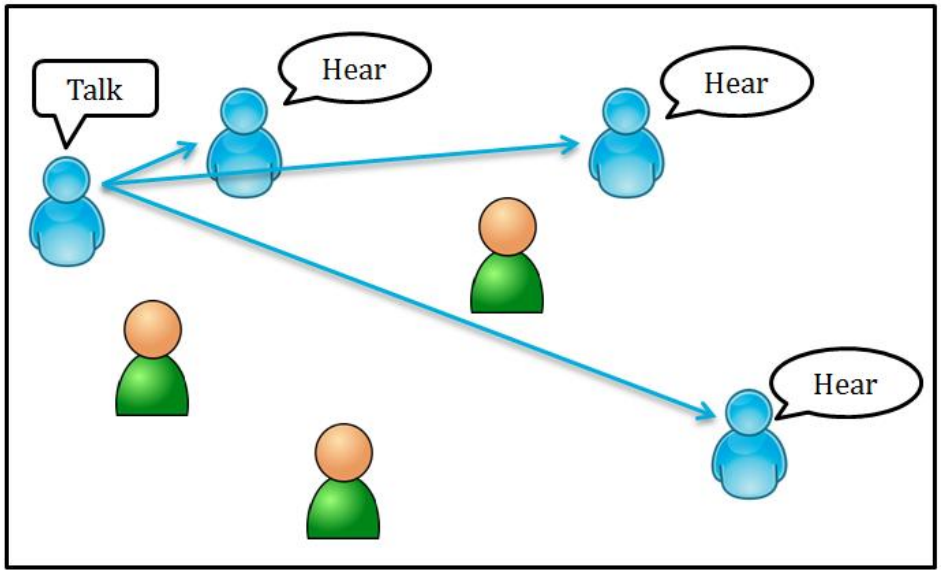


Figure 2.4 Two-way radio metaphor.

In "sound-in-air’" metaphor - which is also called "proximity voice" metaphor - transmission quality varies with the in-game location of player avatars by simulating the passage of sound through air. Player utterances are rendered so as to sound as though they are coming from the location of the speaker’s avatar, and players hear each other’s utterances with a volume and clarity related to the distance between their avatars in the game-world. In a similar way to the physical

world, when people engage in face-to-face conversations, their voices are carried from speaker to listener as sound waves traveling through the air. The volume and clarity of these transmissions are related to the distance between the speaker and the listener. A speaker can shout to be heard at a large distance and/or by a large number of people or can whisper close to someone's ear so as not to be overheard. Figure 2.5 illustrates the "sound-in-air" metaphor.

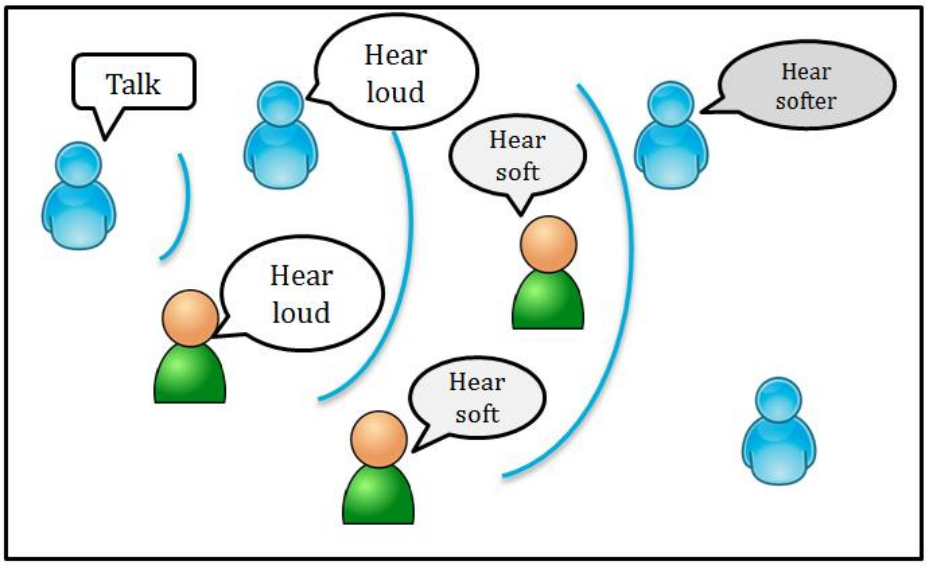


Figure 2.5 Sound-in-air metaphor.

Using this communication metaphor, only players whose avatars are close together in the game world can communicate with each other. Communication is unconstrained by team membership or channels. Problems may occur in massively multiplayer games when large groups of players collect within the same part of the game world. Example of games that integrated this metaphor is two team-based first-person shooter games: Counterstrike Source (CS) and Wolfenstein Enemy Territory (ET) (Gibbs et al., 2006). One of the most interesting side-effects of proximity voice in a game setting is that it allows voice communication between players on enemy teams (Carter et al., 2012). Proximity chat (using the metaphor of sound traveling in air) may be necessary where large numbers of players would clutter a shared radio channel. It may be preferable in a game where team members are normally close to each other (Triebel et al., 2009).

2.6 Voice Communication in Mobile Multiplayer Games

Mobile games usually have a simple game world. Most of the multiplayer mobile games allow a small limited number of players to play together in a simple environment. This is because of the mobile limitations such as small screen sizes

and limited input controls. This limitation on the players' number would make the voice communication feature more appropriate in multiplayer mobile games. A “two-way radio” metaphor can be implemented in mobile games easily. Moreover, it is guaranteed that every mobile phone comes with a built-in microphone and speaker, so there is no need for the players to worry about connecting external devices to their mobiles in order to play a game that includes voice communication feature. There are lots of mobile games out there in the market which makes it a very competitive and challenging task to create a new successful game. However, with voice communication feature developers and game creators will be able to produce new trends and ideas for games that depend on the voice chatting existence in the game.

3. A MULTIPLAYER GAME IMPLEMENTATION: *FIRE&WATER*

In order to study the voice communication feature in a multiplayer mobile game, we built an experimental game called "*Fire&Water*". It is a real-time multiplayer mobile game designed and implemented on Android platform. Since our goal is to explore the voice communication feature, we opt for a simple game environment that allows two players to play in real time in a collaborative way to win the game. The game provides a voice channel between the two players to be used while playing the game. In this section, we introduce the game features, characters, architecture and rules in details, followed by a description of involved technical components.

3.1 General Features of *Fire&Water* Game

Fire&Water is a real-time multiplayer mobile game that works on Android mobile devices. It is a casual and social game where two players collaborate with each other using the voice communication channel to win each level of the game. The game contains two main characters, named as *Fire* and *Water* characters. The two main characters are positioned on the bottom of the screen and can move only in horizontal directions (towards right or left). Each one of these two characters is controlled by a player. The game also contains two types of secondary characters, these are *fire-flames* and *water-drops* characters. These characters appear initially on the top of the screen in random positions. They move in a vertical direction from top to bottom in a falling down animation view. The movement of these secondary characters is controlled by the game engine, meaning that players have no control over them.

Each type of secondary characters can harm and kill one of the main characters if they collide with them. More specifically, the *fire-flame* secondary character should not collide with the *Water* character while falling down from top to bottom. In the same manner, the *water-drop* secondary character should not collide with the *Fire* character while falling down. For the two players to win the game, they should survive three minutes by controlling the movement of the main characters in a way that avoids collisions with falling down secondary characters. If at least one of the two main characters is hit by a falling enemy character twice, the game ends and both players lose the game level. Figure 3.1 shows the main playing screen of the *Fire&Water* game.

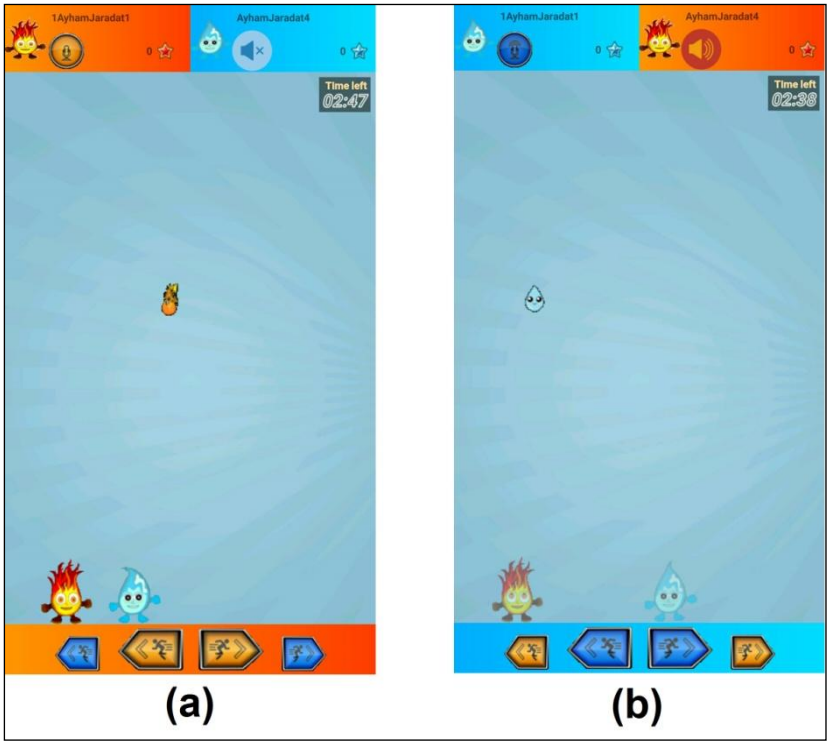


Figure 3.1 *Fire&Water* main game views (a) fire player view, (b) water player view.

In order to encourage the two players to use the voice channel, collaboration between the two players is necessary in order to win. This is achieved by giving each player a partial view of the game world. The fire player who controls the *Fire* character can only see the *fire-flames* secondary characters, and the water player who controls the *Water* character can only see the *water-drops* secondary characters. In this formalization, each player can only see the secondary characters that do not harm his main character. Each player must communicate with the other player to find out how to move his character. For example, water player must tell fire player to move away once a *water-drop* is coming towards the *Fire* character. Similarly, fire player must tell water player to move away once a *fire-flame* is coming towards the *Water* character. This means that each player must help the other player by telling him in which direction to go, and at the same time, each player must listen to the other player to know where to move his own character.

The collaboration between the two players can be accomplished by two ways:

1. Using the voice channel, where the two players speak with each other using the voice communication channel.
2. Sending visual messages, in this approach a player presses a button to immediately send a visual message that appears on the other

player screen indicating him to move his character to the right or to the left direction.

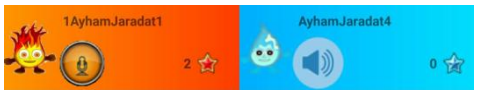
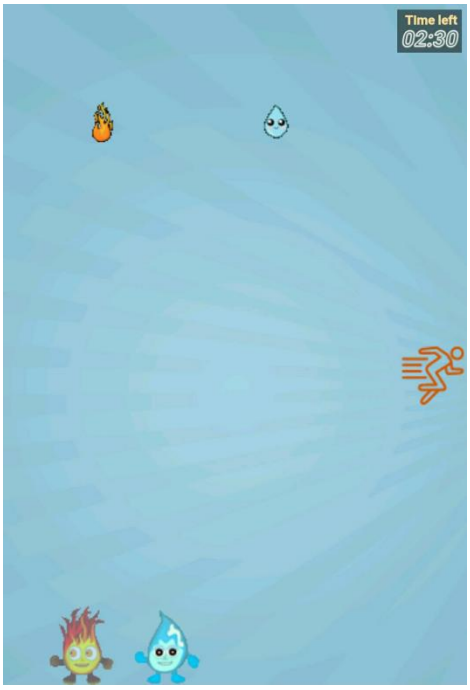
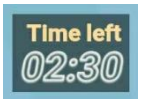
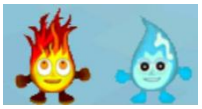
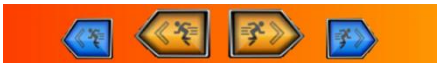
Both of the two collaboration ways can be used at the same time.

The game playing view is divided into three sections:

1. Top section:
   The top section contains the players' characters, names, scores and voice control buttons that allow the player to activate or deactivate the microphone and to mute or un-mute the voice of the other player.
2. Middle section:
   The middle section shows the game canvas where the main and secondary characters move and interact with each other.
3. Bottom sections:
   The bottom section contains the movement buttons of the main character of each player, as well as the buttons to send visual messages to the other player.

Table 3.1 provides more details about each component of the game playing view.

Table 3.1 Gameplay view components.

Section	Component image	Description
Top section		Shows information about the two players, their names, the characters they control, the score they got, and buttons to control the voice channel.
Middle section		Shows the game characters interaction canvas with the following: 1.The Timer  2. *Water* and *Fire* characters  3. *water-drop* and *fire-flame* characters  4. visual message 
Bottom section		Contains the buttons to control the main character and the buttons to send visual messages.

The main characteristic of the game can be summarized as the high dependability on the communication and collaboration between the two players. It is almost impossible to win the game without this communication between the two players. This design of the game makes the voice usage an important feature that enhances the playability experience.

3.2 Game Structure

The game is developed from scratch as a native Android game. For simplicity, the structure of the game code can be divided into four main modules:

1. The game main activity.
2. The characters.
3. The surface view.
4. The game loop thread.

The relation between these four modules is illustrated in Figure 3.2.

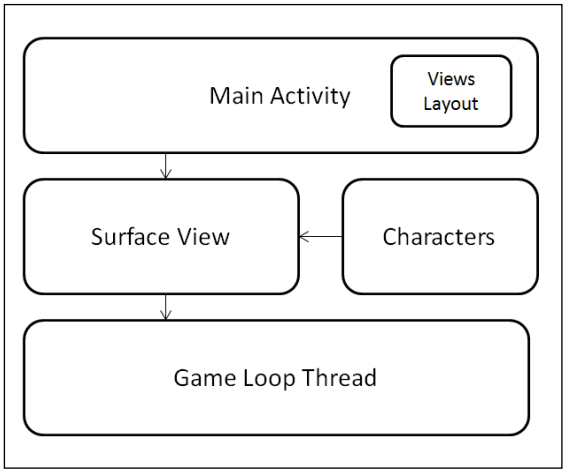


Figure 3.2 *Fire&Water* game modules.

3.2.1 The game main activity and views

The game has one Android activity which is responsible for the game views rendering and navigation, as well as listening and handling for the player inputs and controls. The main activity is connected to a relative layout file which contains all the game views. The navigation logic between the game views is done in the main activity by hiding all the views and showing only the required current view. The game has three main views: The game landing view, the gameplay view, and the waiting view.

The game landing view is the first view that appears when the game is started. As seen in Figure 3.3, this view contains the game main menu that gives the player the following options:

1. **Sign-in or sign-out**: The player is required to sign-in to be able to use the Google Play Games services which are responsible for the multiplayer features.
2. **Choose a playing mode**: The game can be played in two different modes, single-player and multiplayer mode. In single-player mode, the player can play the game alone by controlling both of the main characters. The single-player mode allows the player to get

familiar with the game rules and characters before playing with others. In the multiplayer mode, two players play the game together at the same time. The multiplayer mode is the mode that includes the voice communication feature. The game main menu allows the player to select single player mode, multiplayer mode with a chosen friend or multiplayer mode with a random player.

3. **Check for game playing invitations**: The player can select this option to see if there are any game playing invitations from his friends.
4. **Leaderboard and achievements:** The player can see the public leaderboard in order to compare his score with other players and to see the top players scores. Also, the player can view the list of his accomplished achievements.
5. **Voice usage forms' settings**: The player can select the form of voice usage that he wants to use while performing the play-testing session. The settings button will open a dialog with the implemented voice usage forms' options.

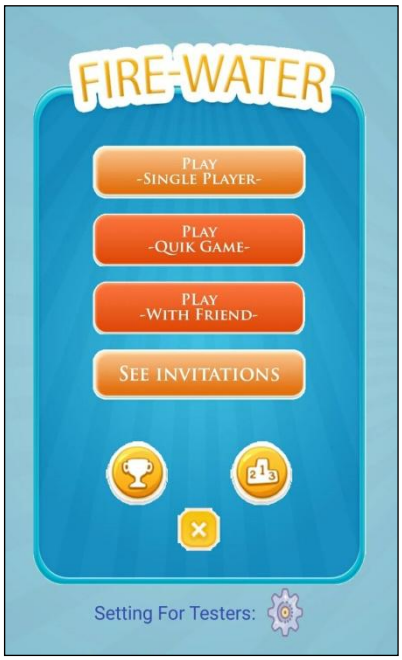


Figure 3.3 The game landing view.

The game playing view is the playing canvas where the characters move and interact with each other. This view is shown when the game session starts. In multiplayer mode, the view colors present the main player character. For example, water player view is given a blue border color and fire player view is given an orange border color. Also, a dialog containing the player main character appears

at the center of the view for a few seconds before the game is started as seen in Figure 3.4(a). Moreover, the game playing view shows the game time, the players' current scores and the players' names.

The last view is the game waiting view, this is a simple view that contains a spinner and the main characters' icons as seen in Figure 3.4 (b). It is used while switching between game views and when waiting for Google Play services responses.

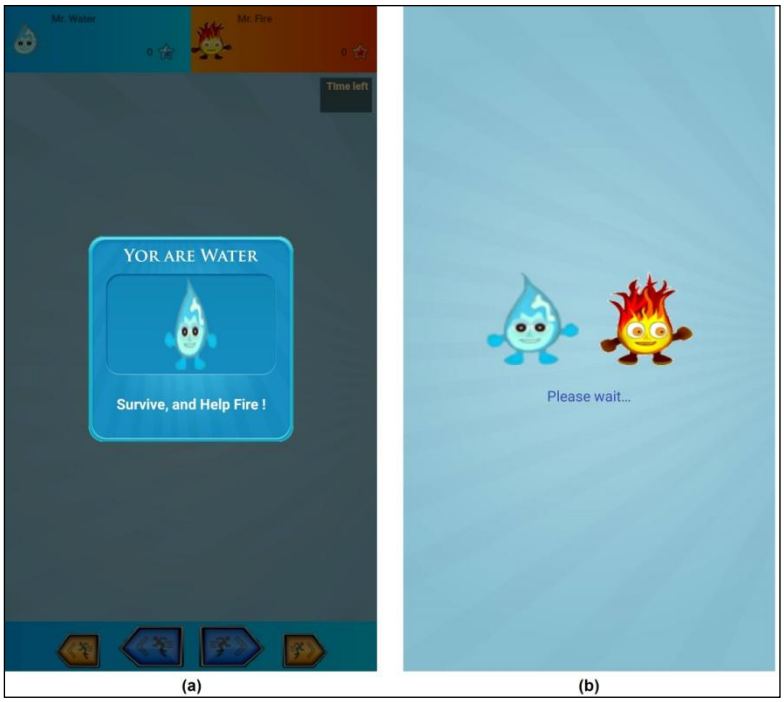


Figure 3.4 Different game views (a) gameplay view, (b) waiting view.

3.2.2 The game characters

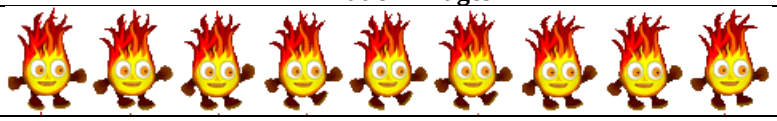
The game contains three different types of characters which have different moving behaviors. These three types are:

1. The main characters (*Fire* and *Water* characters).
2. The falling-down characters (*water-drops* and *fire-flames*).
3. The collision effects characters (explosion and rotating star characters).

The main characters can move only in a horizontal direction at the bottom of the playing canvas. They collide with falling-down characters and cause an explosion or rotating star animation based on the type of the falling-down character.

Each type of the characters has a special animation to represent its moving style. The animation is done by changing the character images throughout a list of small images that differ a little bit in their locations and positions as seen in Table 3.2.

Table 3.2 Animation images of the game characters.

Characters	Animation Images
Fire character moving to the right direction.	
Water character moving to the left direction.	
Falling-down characters (*fire-flames* and *water-drops*)	
Explosion effect (*Water* collides with *fire-flame* character)	
Explosion effect (*Fire* collides with *water-drop* character)	
Rotating star characters.	
Fire-flame hitting the ground effect.	
Water-drop hitting the ground effect.	
Visual messages animation.	

3.2.3 The surface view and the game loop thread

Drawing images on the UI thread puts an upper limit on how long or complex the drawing operations can be. For this reason, we moved the characters drawing work to a different thread using an Android *SurfaceView*. *SurfaceView* is a view that provides a dedicated drawing surface embedded inside of a view

hierarchy. All of the characters referencing, drawing and updating are managed by the surface view class. The surface view updates its content and redraws them in a periodic time managed by the game loop thread. The game loop thread intents to decouple the progression of the game time from user input and processor speed. The game loop thread runs the game at a consistent speed despite differences in the underlying hardware. The game loop thread runs continuously during gameplay. The game loop thread is responsible for:

- Processing user input without blocking the drawing process.
- Updating the game state, including the positions of the characters.
- Rendering the game view.
- Tracking the passage of time to control the rate of the gameplay.

3.3 Technical Components

The game uses two main components:

- Google Play Games Services for managing multiplayer infrastructure.
- WebRTC for managing voice communication channel.

A brief overview of these two components is given in this section.

3.3.1 Google play games services

Google Play Games services provide a range of ready to use features with frontend and backend implementations that can be added to games using a simple API. It includes popular game features, such as achievements, leaderboards, real-time multiplayer, and more. The services help in automating the game production and distribution tasks.

The *Fire&Water* game uses the real-time multiplayer API from Google Play Games services to connect multiple players together in a single game session and transfer data messages between connected players. Real-time multiplayer API handles the following tasks:

1. Manages network connections to create and maintain a real-time multiplayer room (a virtual construct that enables network communication between multiple players in the same game session and allows players to send data directly to one another).

2. Provides a player selection user interface (UI) to invite players to join a room, look for random players for auto-matching, or a combination of both.
3. Stores participant and room state information on the servers of the Google Play Game services during the lifecycle of the real-time multiplayer game.
4. Sends room invitations and updates to players. Notifications appear on all devices on which the player is logged in (unless disabled).

The real-time multiplayer game basics that are covered in Google Play Game Services are: room initialization, room configuration, participants, auto-matching, connected set, in-game networking, invitations, gameplay, sending game data and room closure.

The room sets up a peer-to-peer mesh network between participants where clients can communicate directly with each other. The device user must be signed in to the game to be able to initiate a real-time multiplayer game session on a device. Players can choose to invite specific people or have Google Play Games services automatically select other participants randomly via auto-matching. They can also request a mix of the two. Google Play Games Services can be used to broadcast data to participants in a room or allow participants to exchange messages with each other. Data messages can be sent using a reliable or unreliable messaging protocol provided by Google Play Games Services. In order to implement a real-time multiplayer game using the Google Play Games Services in an Android game, the game must be registered in the Google Play Console, and real-time multiplayer support is enabled (Google Play Game Service, 2017).

3.3.2 Voice communication implementation

Voice communication can be implemented in several ways for mobile applications. In this project, we needed a fast implementation that allows voice communications through wireless networks such as Wi-Fi. We searched for all possible solutions that can provide us with a “two-way radio” metaphor implementation of voice communication. The first approach we tried is to build the voice communication components from scratch, including audio recording and playing, audio coding and data transmission. Using Java low-level audio API, we could record and playback un-encoded audio waveforms represented in pulse-code modulation (PCM) format. The characteristics of the recorded audio we used

are: 8 KHz sampling frequency, 16 bits per sample and a single channel. For audio data transition, we used the Google Play Games services to exchange audio messages between the two players. Although it seemed a good idea to benefit from the Google Play Game services to exchange the audio messages, we could not get an acceptable performance regarding sound latency and sound quality. It also affected the game data message exchanging, and produced a very poor performance during the game playing. For this reason, we tried to find existing open source libraries to handle the voice communication feature. Among the available libraries, we used the WebRTC project which is explained in the next section.

3.3.3 WebRTC

WebRTC is a free, open source project that provides browsers and mobile applications with Real-Time Communications (RTC) capabilities via simple APIs. WebRTC enables rich, high-quality RTC applications to be developed for the browser, mobile platforms, and IoT devices, and allow them all to communicate via a common set of protocols. The WebRTC basic scheme includes media capture, encoding and decoding audio and video, transportation layer, and session management. Figure 3.5 shows the WebRTC basic scheme.

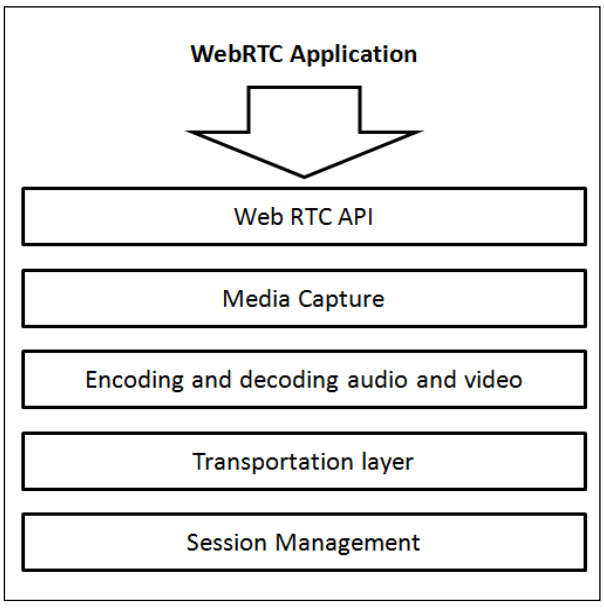


Figure 3.5 WebRTC basic scheme.

WebRTC provides the functionality that allows peers to share media between them using the peer-to-peer connection which is known as RTCPeerConnection, it also needs a mechanism to coordinate communication

and to send control messages, a process known as signaling. Peers use the signaling process to connect to each other by exchanging their connection data before the session is started. Signaling process needs a server that knows the peers involved in the exchange information (Johnston and Burnett, 2014).

The signaling process steps are the following: A local peer set its session description as its local description. Then it creates an offer with its session description and sends that information to the other peer through the server. The information sent contains the type of the message, that in this case will be the offer and the SDP. This SDP is a message where the peer says what they want to receive (video and audio) and much other technical stuff. The second peer will receive this information and on realizing that is an offer request, it will store the session description information that just arrived as a remote description. Then it will create an answer to the offer received. Once the answer is created, it will store locally its session description and will send this description back to the first peer. As the local peer receives the answer, it will store the session description that arrived as a remote description. After doing that, they can connect to each other using the stream they have exchanged during the process. Both peers will exchange its Ice Candidates, that contains the information they both need to connect to each other. After this step, the connection should be set and running, so they can exchange media. Figure 3.6 shows the signaling process diagram.

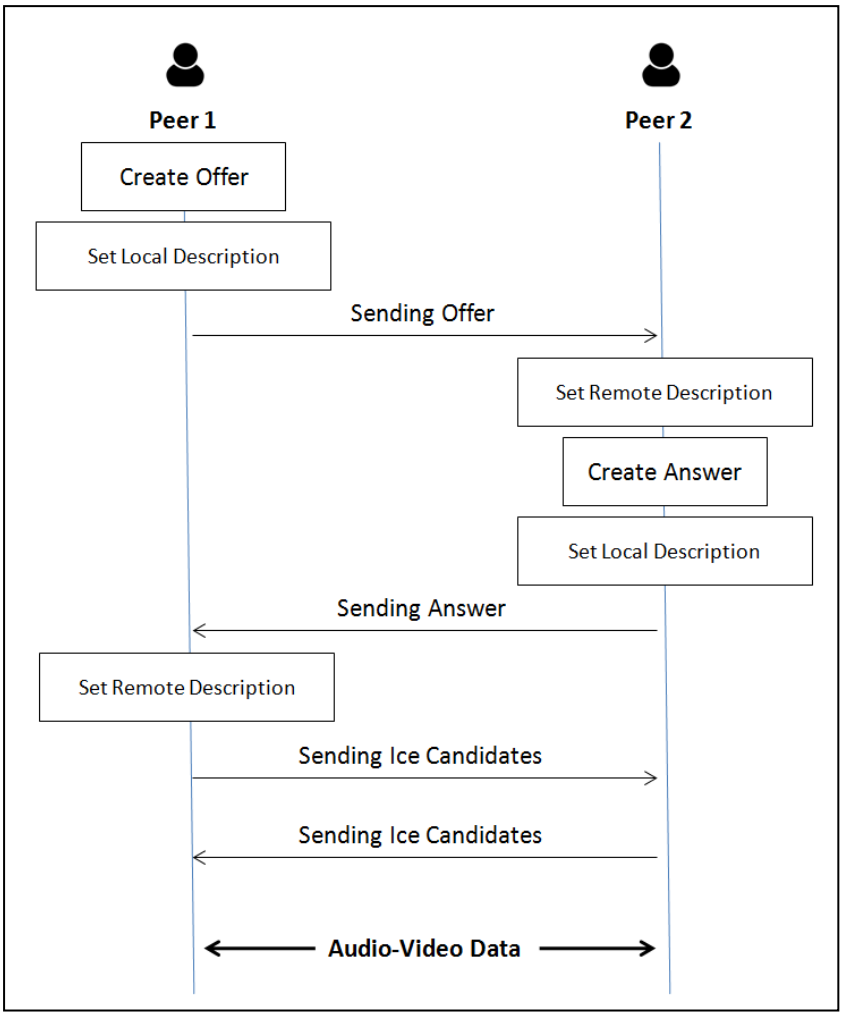


Figure 3.6 The signaling process.

WebRTC is designed to work as peer-to-peer, so users can connect by the most direct route possible. However, WebRTC is built to cope with real-world networking: client applications need to traverse NAT gateways and firewalls. Also, peer to peer networking needs fallbacks in case direct connection fails. As part of this process, the WebRTC APIs use STUN servers to get the IP address of a device, and TURN servers to function as relay servers in case peer-to-peer communication fails.

Most connections work behind a firewall so the connection will be refused. To make the connection possible, STUN server is used to get the direction of the peer on the other side of the connection. To do so, the direction of the STUN server is set as Ice Server in the peers so they will communicate with the server in case they cannot make the connection. When the peers' security is higher, a TURN server is needed to make the connection possible. The difference between a STUN server and a TURN one is that the STUN server will only help in getting

the information to connect to the other end of the conversation and once this process is done, the peers can talk with each other without the need of a server in the middle. Whereas the TURN server will act as an intermediary peer between the two peers that are talking. The peers will send the media to the TURN server and it will manage to send it to the other peers.

3.4 Voice Communication Implementation

Voice channel implementation can be performed in several forms based on how it is going to be used. In this section, we provide and discuss some ideas and forms that can be used to implement the voice communication feature in a multiplayer mobile game. Figure 3.7 illustrates the three different voice communication forms.

3.4.1 Open voice call

In this form, an open voice channel is opened between the two players all the time during a game session. Both players are able to speak and listen to each other simultaneously just like a regular phone call. Each player has the ability to activate or deactivate his microphone, as well as the ability to mute or un-mute the voice of the other player.

As an advantage of this form, a player will have a full connection with the other player all the time, which can increase the interaction and collaboration between the two players. Moreover, a minimum actions' set is required for voice channel control, as there is no need to press or hold a button to communicate with the other player. This behavior allows the players to focus on the game playing. However, with this implementation, the voice channel puts more traffic on the network.

3.4.2 Push to talk

In this form, the voice is not transmitted to the other player unless when the microphone button is pressed. The player needs to press and hold the microphone button to send voice messages to the other player. The behavior of this form is similar to "walkie-talkie" use. Each player has the ability to mute or un-mute the voice of the other player. The microphone of each player is set to the deactivated

mode by default and changes to active mode while the microphone button is pushed.

This form enhances the network traffic as the voice is sent only on demand. It might also be a preferred option for players who do not want to share their voices with the other player all the time during the game session. However, the player needs to put more effort on the voice chatting feature as he must press and hold a button whenever he wants to send voice messages to the other player, this operation causes less focus on the gameplay.

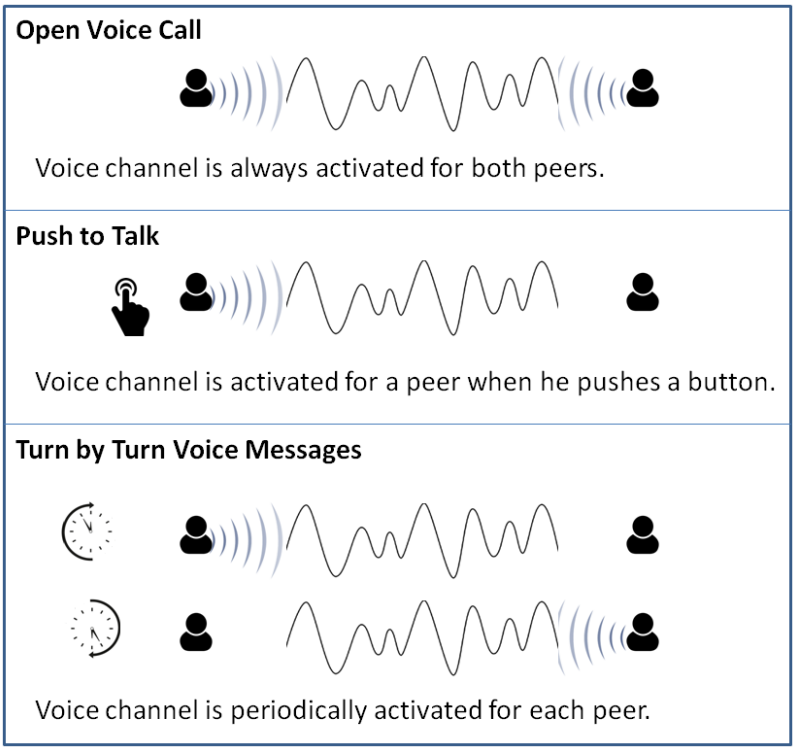


Figure 3.7 Voice communication implementation forms.

3.4.3 Turn by turn voice messages

In this form, each player has his turn to send voice message dynamically without pressing any button. The game itself turns the microphone on and off for each player in turns. The UI indicates the player when its microphone in on. It is an appropriate form for two players games, as the voice channel is split equally in time between the two players.

This form enhances the network traffic and at the same time gives the player full focus on the game playing as there is no need to worry about pressing a button whenever a player wants to send voice messages. However, the usefulness of the

voice channel is questionable, and it depends highly on the game logic. Because the microphone could be deactivated when the player needs it in a certain period of time during the game session.

These three different forms of voice implementation depend mostly on the game logic and the need for voice communication during the game. In our game (*Fire&Water*), first two forms are preferable than the third one, because the game depends heavily on voice communication between the two players and turn by turn voice communication will not be suitable for such a game. So we implemented only the first two forms (Open-voice-call and Push-to-talk) beside the non-voice communication form named as visual messages.

The visual messages communication form is a simple way for players to communicate without using a voice channel. It consists of prepared visual messages that a player can send to another player by pressing a button. The messages appear on the other player screen immediately as a moving animation to the required direction as sent by the first player.

4. USABILITY OVERVIEW

Usability refers to the ease of access and use of a product or website. Usability is a sub-discipline of user experience design (UX design) which replaced the outmoded label “user-friendly” in the early 1990s. The official ISO 9241-11 definition of usability is:

> “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use with a minimum of errors.”

Usability is a narrower concept than user experience since it only focuses on goal achievement when using a product. By contrast, user experience encompasses all aspects of the end user's interaction with the company, its services, and its products. User experience refers to a person's subjective feeling and attitudes about using a particular product. This essentially means that user experience includes aspects such as human factors, design, ergonomics, HCI, accessibility, marketing as well as usability.

Usability is not a single, one-dimensional property of a user interface, but it has multiple components and is traditionally associated with the five usability attributes: Learnability, efficiency, memorability, errors, and satisfaction. Usability is an important quality indicator for an interactive product. It refers to the degree to which products are effective, easy to use, easy to learn, efficient, fewer errors and satisfying to users. Generally, a usable interface should be easy for the user to become familiar with and competent in using it during the first contact. Also, it should be easy for users to achieve their objective through using the software. Moreover, it should be easy to recall the user interface and how to use it on subsequent visits.

When it comes to evaluating the quality of a software product, usability is considered one of the most important quality attributes in software architecture. This is because users can see directly how well the usability attribute of the system is worked out. Moreover, usability plays an important role in all quality perspectives of a product. For example, usability is used in recognizing the quality of a software product, in determining if the product is fit for purpose, and in affecting the value that the user will be willing to pay for a usable –or less usable– product (Xenos, 2001). Usability is one of the main quality characteristics of the

ISO 9126, which is an international standard for the evaluation of software. The ISO 9126 software quality model identifies 6 main quality characteristics:

- Functionality
- Efficiency
- Reliability
- Maintainability
- Usability
- Portability

These characteristics are broken down into sub-characteristics, For example, the usability sub-characteristics are (Bevan, 1997):

1. **Understandability:** Determines the ease of which the system's functions can be understood, relates to user mental models in Human-Computer Interaction methods.
2. **Learnability:** Learning effort for different users such as novice, expert and casual users.
3. **Operability:** The ability of the software to be easily operated by a given user in a given environment.

4.1 Importance of Usability

Usability provides great benefits for both systems and users at the same time. For example, usable systems lead to a competitive advantage, enhanced reputation, and loyal customers. Moreover, usability is very important for users because it leads to efficiency, increased productivity, job satisfaction and improved quality of life. Products that satisfy usability requirements make users feel more convenient, and comfortable after using the product, and also reduces wrong operations made by users. Obviously, it will arouse a good emotional experience and make the user feel happy and enjoyable, then it will improve the user experience design of the product.

The key point of achieving a high usability is iteration design. To optimize the design gradually by evaluation from the early stages, and the evaluation process enables designers and developers to gather users feedback until the system reaches an acceptable level of usability. The perfect way to ensure usability is to test the actual users on the working system. Achieving high usability requires the design work to focus on the end users of the system.

4.2 Usability Evaluation Methods

Usability evaluation focuses on how well users can learn and use a product to achieve their goals, It also refers to how satisfied users are with that process. To gather this information, practitioners use a variety of methods that gather feedback from users about an existing product. During usability testing, users of a product

are asked to perform certain tasks in an effort to measure the product's ease-of-use, task time, and the user's perception of the experience. Usability testing can be done formally, in a usability lab with video cameras, or informally, with paper mock-ups of an application or website. Changes are made to the application or site based on the findings of the usability tests. Whether the test is formal or informal, usability test participants are encouraged to think aloud and voice their every opinion. Usability testing is best used in conjunction with user-centered design, a method by which a product is designed according to the needs and specifications of users.

Usability plays a role in each stage of the design process, from wireframes to prototypes to the final deliverable. There are several methods that can be used to evaluate usability throughout the life cycle of a product:

1. Card Sorting:

Card sorting is a useful tool to determine how users categorize the information that will appear on a website. It is helpful at the early stage of creating a site and later on while optimizing the architecture of a site. In a card sorting session, participants organize topics into categories. The main goal is to establish how users perceive the hierarchy of elements. The study usually involves 5-15 participants with 30-40 cards. The results of a card sort session may be used to develop an application or website's information architecture (Traczyk, 2016).

There are two types of card sorting:

- Open Card Sort:

In an open card sort session, participants are given a stack of cards and are asked to organize and group them together as it makes sense to them. Then they are asked to name each group they created in a way that they feel accurately describes the content. Open card sort shows how users group the content and the terms or labels they give to each category. This method is useful while creating new websites or applications.

- Closed Card Sort or Tree Sort:

In a closed card sort session, participants are asked to sort cards into pre-defined categories. The main categories used in the study are pre-defined and cannot be changed. This method works best when adding new content to an already existing website.

2. Paper Prototyping:

Paper prototyping is an early-stage testing method that uses paper models to simulate an interface which is evaluated by a user. It is used to verify first interfaces and it can be used for testing a complete user workflow in a wireframe or a fully designed portion of a product before it goes into development. Prototype testing will assist in fixing usability issues before development engineering begins. Also, it facilitates discovering functional errors in a system without focusing on the layout of a product (Stumpf, 2018).

3. User Testing:

User testing - known also as usability testing- requires having real people use an application to see how well it functions from a nonbiased and unfamiliar perspective. This method is used to evaluate a product or a service by testing it with representative users. Typically, during a test, participants will try to complete typical tasks while observers watch, listen and take notes. The goal is to identify any usability problems, collect qualitative and quantitative data and determine the participant's satisfaction with the product. To run an effective usability test, a researcher needs to develop a solid test plan, recruit participants, and then analyze and report the findings (Babich, 2017).

Usability testing is the best way to understand how real users experience a website or an application. It's also flexible for collecting a range of information about users, and it's easy to combine with other testing techniques. Live communication with test participants is a strength of this type of testing, because nothing beats watching participants in real time, and being able to ask probing questions about what they are doing. Moreover, watching how real people use and interact with software is highly beneficial to understanding user stories and insights. Usability testing should be conducted at various times throughout the iterative design process to ensure that all usability requirements have been met in the final product.

4. Usability Lab Testing:

In usability lab testing, a testing session takes place in a prepared lab where users follow pre-defined scenarios. Usually, the prepared lab is a room divided into two parts by a one-way mirror, participant of the study are in one part of the room while observers are in the second part. This type of testing is used to

discover user experience problems and functional issues in a product. Usability lab tests are typically performed in greater depth than tests conducted with random or casually recruited participants, and with more emphasis on documentation such as video and audio recording, screen capturing, heat maps, and task timing (Traczyk, 2016).

5. Focus Groups:

A focus group test is a moderated discussion between a researcher and users. A moderator facilitates a small group of 4 to 8 participants by demonstrating or showing them a product or concept. The participants are encouraged to freely give their honest opinions about the product, including suggestions to make it better. The study aims at engaging participants in a discussion to confront their opinions, uncover their attitudes, emotions, and motivations (Babich, 2017). Focus groups can be a powerful tool in system development. This technique reveals user needs and feelings both before a product's design and long after its release. In website or mobile app development, the proper role of focus groups is not to assess design usability, but to discover what users want from a product, their personal thoughts, and preferences.

6. A/B Testing:

An A/B test is an appropriate testing method to determine which of two alternatives for a product is better. In this test, two versions of one product (version A and version B) are tested over a period of time. Then data is collected on their performance. The collected data can be based on the time on page, bounce rate, or conversion rate. The best version can be selected by reviewing analytics on which version accomplished a specific goal more effectively (McPeak, 2017). The two versions can be any changes on a product. For example, a complete website redesigns or changing the color of buttons. Almost anything can be A/B tested to find out what engages the most customers. Additionally, users' feedback can be requested to find out why they preferred one version over the other.

7. Surveys/Questionnaires:

Questionnaires and surveys are an easy way to gather a large amount of information about users, with minimal time invested. A researcher can create a survey using tools like SurveyMonkey or Google Forms, send it out, and receive

hundreds of responses in just minutes. The right questions can uncover customer needs, desires, and pains. Surveys are not precise as other forms of testing, but they do provide general feedback from user groups. And because they can be used to collect a large amount of information in a short amount of time, they can be a more economical solution. Moreover, surveys can be used to accumulate quantitative data about overall user satisfaction or collect quantitative data to support qualitative research findings. Surveys are best used as tools to rate user experiences and users' needs and preferences as they relate to system features (Stumpf, 2018). Surveys should be used when users' task procedures are clearly defined, and when researchers are interested primarily in opinions about a task procedure.

8. Heuristic Evaluations:

In a heuristic evaluation, evaluators explore the interface while looking for problems based on a set of usability principles called heuristics. They look for instances where there is a mismatch between the principles and the design, and record mismatches when they are real usability problems (Nielsen, 1994). The analysis results in a list of potential usability issues. Heuristic evaluation method can provide some quick and relatively inexpensive feedback to designers early in the design process. However, heuristic evaluation requires knowledge and experience to apply the heuristics effectively. Usually, multiple trained usability experts are used to carry out the evaluation, then their results are aggregated to identify the usability issues.

9. Expert Reviews:

The product is evaluated by the user experience experts. The experts point out potential issues with the product and provide a general usability assessment. Experts are able to look at a product from different perspectives, handle it as a user would, and test its limits. They are trained and knowledgeable about lots of usability issues. In an expert review, the reviewers usually know and understand the accepted usability principles so they do not use a specific set of heuristics. In this case, the expert review tends to be less formal, and they are not required to assign a specific heuristic to each potential problem (McPeak, 2017). However, expert reviews can include some other usability testing methods such as heuristic evaluation, cognitive walkthrough or checklist.

10. Eye Tracking:

Eye tracking technology is a very specific type of test that places a user in front of a camera while he is using the product or website and tracks the user's eye movement and gazes. Products analyzed with the use of this method are graphic designs, operating websites, marketing materials. Eye tracking involves measuring either where the eye is focused or the motion of the eye as the user views a web page. As a participant looks at a webpage, the eye tracking device focuses on the pupil of the participant's eye and determines the direction and concentration of their gaze. The software generates data about these actions in the form of heat maps and saccade pathways. These tests are normally performed on a defined group of 10 or more users, then the data is analyzed and decisions are made about how design and UX performance can be improved (Stumpf, 2018).

11. Interviews:

Interviews help researchers learn about users' attitudes and beliefs surrounding a website or application and specific tasks that the website or application supports. In structured one-on-one interviews, the moderator conducts the interview on the basis of a prepared scenario which includes bullet points for the conversation or includes a detailed set of questions. The moderator focuses on asking open-ended questions and extending with additional questions to get to know interviewee's behavior better. It is often best to first observe users in their natural work environment, and then use a one-on-one interview to follow up the observation and clarify what was witnessed. During these interviews, researchers watch and listen as users work in the user's own environment, as opposed to being in a lab. Interviews tend to be more natural and sometimes more realistic. The results are usually qualitative and observed data, rather than quantitative and measured data (Traczyk, 2016).

12. Remote Testing:

Remote usability testing is an online user research without physical contact with the participants of the test. Users' behaviors are observed and analyzed while they work in their natural environment. Usually, it is conducted by employing screen-sharing software or online remote usability vendor services that automatically gather participant feedback and record their behavior. Remote usability tests can be moderated in the same manner as an in-person lab test or un-moderated where participants complete the tasks independently. Moderated

remote usability testing session enables direct interaction with users online or observing users while they complete tasks for a test. In an un-moderated remote usability testing session, participants independently complete testing without interaction with the test moderator. Participants complete tasks online and their results are available in an application or a system later on. Numerous parameters are measured during the test. For example, information on success or failure, time of implementation of a task, number of visited subpages. Also, desktop and facial expressions of users can be recorded during the testing session (Babich, 2017).

13. Cognitive Walkthroughs:

The cognitive walkthrough is a usability evaluation method in which one or more evaluators work through a series of tasks and ask a set of questions from the perspective of the user. The focus of the cognitive walkthrough is on understanding the system's learnability for new or infrequent users. It is an inspection method for evaluating the design of a user interface, with special attention to how well the interface supports exploratory learning; for example, first-time use without formal training. The evaluation is done by having a group of evaluators go step-by-step through commonly used tasks. During each task, the evaluator asks himself the following four questions about his expectations of users' behaviors:

1.Will the user try to achieve the right effect?

2.Will the user notice that the correct action is available?

3.Will the user associate the correct action with the effect to be achieved?

4.If the correct action is performed, will the user see that progress is being made toward the solution of the task?

The biggest benefit of the cognitive walkthrough is that it is extremely cost-effective and fast to carry out when compared to many other forms of usability testing. It can also be implemented prior to development during the design phase which can give rapid insight before a budget is spent developing an unusable product (Polson et al., 1992).

4.3 Usability of Games

Gaming is an important, rapidly growing type of software applications. The game application is one of the most popular applications available to users and has a huge market share. Game developers are trying to release games that are more enjoyable and addictive to play. However, only a small minority of these games

are successful. Similar to other types of software applications, development of a successful game requires taking usability into account during the game development process. This is valid for all types of games whether it is a video game played on PCs or dedicated game consoles or mobile game.

Computer games and productivity software applications are fundamentally different in terms of user experience. The player experience is much more extensive than the user experience. In games, player interaction has to be streamlined to increase enjoyment and flow, while in software applications, the aim is to increase productivity. The usability of a software product is often defined as effectiveness, efficiency, and user satisfaction in a specified context of use. Games, however, are most enjoyable and fun when they provide sufficient challenge for a player. The challenge can be, for instance, in learning the game, solving problems or discovering new things.

Usability is an integral part of any software development including game development. Ease of use and optimal user experience are important factors in games. Usability of a game is deeply rooted in the overall experience of the players and can affect their interaction with the game. Usability is considered more important in games than it is in other software for the following reasons:

1. Playing a game is voluntary:
   If the player has to struggle with problems that make playing less fun than doing something else, then there is nothing to stop the player from switching off the game. This is a serious risk as the user experience is very sensitive to usability problems. Even the smallest glitch in the user interface may render a good game into an annoying experience.
2. The heavy competition:
   There is a huge number of games available in the market. The gamers can choose which game to play from a wide variety of available games. With so many games to choose from in the market, users will not waste their time and money on a bad game when they can get a better, more enjoyable experience with a different game. Usability is one of the key factors that make the game stand out of the crowd.
3. Modern games are large and complex programs:
   In even the most focused games there are tons of menus and ways to interact within the game. Usability is important when making a game as easy and intuitive to play as possible.

4. Future of the game:
   For a game to continue to increase its popularity, the ease of setting up the game and its fluent gaming experience are of the essence. This is because novice or first-time users are not familiar with the conventions and common pitfalls of the game.

Playing a game is not straightforward, it is challenging, and the player needs to work towards goals. Therefore, applying only general usability testing methods in game evaluations is not sufficient and using only them would leave many important aspects of the game unprocessed.

4.3.1 Usability evaluation methods for games

In order to identify experience of players playing a game and to indicate whether a game is playable or not, the quality of a game should be analyzed in terms of its playability. Which is the degree to which a game is fun to play and usable, with an emphasis on the interaction style and the quality of gameplay. Playability is affected by the quality of the storyline, responsiveness, usability, customizability, control, intensity of interaction, and strategy, as well as the degree of realism and the quality of graphics and sound.

A good game is typically highly playable. In other words, playability is one of the most important factors in designing a successful game, and the existing playability problems have to be identified and solved before a game is ready to be released. The most common methods used for evaluating games are playtesting and expert evaluation with playability heuristics.

1. Playtesting:

This method is commonly used to identify playability problems in games. In a playtesting session, real people play the game to see how well it functions from a nonbiased and unfamiliar perspective. This method is used to evaluate the game by testing it with actual players. Typically, during a test, observers watch, listen and take notes while players are playing the game in real time. The goal is to identify any usability problems, collect qualitative and quantitative data and determine the player's satisfaction with the game. To run an effective playtesting session, a researcher needs to develop a solid test plan, recruit participants, and then analyze and report the findings. It is recommended to combine this testing method with other testing techniques such as encouraging players to think aloud

while playing the game, casting the game screen, recording audio and video of players, conducting interviews with the players after finishing the testing session, or asking the players to fill a questionnaire to get their final feedback and thoughts. However, playtesting is only applicable to a fully functional prototype of a game and it is time-consuming.

2. Expert Evaluation with Playability Heuristics:

The expert evaluation method is used for usability evaluation of software product, but it is not sufficient for evaluating games due to lack of comprehension context. This means it does not cover all aspects of the games such as game story, gameplay, mobility, or multiplayer features. The design objectives of games and other software applications are different in nature. The expert evaluation method should be able to recognize these differences prior to use for games evaluation. Therefore, it is usually combined with the playability heuristics evaluation method. For experts to effectively evaluate a game, they must have a set of specific, suitable playability heuristics. In an expert evaluation with playability heuristics session, experts explore the game while looking for problems based on a specific set of usability principles called heuristics. They look for instances where there is a mismatch between the principles and the design, and record mismatches when there are real usability problems.

4.3.2 Playability heuristics lists for games evaluation

Many researchers produced and defined several different playability heuristics sets that can be used to evaluate games with expert evaluation method. Each set of heuristics focuses on a specific context of games, These different contexts could be the platform of the game (computer, console or mobile games), the game genre (serious, action, strategy, or puzzle game), and the game type (single player or multiplayer game). The following four pieces of research show some of the playability heuristics defined for a specific game context.

1. Playability heuristics for PC video games.

The playability heuristics provided in Table 4.1, were developed to be used in evaluating PC video games. These heuristics can be used to avoid common game usability problems (Pinelle et al., 2008).

Table 4.1 List of playability heuristics for PC video games.

1. Provide consistent responses to the user's actions.
2. Allow users to customize video and audio settings, difficulty and game speed.
3. Provide predictable and reasonable behavior for computer controlled units.
4. Provide unobstructed views that are appropriate for the user's current actions.
5. Allow users to skip non-playable and frequently repeated content.
6. Provide intuitive and customizable input mappings.
7. Provide controls that are easy to manage, and have an appropriate level of sensitivity and responsiveness.
8. Provide users with information on game status.
9. Provide instructions, training, and help.
10. Provide visual representations that are easy to interpret and that minimize the need for micromanagement.

2. Playability heuristics for mobile games.

The playability heuristics provided in Table 4.2 cover several mobile context aspects such as general usability, mobility, and gameplay. These playability heuristics can be used with an expert evaluation method to identify possible playability problems in the user interface and game design in the early phase of a mobile game project (Korhonen and Koivisto, 2006).

Table 4.2 List of playability heuristics for mobile games.

1. The screen layout is efficient and visually pleasing.
2. Device UI and game UI are used for their own purposes.
3. Navigation is consistent, logical, and minimalist.
4. Control keys are consistent and follow standard conventions.
5. Game controls are convenient and flexible.
6. The game and play sessions can be started quickly.
7. The game accommodates with the surroundings.
8. Interruptions are handled reasonably.
9. The first-time experience is encouraging.
10. The player sees the progress in the game and can compare the results.

3. Playability heuristics for multiplayer games.

The playability heuristics provided in Table 4.3 are specifically oriented towards the needs of multiplayer games. This set of heuristics can be used in the design and evaluation of the multiplayer games. The set focuses on usability

issues related to group play with the involved communication and coordination between the players (Pinelle et al., 2009).

Table 4.3 List of playability heuristics for multiplayer games.

1. Simple session management.
2. Flexible matchmaking.
3. Appropriate communication tools.
4. Support coordination.
5. Meaningful awareness information.
6. Identifiable avatars.
7. Training for beginners.
8. Support for social interaction.
9. Reduce game-based delays.
10. Manage bad behavior.

4. Playability heuristics for mobile multiplayer games.

The playability heuristics provided in Table 4.4 correspond to usability issues addressed in multi-player mobile games. This set of heuristics focuses on the player-to-player interaction and competing between real players of mobile games (Korhonen and Koivisto, 2007).

Table 4.4 List of playability heuristics for mobile multiplayer games.

1. The game supports communication.
2. There are reasons to communicate.
3. The game supports groups and communities.
4. The game helps the player to find other players and game instances.
5. The game provides information about other players.
6. The design overcomes lack of players and enables soloing.
7. The design minimizes deviant behavior.
8. The design hides the effects of the network.

5. USABILITY EVALUATION OF VOICE COMMUNICATION FEATURE

In order to evaluate the usability of voice communication feature, we created the *Fire&Water* game that is introduced in section 3. Although we created a complete multiplayer mobile game, our usability evaluation focuses only on the voice communication feature in the game. This chapter introduces the full methodology we used to evaluate the voice communication feature.

We used a user-centered, iteration-based design process to implement the voice communication feature in the game. We optimized the design gradually by evaluating it from the early stages. We aimed to gather users feedback throughout the development stages until we got an acceptable level of usability.

Our implementation and usability evaluation of the voice communication feature passed through the following stages:

- Define the goals and objectives of the voice communication feature.
- Create paper prototypes.
- Develop the game.
- Refine the design through usability evaluation.
  - Perform A/B testing.
  - Perform playtesting.
  - Conduct interviews with the participants of the test sessions.
  - Use surveys to accumulate quantitative data.
- Usability evaluation analysis and findings.

5.1 Goals of Evaluating The Voice Communication Feature

The usability evaluation of the voice communication feature aimed to answer the following questions:

1. Do first-time players understand the voice communication feature well?
2. How easy it is for players to figure out and use the voice communication feature?
3. How does this feature affect the overall gameplay experience?
4. Is the voice communication feature helpful in collaboration between the players?
5. What is the best implementation form of the voice communication feature?

6. What are the possible usability issues or problems related to the voice communication feature?

During the usability evaluation process, we tried to get the answers to these questions from the actual users who participated in the testing sessions. The answers combined with the users' feedback helped us in enhancing the usability of the voice communication feature. Moreover, these questions directed the evaluation process towards the following overall goals:

1. Finding the best practices for implementing voice communication in multiplayer mobile games.
2. Proposing a usability heuristics set for evaluating voice communication feature in multiplayer mobile games.
3. Finding the level of acceptance by different gamers for voice communication in multiplayer mobile games.

5.2 Paper Prototyping

Before starting the development process, we created a simple prototype that simulates the game interface. The goal of creating this prototype is to test the usability of the game workflow, starting from the main menu view of the game and navigating to other views such as selecting a friend to play with, up to the game playing view. We tested the prototype with five users and made sure it is easy for a player to completely navigate between all of the views of the game.

We used a prototyping tool called *Axure* to create the prototype. *Axure* is a software used to wireframe and prototype software projects. This software allows designers to create simple click-through diagrams or highly functional, rich prototypes with conditional logic, dynamic content, animations, math functions, and data-driven interactions without writing a single line of code (Pierre, 2016).

The prototype contains all of the game views, which are: The game landing view (Main Menu), The game-play view, and the waiting view. As well as some dialog views such as: choosing a friend to play with, game finishing dialog (score view).

Using a prototype helped us making the following decisions:

- Where and how to place the moving characters' buttons (move right, move left buttons).
- Where and how to place the voice control buttons (activate/deactivate the microphone buttons, mute/unmute the voice buttons).
- Where to place the timing counter.
- How to tell the player which character he is controlling during a play session.

Figure 5.1 shows a direct workflow scenario from the prototype, the scenario shows the expected views that will appear when a player chooses to play the game with a friend.

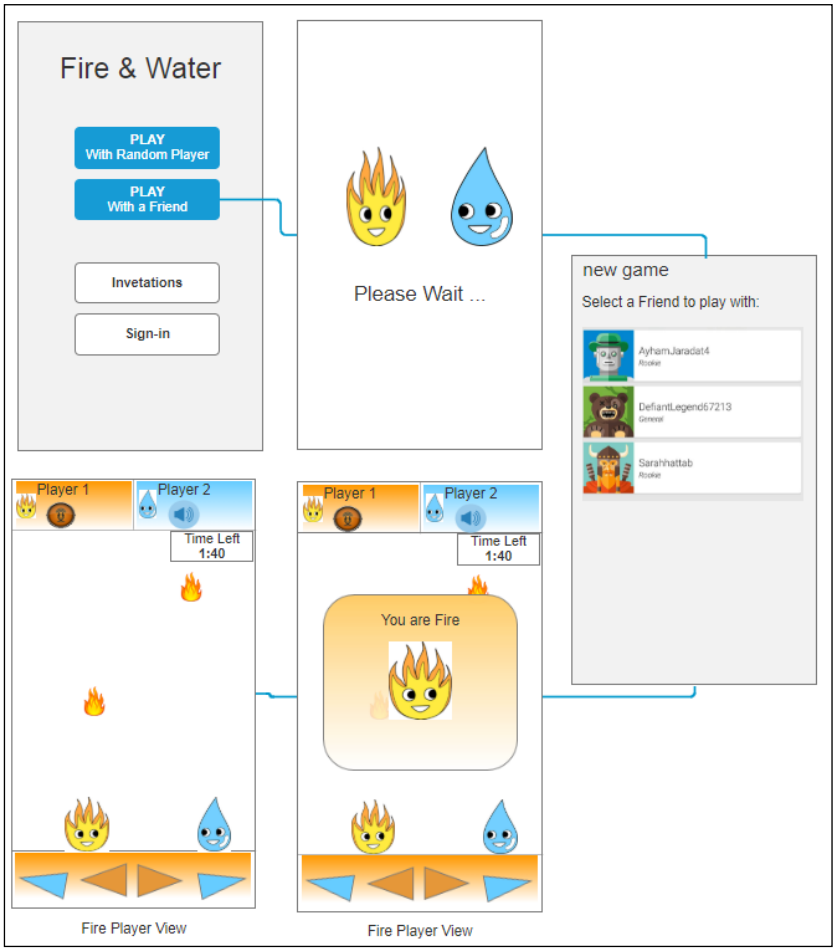


Figure 5.1 A workflow scenario from the prototype.

The prototype was refined and enhanced several times to cover the usability issues found based on the test with the five participants. One of these usability issues was related to identifying the current player character. In the game, we have two main characters, each player can control only one of these two characters. Players faced a problem identifying the character they are controlling in each playing session. To fix this usability issue we updated the play game view prototype design as follow:

- When a gameplay session starts, a dialog containing the player character appears for a few seconds. The dialog disappears before the timer of the game starts.
- Each player has different gameplay view colors on the bottom bar. The color of the bottom bar reflects the character in control, For *Fire* character, an orange gradient color fills the bottom bar, while for *Water* character, a blue gradient color fills the bottom bar.
- The colors of the main movement buttons in the bottom bar reflects the character in control.
- On the top bar, the character in control appears always in the top left rectangle, while the other player character appears always in the top right rectangle.

These changes are shown in Figure 5.2, which shows the gameplay view as they appear for the two players.

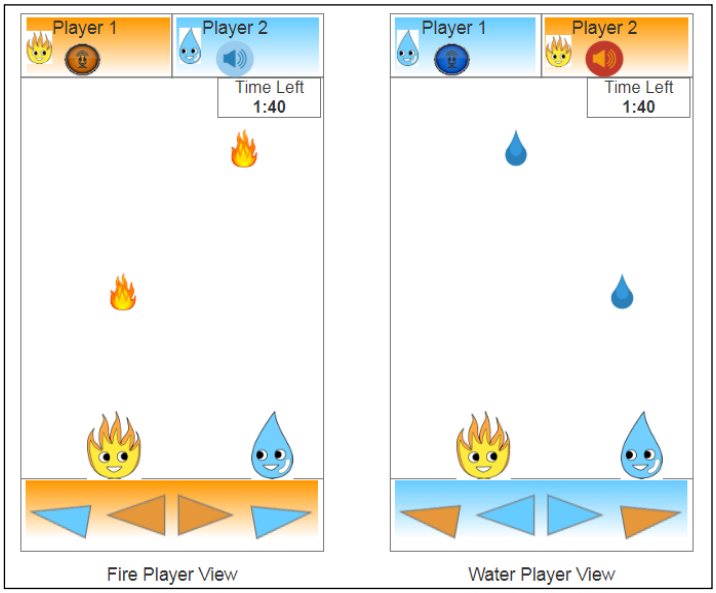


Figure 5.2 Gameplay views as they appear for the two players.

After finishing the first iteration of the development process based on the final prototype design, we started the usability evaluation by recruiting the test participants and conducting the test sessions.

5.3 Participants

Selecting a group of people to act as participants of usability evaluation testing methods is a crucial part of the usability evaluation process, especially when evaluation a game. For this reason, we tried to get a variety of participants that can represent the actual game players community. In order to recruit a good sample of participants, firstly, we searched for the appropriate age range that covers the majority of casual game players. It was found that most of the mobile casual game players are young people with age less than 30 years. Moreover, we aimed to get enough participants from both genders (male and female) because the voice communication feature itself can be judged differently by different gender players. Another important selection criteria were to recruit participants with different playing experience in order to get different feedback and to better measure the effect of voice communication feature as seen by different experienced players (novice and experts). Lastly, we focused on getting participants with different relationships among each other, ranging from friends, family members, and strangers.

We performed the testing with 40 different participants on different testing sessions. The participants downloaded the game on their phones and were asked to play the game during different usability evaluation sessions. All of the participants' ages were between 20 and 30 years. 60% of them were men and 40% women. They had different game-play experiences, 45% of them play every day, 27.5% of them play once a week, 22.5% of them play rarely and 5% of them do not have any playing experience. Figure 5.3 shows list and diagrams of the participants' demographic data representation. Some of the participants chose to play with their friends and some of them played with other random participants.

#	Age	Gender	Experience
1	20-30	Female	I rarely play.
2	20-30	Male	I rarely play.
3	20-30	Female	I rarely play.
4	20-30	Female	I play every day.
5	20-30	Female	I play once a week.
6	20-30	Female	I play every day.
7	20-30	Male	I rarely play.
8	20-30	Male	I play every day.
9	20-30	Female	I play every day.
10	20-30	Male	I rarely play.
11	20-30	Male	I rarely play.
12	20-30	Female	I rarely play.
13	20-30	Male	I play once a week.
14	20-30	Male	I play every day.
15	20-30	Male	I play every day.
16	20-30	Male	I play once a week.
17	20-30	Male	I play once a week.
18	20-30	Female	I play once a week.
19	20-30	Male	I play every day.
20	20-30	Male	I play every day.
21	20-30	Male	I play every day.
22	20-30	Female	I play once a week.
23	20-30	Male	I play every day.
24	20-30	Female	I play every day.
25	20-30	Female	I've never played a mobile game.
26	20-30	Male	I play every day.
27	20-30	Male	I play every day.
28	20-30	Male	I play every day.
29	20-30	Female	I play every day.
30	20-30	Male	I play every day.
31	20-30	Female	I play once a week.
32	20-30	Male	I rarely play.
33	20-30	Female	I play every day.
34	20-30	Male	I play every day.
35	20-30	Male	I play once a week.
36	20-30	Male	I rarely play.
37	20-30	Male	I play once a week.
38	20-30	Female	I've never played a mobile game.
39	20-30	Female	I play once a week.
40	20-30	Male	I play once a week.

Figure 5.3 List and diagrams of the participants' demographic data representation.

5.4 A/B Testing

One of the most important objectives of our usability evaluation is to find the best usable implementation form of voice communication feature. There are several options for voice communication implementations:

- Open Voice Call
- Push to Talk
- Turn by Turn Voice Messages

These forms of implementation are introduced in section 3.4.

Based on the users feedback from the prototyping testing, it was clear that the third implementation form "Turn by turn voice messages" is not suitable for our *Fire&Water* game, because the game depends heavily on the voice communication feature between the two players, and periodically activating and deactivating the voice channel for a certain period of time will make the voice

channel unuseful for the players. For these reasons, we left with the first two implementation forms to test.

Other important objectives of our usability evaluation were to measure the effect of using the voice communication feature on the gameplay experience and to find out if using the voice communication feature enhances the collaboration process between the two players during the playing session. For these reasons and in order to allow the participants to easily compare the effect of the voice communication feature in the game, we implemented another non-voice communication form between the players, which we called as "Visual Messages".

Visual Messages is a simple communication form that allows players to communicate with each other without using a voice channel nor typing a text. It consists of pre-prepared visual messages that a player can send to another player by pressing a button. The visual messages appear on the other player screen immediately as a moving animation pointing to the required direction of movement. There are two pre-prepared visual messages in the game, which are "move-right" and "move-left". Each one of these messages has a separate button for it.

With these different alternative implementations of communication forms, we used A/B testing method to determine which one of these alternatives is better for our game. The A/B test session was divided into two phases:

1. **Testing for the best voice implementation form.**

For this test session, we had two alternatives to the voice communication implementation, which are :

A. Open Voice Call.
B. Push To Talk.

Each one of the participants was asked to play the game two times during this testing session. They were asked to play the game with the two alternatives of the voice communication implementations. Then we asked them to provide us with their feedback about the two alternatives, which one they preferred and why they preferred it over the other.

2. **Testing for the effect of the voice communication feature.**

For this test session, we had two different alternatives for playing the game, which are:

A. Play with voice communication.
B. Play without voice communication (using visual messages).

Each one of the participants was asked to play the game two times during this testing session. One time by using their preferred voice communication implementation form, and the second time by using the visual messages form (without using any voice communication). We asked the participants about their feedback and how using the voice communication feature affected their playing experience, we also asked which one of these two alternatives they preferred and why they preferred it over the other.

5.4.1 Results and analysis of A/B testing sessions

The data collected from the two phases of A/B testing sessions were qualitative data based on the participants' views and feedback. Our focus was to find out which one of the voice implementation is more usable and positively affects the gameplay experience.

First A/B testing phase:

The first A/B testing phase aimed to test the two voice communication implementation forms (Open Voice Call, and Push To Talk). The results of this test session showed that 85% of the participants preferred the Open-Voice-Call form over the Push-To-Talk implementation form.

The participants who preferred Open-Voice-Call form declared that it is easier to use this form than the Push-To-Talk form. They explained that it is easier to use as there is no need to press or hold any buttons while talking with the other player. They also said that with this form they could feel that they are in the same physical place as the other player, which made playing the game more exciting and interesting. Moreover, participants mentioned that it is easier with this implementation form to focus on the game itself and try to win it without worrying about pressing voice control buttons.

On the other hand, the participants who preferred Push-To-talk mentioned that it is better because it causes less noise, as they felt it is noisy to hear the voice of the other player all the time. Other participants indicated that they were playing the game outside and they felt more comfortable with the push-to-talk form.

Although there are some advantages and disadvantages of the two voice implementation forms, the majority of participants preferred the Open-Voice-Call and thus we considered this form as the best form for our *Fire&Water* game. Table 5.1 shows a summary of the first A/B testing phase.

Table 5.1 Summary of the first A/B testing phase.

What is tested	**The best voice implementation form.**	
Alternatives	**Open Voice Call**	**Push To Talk**
Users feedback	- Easier to use. - More realistic and exciting. - Allows to focus on the game playing.	- Less noisy. - Better when playing in outside environments.
Users preferences	Selected by 85% of the participants.	Selected by 15% of the participants.
Results	**Open Voice Call is more preferable.**	

Second A/B testing phase:

The second A/B testing phase allowed participants to play the game with and without voice communication. This testing session aimed to measure the effect of the voice communication feature on the overall gameplay experience and to find out if the voice communication feature can enhance the collaboration process between the players. Table 5.2 summarizes the result of this test.

The results of this testing session showed that 80% of the participants preferred the voice communication feature over the visual messages. The participants who preferred the voice communication feature declared that voice communication feature made the game funnier and more enjoyable. Also, they said that the collaboration process between the players during the game session was more useful with voice communication than with visual messages.

Participants who selected visual-messages form as their favorite form indicated that they had a delay in the voice while using voice communication, which made the game confusing and unplayable with voice communication, they felt more satisfied using the visual messages only.

Some participants suggested that the game should include both voice communication and visual messages form at the same time. Allowing the players to use any one of them as they wish.

Based on the two A/B testing phases, we decided to implement Open-Voice-Call communication form along with visual-messages form in the game to be used interchangeably at the same time.

Table 5.2 Summary of the second A/B testing phase.

What is tested	**The effect of the voice communication feature.**	
Alternatives	**Play with voice communication.**	**Play without voice communication** (using visual messages).
Users feedback	- Makes the game funnier and more enjoyable. - Makes the collaboration more useful.	- Better in weak network connectivity situations.
Users preferences	Selected by 80% of the participants.	Selected by 20% of the participants.
Results	**Voice communication positively affects the gaming experience, and it is more preferable than visual messages.**	

5.5 Playtesting, Interviews, and Surveys

In order to find out how easy it is for players to figure out and use the voice communication feature, and to find out the usability issues or problems that might face the players while playing a game with the voice communication feature, we asked the participants to perform a monitored playtesting sessions, followed by one-on-one short interviews and survey filling.

The play-testing sessions were performed in different places, each time with a different group of the participants. Before starting a game-play session, a brief introduction was made for the participant explaining to them the main goal of the test and how to play the game. Then participants were allowed to download the game on their own smartphones and start the playing sessions. Participants were also asked to think-aloud while playing the game. Their notes and comments were taken after finishing the playing session through interviews, and they were asked to fill a survey at the end.

Playtesting, interviews and surveys are combined together in one testing session because their objectives are very close to each other. Playtesting allows real players to play the game freely in order to discover the usability issues related to the voice communication usage. Then we held short interviews to get the players feedback and feelings regarding their gameplay experience. Lastly, we asked the participants to answer the survey questions to collect their demographic data and to accumulate some quantitative data such as the voice quality and the overall player satisfaction.

5.5.1 Interviews

We held structured one-on-one interviews with most of the participants after we watched and listened to them as they were playing the game in the playtesting sessions. The main goal of the interviews was to get the participants' attitudes and beliefs surrounding the usage of the voice communication feature in the game. We used the following prepared open-ended questions during the interviews :

1. Do you think voice communication can add more fun to a mobile game in general?
2. Do you think voice communication adds more fun to the *Fire&Water* game?
3. Did you face any problem that affects the usage of the voice communication feature in the game? e.g: slow network, high noise.
4. Do you have any other ideas or suggestions of how to implement or enhance the voice communication feature?
5. Would you use voice communication in a mobile game if it exists? and why?
6. Is there anything else you want to tell us?

The results of the interviews are qualitative, observed data summarized as follows:

1. **Participants beliefs surrounding the effect of adding voice communication feature in mobile games -in general-:**

The goal was to get a general sense of the participants' attitude towards adding voice communication feature in mobile games. The majority of the participants had a positive attitude, where 70% of them declared that they think voice communication adds more fun to a multiplayer mobile game in general and makes it more enjoyable.

Some participants said that it depends on the game logic, the voice communication would be more useful and acceptable in games that need fast interaction between players, or in games that need a high level of collaboration between the players.

2. **Participants beliefs surrounding the effect of adding voice communication feature in the *Fire&Water* game specifically:**

Generally, during the play-testing sessions, it was obvious that participants are enjoying the usage of the voice communication feature in the game. 85% of the participants declared that the existence of voice communication in the game made it more fun and more playable. 15% were unsure if the voice communication adds more fun to the game.

Moreover, 80% of the participants said that the voice communication was helpful in achieving the required collaboration between the players which made the game easier and funnier.

3. **The problems and issues that faced the participants during the playtesting session:**

The list of problems and issues that were mentioned by the participants are:

- Some participants were having a delay in the voice communication as they were using a relatively slow network.
- On some devices, the players were hearing an echo of their voices.
- Some participants felt that the game characters sounds are confusing and interrupting the other player voice.
- Other participants indicated that they could not play in an outside environment without using the headphone because it was noisy to hear the other player.
- Sometimes, the voice channel was disconnected during the game session due to a network error. The players did not notice that and they kept trying to talk to each other.

4. **Participants ideas and suggestions of how to improve the voice communication feature:**

Few numbers of participants shared with us some suggestions that can make the game better:

- Provide an option to mute the game sounds (character running sounds, collision sounds). The player should be able to mute or lower the game sounds if he wants to listen clearly to the other player voice.
- The game should include both the voice communication feature as well as a visual messages communication option. A player should be able to choose any communication form he likes and feels comfortable with. Also, the player should be able to use both of them easily and interchangeably.
- The game should include tutorials for first-time players. And the game should contain different levels to complete, starting from easy to win level to more difficult levels.
- The game should be easier to win, a way to do that is to increase the number of lives of a character when it hits one of the same type falling objects (e.g. Fire character hitting a fire-flame character).

5. **The willingness of participants to use a voice communication feature in a mobile game:**

Most of the participants declared their willingness to play a mobile game that has a voice communication feature, especially if the game needs a high level of communication and cooperation between the players. Some participants said they would play such a game only with their friends or family members as they do not feel comfortable talking with strangers. Other participants said that they would use a voice communication feature in a game only if they were alone in an appropriate environment that allows them to speak freely. Other participants also mentioned that they would use voice communication if it does not affect the game playing performance. They specified that if the voice channel causes the game to be slower or interruptible, they would not use the voice channel.

5.5.2 Survey

Participants were asked to fill a survey of nine questions. the questions were divided into two sections, The first section determines static user factors such as age, gender and playing experience of the participant. This section contains three questions with answers in form of radio-button selections and its purpose is to be able to divide answers among user groups.

The second section is the actual survey and it consists of six questions that are answered by the 5-point integral scale, where in general 1 is bad and 5 is excellent. The purpose of the survey questions is to accumulate quantitative data regarding the voice communication feature in the *Fire&Water* game. The survey was intentionally designed to be short and well-structured to avoid survey fatigue. The survey questions are listed in table 5.3.

Table 5.3 List of the survey questions.

Section 1: Static user factors questions.				
Q1.1	How old are you?			
	• Less than 18	• 18-20	• 20-30	• More than 30
Q1.2	What is your gender?			
	• Male		• Female	
Q1.3	Approximately, what is your experience with playing mobile games?			
	• I play every day.	• I play once a week.	• I rarely play.	• I've never played a mobile game.
Section 2: Actual survey evaluation questions.				
Q2.1	How easy was it to use and figure out the voice communication feature?			
	Very difficult • 1 • 2 • 3 • 4 • 5 Very easy			
Q2.2	How helpful was it to use the voice communication feature in collaboration between the players?			
	Not helpful • 1 • 2 • 3 • 4 • 5 Very helpful			
Q2.3	How did voice communication feature affected the gameplay experience?			
	Very negatively • 1 • 2 • 3 • 4 • 5 Very positively			
Q2.4	Rate the overall audio quality of the voice communication feature.			
	Very bad • 1 • 2 • 3 • 4 • 5 Excellent			
Q2.5	How likely are you to play a mobile game that has a voice communication feature?			
	Very unlikely • 1 • 2 • 3 • 4 • 5 Very likely			
Q2.6	How important is it to have a voice chat in the game (knowing that it can be played with visual messages only)?			
	Very unimportant • 1 • 2 • 3 • 4 • 5 Very important			

The purpose of this survey is to accumulate quantitative data concerning the quality of experience as perceived by actual players. And to find out what categories of players (gender and level of experience) are most positive and negative towards the voice communication feature.

The following sections present and discuss the answers of the last six questions of the survey both as total scores per question and average scores per players categories. Survey data can be found in Appendix A.

The average scores per players categories are calculated as a weighted average for the 5-point rating scale. In order to correctly calculate the average overall response to each category label, we did the following:

1. For each category label, multiply the number of individuals selecting each rating by the corresponding rating value (1 - 5).
2. Add the results of those calculations together.
3. Divide the obtained result by the total number of responses to this category label.

Figure 5.4 shows an example of how the weighted average is calculated for the male label of the gender category for question 2.1.

Weighted Average Score For question 2.1,
Gender Category, Male Label:

5-points rating scale:	1	2	3	4	5
Number of **Male** responses for each rating:	0	0	4	11	9
Multiplication of the number of responses by the corresponding rating value:	0	0	12	44	45

Sum of multiplication:	101	=>	SUM(0,0,12,44,45)
Weighted Average	**4.21**	=>	101/SUM(0,0,4,11,9)

Figure 5.4 An example of the weighted average calculation.

1. Results and analysis of question 2.1:

The purpose of this question is to find out if the players can easily understand the voice communication feature of the game, and if they can learn fastly how to use it. This is very important regarding the usability of this feature as it does not make sense to add a good feature to a game if the players cannot understand it or have troubles using it.

Results show that most players evaluated question 2.1 as 3 or better, see Figure 5.5. This gives us an indication that the voice communication feature in the game can be easily understood and used by players.

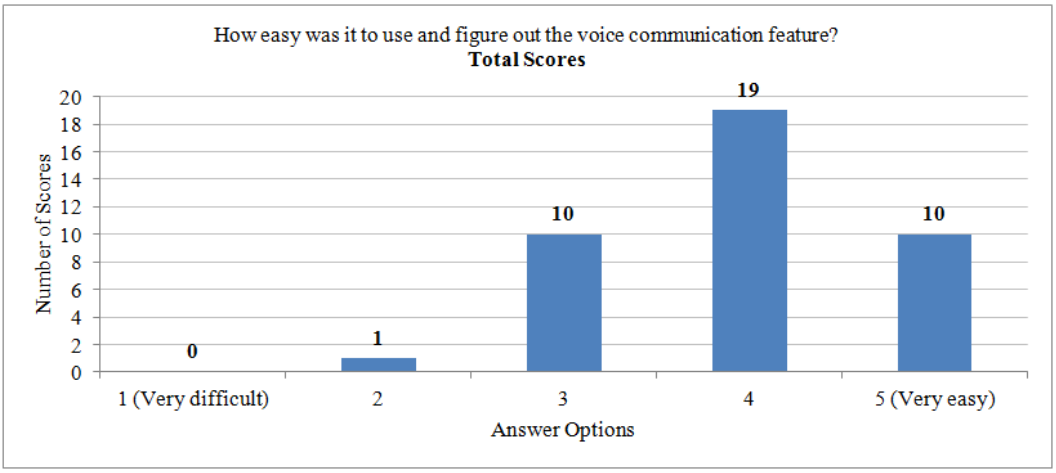


Figure 5.5 Total scores of survey question 2.1.

The results also showed that the average of male players' scores was slightly higher than the female average scores, which generally means, it was a little bit easier for male players to figure out the voice communication feature. For experience level of the players, there were no significant differences between the scores. Both experienced players and novel players could figure out and use the voice communication feature. Figure 5.6 shows the average scores by the two categories.

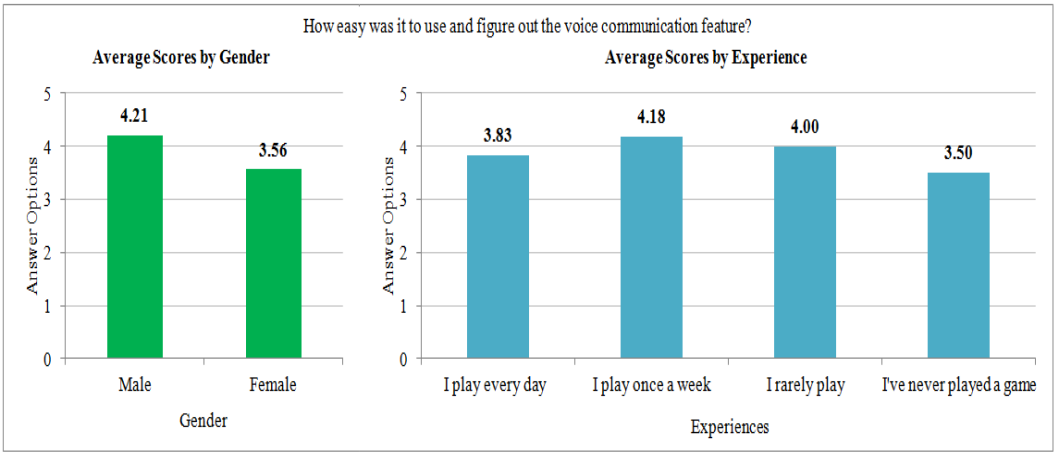


Figure 5.6 Average scores of survey questions 2.1.

2. <u>Results and analysis of question 2.2:</u>

The purpose of this question is to find out if the voice communication feature is helpful in achieving a better collaboration between the players. Enhancing the collaboration process between the players during a game session is one of the important goals of including the voice communication feature in the game.

Results show that most players evaluated question 2.2 as 4 or better, see Figure 5.7. This proves that the voice communication feature is helpful and important in accomplishing a good cooperation between the players.

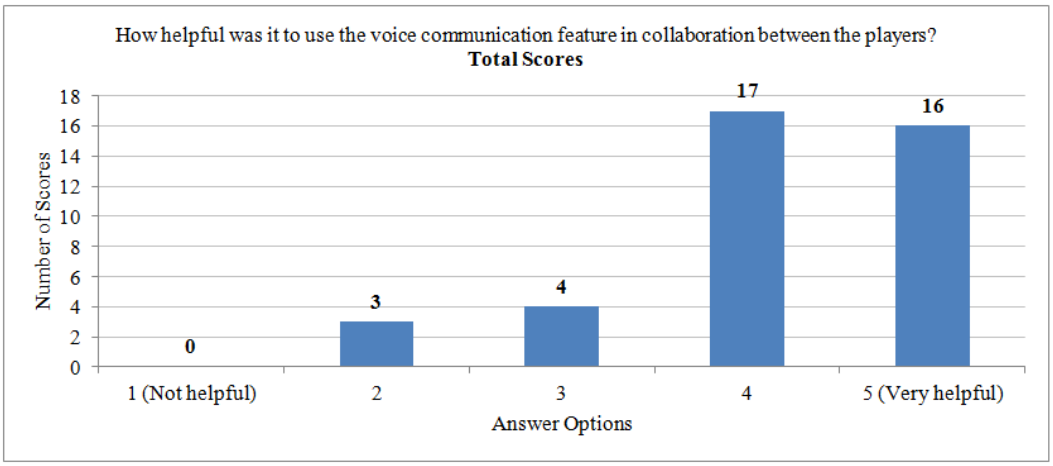


Figure 5.7 Total scores of survey question 2.2.

The average scoring of male and female genders was around 4, with a very small difference, which means both agreed that the voice communication feature is very helpful for collaboration between the players in the game. The results also showed that players with a higher level of experience attend to give a higher rating for the importance of this feature regarding the cooperation process. Figure 5.8 shows the average scores by the two categories.

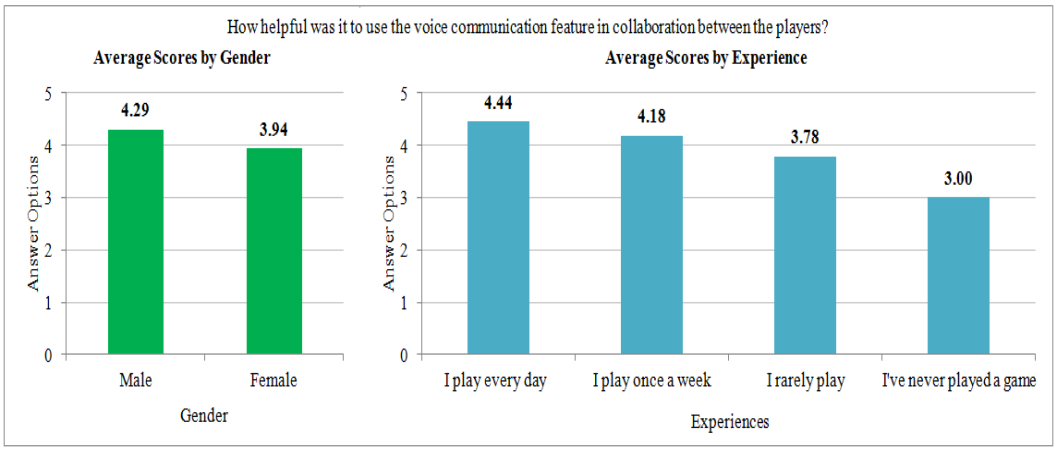


Figure 5.8 Average scores of survey questions 2.2.

3. Results and analysis of question 2.3:

The purpose of this question is to find out the general effect of the voice communication feature on the gameplay experience. This question also gives us

an indication of the overall satisfaction of players regarding the usage of the voice communication feature.

The majority of players rated question 2.3 as 4 and 5, which means that most of the players had a positive gameplay experience while using the voice communication feature in the game. The question scores can be seen in Figure 5.9.

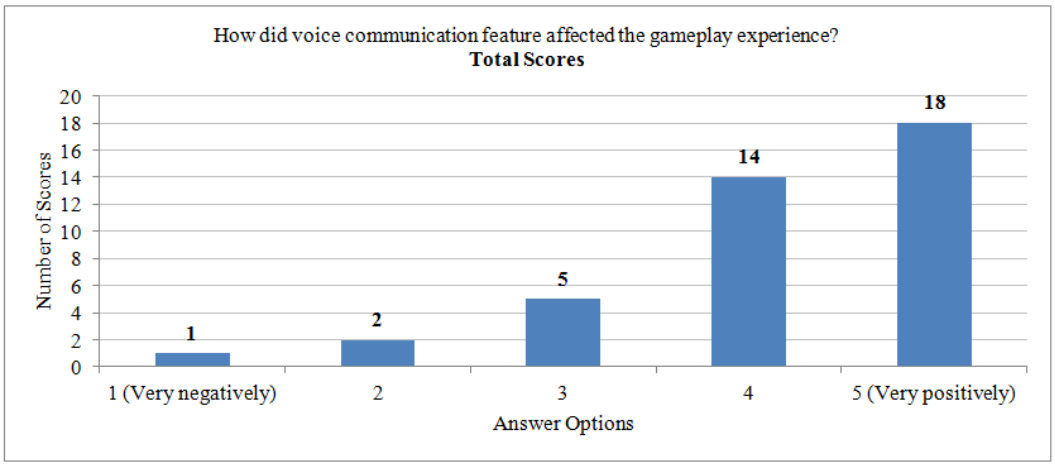


Figure 5.9 Total scores of survey question 2.3.

Regarding the average scores per players categories, the gender category did not make a significant change of players average rating, both male and female average scoring was around 4. For experience level, the average scores of players who have gaming experience were noticeably higher than those who do not have a gaming experience at all. Players who play games every day gave the highest average scoring. Figure 5.10 shows the average scores by the two categories.

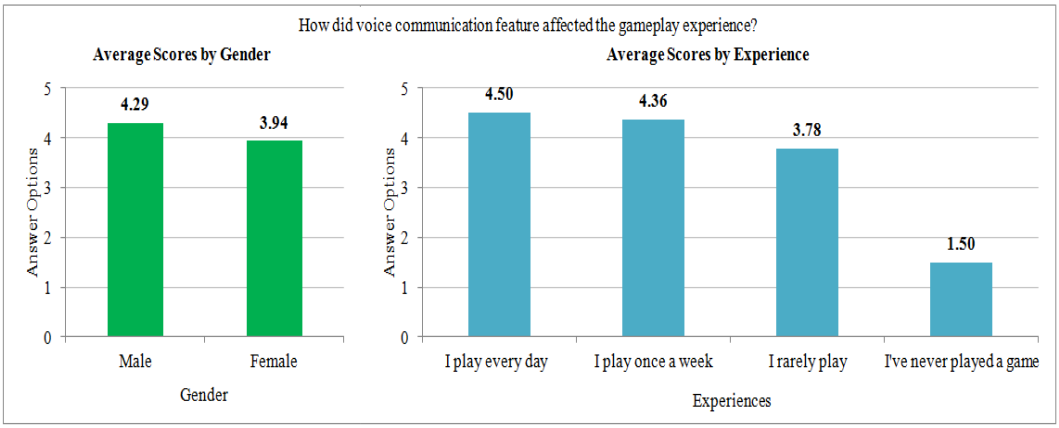


Figure 5.10 Average scores of survey questions 2.3.

4. Results and analysis of question 2.4:

The purpose of this question is to find out the overall audio quality of the voice communication feature. The quality of the audio can affect the whole experience if it was not good enough because the voice communication feature depends heavily on the audio quality of the implemented channel.

The average total scores for this question was 3.1. The majority of the players gave a middle-quality rating. 17% of the players selected 2 as their answer, 37% of the players selected 3 as their answer. and 32% of the players selected 4 as their answer. Figure 5.11 shows the total scores for this question. The answers show that the majority of the players was not very satisfied with the audio quality of the voice communication feature.

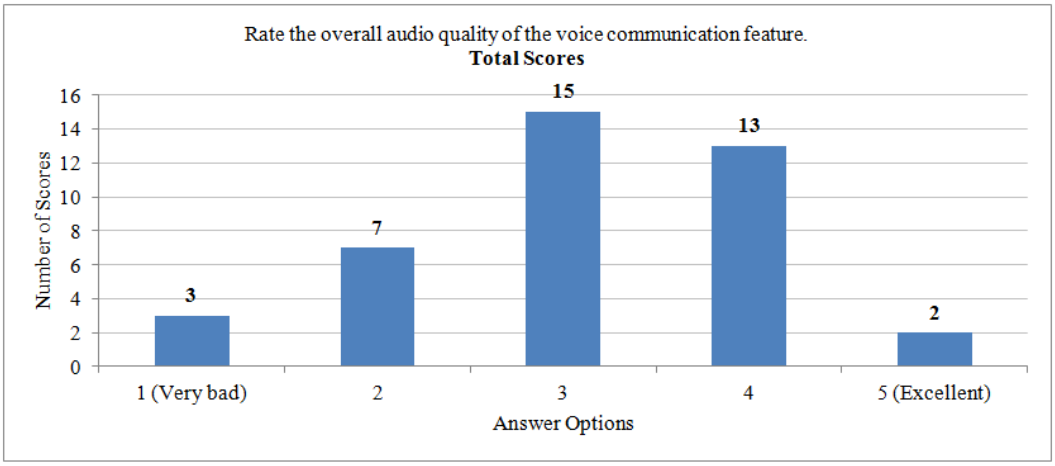


Figure 5.11 Total scores of survey question 2.4.

Female players gave a lower average rating than male players. The female average rating was 2.69 while male average rating was 3.38. This shows that generally female players were more unsatisfied with the audio quality than male players. Experience level did not affect the audio quality rating, as there is no clear relation between the players level of experience and their rating. Figure 5.12 shows the average scores by the two categories.

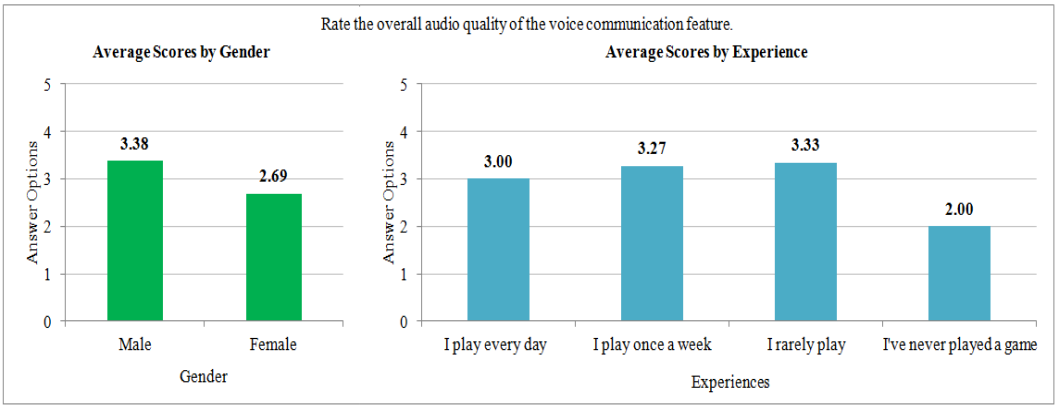


Figure 5.12 Average scores of survey questions 2.4.

5. Results and analysis of question 2.5:

The purpose of this question is to find out the level of acceptance by different gamers for voice communication feature in multiplayer mobile games. The question measures how likely are different players to play a mobile game that has a voice communication feature.

The majority of players rated question 2.5 as 4 and 5, which means that most of the players are very likely to play games that have a voice communication feature. Figure 5.13 shows the total scores for this question.

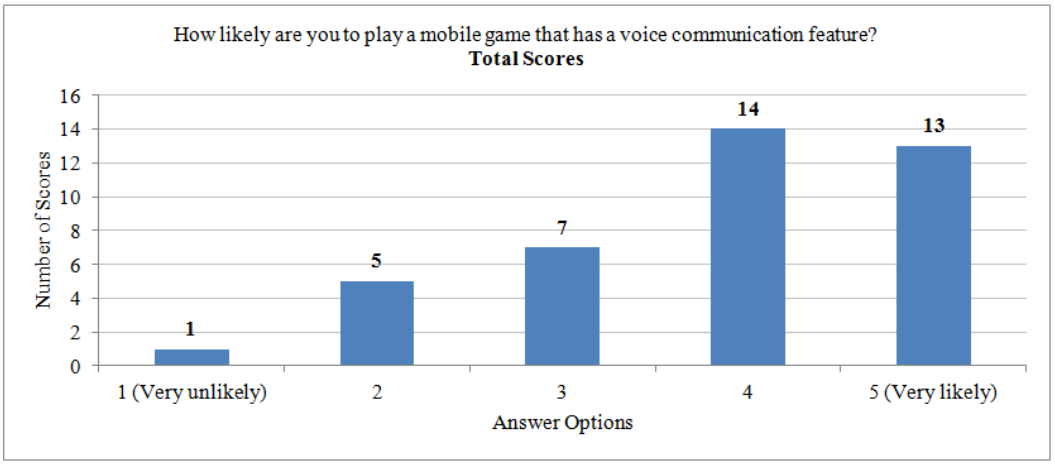


Figure 5.13 Total scores of survey question 2.5.

Regarding the average scores per players categories, female players gave a lower average rating than male players. The female average rating was 3.25 while the male average rating was 4.21. The acceptance of voice communication feature in a multiplayer mobile game seems to have a positive relationship with

the player level of experience. As shown in Figure 5.14, Players with a higher level of experience tend to give a higher average rating for this question.

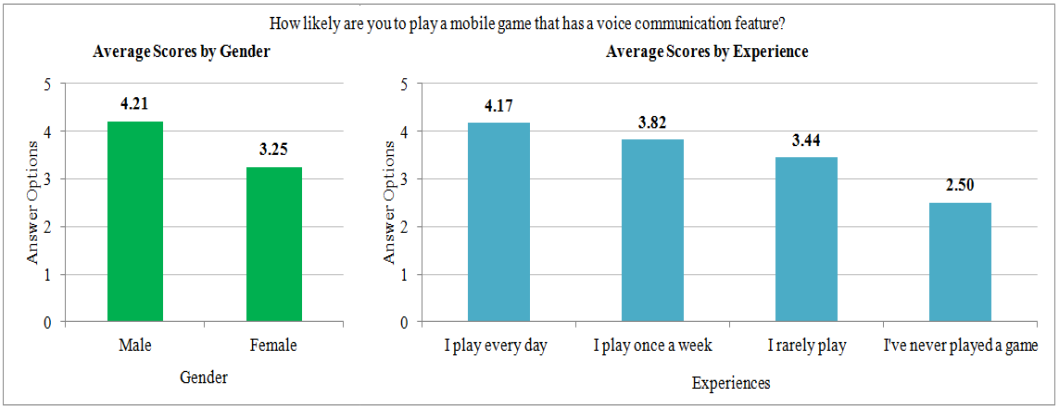


Figure 5.14 Average scores of survey questions 2.5.

6. Results and analysis of question 2.6:

The purpose of this question is to find out the importance of adding the voice communication feature to the game as seen by different players. This question also reflects the overall satisfaction of the players regarding the voice communication feature.

As shown in Figure 5.15, the majority of players rated this question as 4 and 5. Most of the players believe that the voice communication feature is important in the game. The average of the total scores is 4.08.

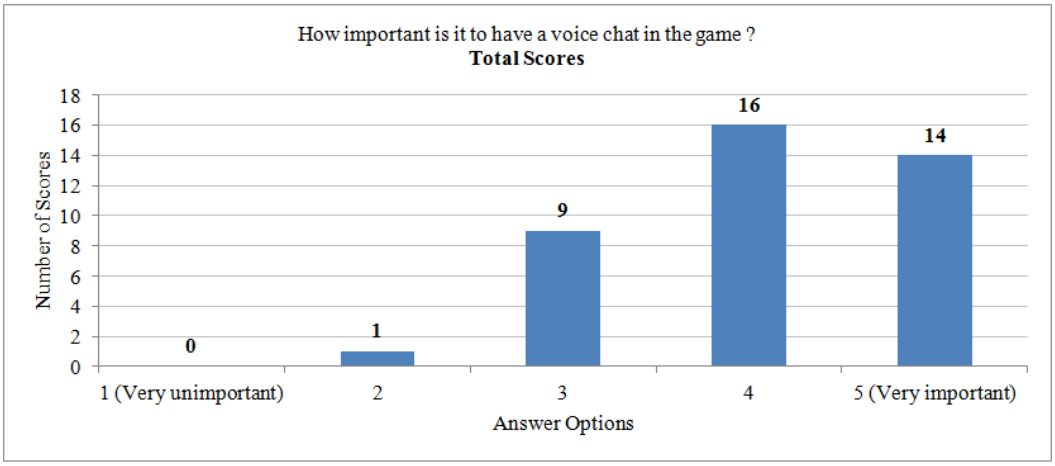


Figure 5.15 Total scores of survey question 2.6.

For the gender category, both female and male players gave an equal average rating for the importance of the voice communication feature question.

For the experience category, players with game experience gave a slightly higher average rating than less experienced players. Figure 5.16 shows the average scores by the two categories.

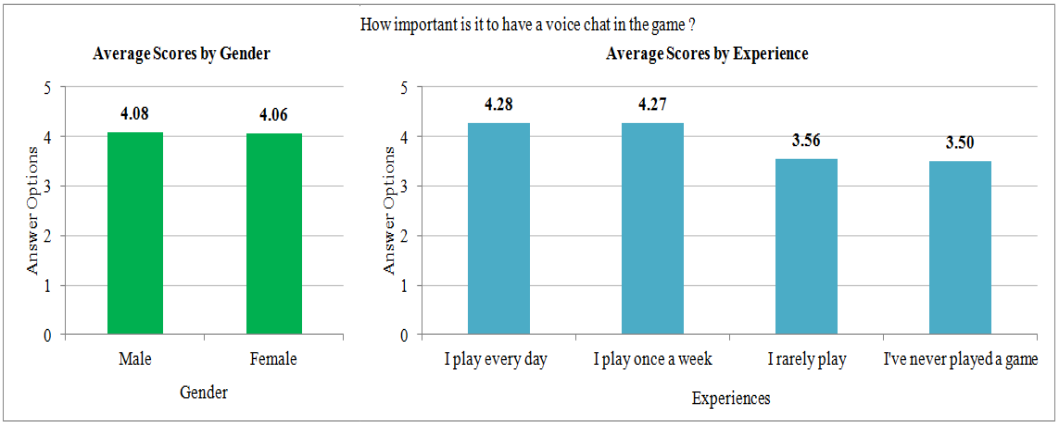


Figure 5.16 Average scores of survey questions 2.6.

6. DISCUSSION AND RESULTS

This chapter discusses the evaluation of the voice chat implementations and attempts to interpret the obtained data to a greater extent. We performed several usability evaluation methods and obtained different types of data (qualitative and quantitative). In order to organize the different obtained data from all of the testing session, we divided the discussion into the following four main categories:

1. The importance of voice communication in a multiplayer mobile game.
2. The level of acceptance by different gamers for voice communication in multiplayer mobile games.
3. Possible usability problems and issues related to the usage of voice communication feature in multiplayer mobile games.
4. Best practices and guidelines for implementing voice communication feature in multiplayer mobile games.

We used the obtained data from the different usability evaluation methods (including participants feedback, comments, answers, and behaviors) to generate the content and answers of these four main categories. Then we combined and rewrite the results as a set of usability heuristics that can be used to evaluate the voice communication feature in a multiplayer mobile game.

6.1 The Importance of Voice Communication Feature.

Adding a new feature to a game is not a trivial process in the development life cycle of the game. Generally, there must be a good reason and noticeable benefit from adding a feature to a game. In order to find out the importance and benefits of the voice communication feature, we combined and analyzed the obtained data from the following usability evaluation methods:

- The second phase of the A/B testing method:
    - Testing for the effect of the voice communication feature.
- The first two questions of the interview:
    - Do you think voice communication can add more fun to a mobile game in general?
    - Do you think voice communication adds more fun to the *Fire&Water* game?
- Questions number 2.2, 2.3, and 2.6 from the survey:

- How helpful was it to use the voice communication feature in collaboration between the players?
- How did voice communication feature affected the gameplay experience?
- How important is it to have a voice chat in the game?

The data obtained from these usability evaluation methods showed that the majority of participants found the voice communication feature to be an added value to the game playing experience. Examples of the Participants feedback are:

- Voice communication capability made the game funnier and more enjoyable to play.
- Talking with the other player is much easier to collaborate than sending visual messages.
- Voice chatting feature depends on the game logic, the voice communication is more useful and acceptable in games that need fast interaction between players.

By looking at the obtained data and the results of these methods and questions, we can summarize the importance of the voice communication feature into two main points:

1. **Generally, Voice chat adds more fun to a multiplayer mobile game. But it depends on the game logic and design.**
2. **Voice chatting is very useful in collaboration games.**

Voice communication in a multiplayer mobile game can positively affect the overall rating of the game. It depends on the game trend and logic, for example, voice communication is very important in games that require collaboration between the players, or team planning and strategy building. The existence of voice communication capability in the game makes the game more interactive and allows players to feel like playing together as if they were in the same room. This playing experience is considered funnier and makes the game more attractive for players. However, adding the voice communication capability should not affect the game speed or performance. Players will not use the voice communication feature if it confuses the game playing, makes it difficult or causes interruption of the game flow.

In fast-based games where the speed of interaction between collaborating team members is very important, Voice chatting is found to be the best choice for

players. It is more useful to speak to other players rather than typing text messages or sending visual messages. Talking to the other player is easier and faster. It allows the player to provide all necessary information to the other player as fast as possible. This is more appearing in small size teams where voice messages are translated between a limited number of players. Also, voice chatting is more useful in collaboration situations, where players attempt to help each other by sharing information about enemies or when building a shared strategy to be used by team members.

6.2 The Level of Acceptance by Gamers for Voice Communication Feature

Usually, a well-implemented feature in a game is useless if the actual players do not accept it or refuse to use it. In order to find out the level of acceptance by gamers for the voice communication feature, we can look at the obtained data from the following usability evaluation methods:

- The fifth question of the interview:
    - Would you use voice communication in a mobile game if it exists? and why?
- Question number 2.5 from the survey:
    - How likely are you to play a mobile game that has a voice communication feature?

These two questions asked the players about their willingness to play a game that has a voice communication feature. Most of the participants gave a positive feedback and declared their willingness to use a voice communication feature in a game if it exists. However, it is worth mention that, male players are more likely to play a game with a voice communication feature than female players. Moreover, players with a higher level of experience in gaming are more likely to use the voice communication feature than players with lower or no level of experience.

From the participants answers to the interview questions, we can derive the following factors and situations that encourage players to play and use the voice communication feature:

- When the game itself depends highly on the communication and cooperation between the players.

- When players can choose to play with friends and family members, not with strangers.
- When the voice communication feature does not affect the game performance and smoothness.

6.3 Usability Issues Related to The Voice Communication Feature

Adding a voice communication feature to a mobile game is not a simple task. This feature could cause lots of issues and problems that can affect the usability and playability of the game. During our usability evaluation, we tended to find and discover these possible issues throughout the following methods:

- Prototyping.
- Monitoring playtesting sessions.
- The third and fourth questions of the interview:
    - Did you face any problem that affects the usage of the voice communication feature in the game?
    - Do you have any other ideas or suggestions of how to implement or enhance the voice communication feature
- Questions number 2.1 and 2.4 from the survey:
    - How easy was it to use and figure out the voice communication feature?
    - Rate the overall audio quality of the voice communication feature.

Based on the feedback and reviews we got from the participants during these usability evaluation methods, we summarized the possible usability issues as follow:

1. **First-time players do not understand the feature.**

This issue was noticed during the prototyping testing session with first-time players. The voice communication feature in mobile games is relatively new, thus most of the players do not have any experience with this feature. It is difficult for first-time players of the game to understand why and how to use the voice communication feature. For this reason, it is recommended to add an interactive tutorial that helps the novice players in understanding and figuring out the voice communication feature in the game.

2. Discovering and controlling the voice control buttons is not easy.

The voice communication feature should contain some voice control buttons that allow players to mute or unmute the other player voice, and allow players to activate or deactivate their microphone when needed. These buttons can confuse the player if they are not clear and well designed. The buttons should use familiar icons or colors to the player in order to be easily identified and used. Participants mentioned that the used icons in the *Fire&Water* game were suitable because they look similar to known icons on other voice chatting applications.

3. Bad quality of the transmitted voice between the players.

It is very important to have a high quality of the transmitted audio between the players. Bad quality could cause a corrupted or delayed voice, which can negatively affect the whole game playing experience. Also, a bad quality implementation could cause an echo of the transmitted voice, which makes the conversation between the players annoying and useless.

4. Players confuse between the game sounds and the other player voice.

Usually, each game has its own sounds that are used to make the game more attractive. There are several different sounds such as a background sound, character moving sounds, firing sounds, and collision sounds. Adding a voice communication feature in a game can cause a confusion between the players' voices and the game sounds. During the performed playtesting sessions, three participants felt that the game characters sounds are confusing and interrupting the other player voice.

In order to avoid such an issue, the player should be able to mute the game sounds while keeping the other player voice. Another possible solution is to use different volume level for the players' voices and the game actual sounds, The player voices can have a higher volume level so the players can hear each other clearly.

5. **The voice transmission state of the other player is not clear.**

Voice communication is one of the features that cannot be seen clearly in the game. Therefore there should be visual appearing feedback that gives the players an informative indication about the voice transmission status. The player

should be able to recognize when the voice channel is connected and when it is disconnected, also the player should be notified about a weak network connection or high delay transmission situations. It is also useful to show visual signs of the other players status regarding voice control. For example, a player should be indicated if the other player is muted or if he does not receive the voice messages due to some sort of network errors.

6. **Headphones and external microphones are not technically supported.**

Mobile devices come in a wide range of differences and types, The voice channel should work on all kinds of targeted devices. Moreover, players would use different kinds of accessories such as wired or Bluetooth headphones as well as different kind of external microphones. During the evaluation sessions, we found that the voice functionality did not work on one specific device when using a wireless headphone, so it is important that the voice implementations should support such accessories.

6.4 Best Practices for Implementing Voice Communication Feature

This section will highlight some important notes and observations that were obtained throughout the usability evaluation sessions. We provide these notes as a list of best practices and guidelines for game developers in order to implement a good, usable voice communication feature in their games.

1. **Voice communication implementation should not affect the game performance.**

One of the most important characteristics of a good game is its high performance and smoothness. The game should not have any performance issues such as glitches, slowness, lateness or delay. Such issues will be a reason for players to quit the game as mentioned by several participants. Adding voice communication feature should be implemented and tested carefully to not affect the game performance or cause unexpected bugs.

Moreover, the quality of the voice communication itself should be kept at the highest possible level. Unclear sound, delay or voice echo are considered serious usability issues that negatively affect the gameplaying experience.

2. **Select the best voice implementation form that fits the game style and logic.**

There are several possible voice implementation forms that can be used to develop the voice communication feature. The best form of voice implementation depends on the game trend, logic and playing style. In *Fire&Water* game and similar games where the player must focus all the time on the game characters and their actions, Open-Voice-Call is better than Push-To-Talk form. This is because it is hard to focus on controlling the character of the game and at the same time pushing a button to talk every time the player wants to talk. In other game types, another voice implementation form could be better. The voice implementation form should be carefully selected and tested.

3. **Allow the player to have full control over the voice functionality.**

The player should have the ability to deactivate his microphone at any time during the game session, He should also have the ability to mute the voice of other players as he wishes. It is better to separate these abilities into two buttons, one for activating or deactivating the player microphone, and one to mute or un-mute the voice of the other player. This is because there could be some situations where the user does not want to hear the other players' voices, but at the same time wants to help them by sharing some information with them. This situations depend on the game logic and can be changed to better fit a game.

4. **An alternative to the voice communication feature should exist in the game.**

Voice communication between players in a multiplayer mobile game is very important and makes the game more attractive for players, but it should not be the only form of communication in the game. It is necessary to add another form of communication in the game that can be used in bad situations where the voice communication cannot be used. For example, in slow network environments, the voice communication may be difficult to use due to high delay. Also, not all of the players like to use voice. So there should be an alternative form of communication in the game such as text messages or visual messages. A player should be able to choose any communication form he likes and feels comfortable with. Also, the player should be able to use both of them easily and interchangeably.

Most of the participants of our usability evaluation sessions tended to use both the voice communication feature and the visual messages at the same playing session. One of the participants said: "It is better and more interactive to talk and send visual messages to the other player at the same time".

5. Ensure a high level of synchronization between the players' views.

The voice communication feature will be used in multiplayer games, and usually, in these games, a different partial view of the game world will be shown in each player screen. With these settings, the synchronization between the players' views is very important and should be kept at its highest level. For example, in *Fire&Water* game, if the game session starts a few seconds on one player device before the second player device, the game will be unplayable and unreasonable, this is because each player will be seeing different positions for the falling down characters. another important point is to synchronize the initialization of the voice communication channel when starting the game session. The voice communication channel should starts on both devices at the same time, otherwise, the first player might start talking to the second player before finishing the connection setup on the second player device.

6.5 List of Usability Heuristics for Voice Communication in Mobile Games

In this section, we present a set of usability heuristics that can be used to evaluate the voice communication feature in a multiplayer mobile game. The heuristics are driven from the usability issues that encountered players of the *Fire&Water* game and from the discussed guidelines and best practices for implementing voice communication feature. The heuristics are listed in Table 6.1.

Table 6.1 Usability heuristics set for evaluating voice communication feature.

Usability heuristics set for evaluating voice communication feature.	
1.	**First-time players should be able to easily understand the voice communication feature:** First-time players of the game should be able to understand why and how to use the voice communication feature. for example, the game can have an interactive tutorial that helps the novice players in understanding and figuring out the voice communication feature in the game.
2.	**The game logic should provide reasons for communication in order for voice communication to add a positive experience to the gameplay:** Voice chatting is more important and useful in collaboration games, where players communicate and cooperate with each other to achieve the game goals. Generally, voice communication feature will not be used by players if the game has no reasons for this communication.
3.	**Voice communication implementation should not affect the game performance:** The implementation of the voice communication feature should not affect or decrease the game performance or smoothness. Also, it should not cause any glitches, slowness, or delay in the game flow.
4.	**The transmitted audio should be maintained at a high quality:** The implementation should ensure a high audio quality of the voice communication feature. The players should be able to hear each other clearly and without a delay or echo.
5.	**The implemented voice communication form should fit the game style and logic:** The voice implementation form should be chosen based on the game playing style. Each implementation form has its advantages and disadvantages that should be considered when selecting an implementation form for a specific game.
6.	**An alternative to the voice communication feature should exist in the game:** Voice communication should not be the only available communication form in the game. An alternative (non-voice communication) form should exist. The player should be able to choose and switch between the implemented communication forms easily during a game session.

7.	**The game should allow players to have full control over the voice channel:** The player should be allowed to enable or disable his microphone, change volume levels or mute voices of other players.
8.	**The design of the voice control buttons should be clear and familiar to the players:** The voice control buttons that enable and disable the microphone and speaker should be well designed. Selected icons and colors should be familiar to the players and represent the state of voice (muted/unmuted).
9.	**The players' voices should be differentiated from the game sounds:** Players' voices and game sounds can easily interfere with each other and cause annoying experience for the players. The player voices should have a higher volume level than game sounds, or the player should be able to mute the game sounds while keeping the other player voice.
10.	**The players should be visually informed and notified about the voice transmission status:** The game should provide visual feedback that gives the players an informative indication about the voice transmission status. For example, the player should be able to recognize when the voice channel is connected or disconnected, and if the other player is muted or not.
11.	**The game view should be synchronized well between the players' devices:** The game playing session should start on all of the players' devices at the same time and keep the views on the devices synchronized. Also, the voice communication channel should be initialized on the players' devices at the same time.
12.	**Using external headphones and microphones should be supported:** The voice communication feature should work correctly on all smart-phones external accessories such as wired or wireless microphones and headphones.

7. CONCLUSION AND FUTURE WORK

In this experimental study, we implemented a multiplayer mobile game that contains a voice communication feature, then we used it to explore the usability of the voice communication feature in multiplayer mobile games. The purpose of exploring the usability of the voice communication feature was to find out:

1. The importance of voice communication feature.
2. The level of acceptance by different gamers for this feature.
3. The possible usability issues that might encounter players when using the voice communication feature.
4. The best practices and guidelines for implementing a usable voice communication feature.

In order to achieve our goals, we developed a simple android multiplayer mobile game called Fire&Water. The game allows two players to play in real time and collaborate with each other using an in-game voice communication feature. The game is designed to make the collaboration between the two players necessary to play the game. With this design, we encouraged the two players to use the voice communication feature during the game session, which helped us in performing the required usability evaluation methods on the voice communication feature.

The voice communication feature was implemented based on the WebRTC technology. We developed the voice communication feature in two different implementation forms (Open Voice Call and Push To Talk). We also developed a non-voice communication form that allows players to exchange pre-prepared visual messages. Each one of these communication forms allowed the players to communicate and cooperate with each other during the game session. These forms are different in their background functionalities and their usage. The objective of implementing these different communication forms was to assist the participants in making a comprehensive comparison during the different usability evaluation sessions.

We recruited around 40 participants with different playing experience level to participate in the usability evaluation of the voice communication feature. We performed several usability evaluation methods including A/B testing, play-testing, interviews, and surveys. While performing these evaluation methods, we focused on testing the usability of the voice communication feature in the game, not the whole game. In order to achieve high usability of the voice communication

feature, the evaluation methods concentrated on feedback and reviews from the actual players of the game.

In the early stage of the development, we created a prototype model to simulate the game interface and test the usability of the game workflow. We conducted A/B testing sessions to find out the best usable implementation form for the voice communication feature in our game. A/B testing method was also used to measure the effect of using the voice communication feature on the gameplay experience. We observed the participants while freely playing the game in playtesting sessions. The main objective of the playtesting sessions was to identify any usability problems and to determine the players' satisfaction with the game. After observing the participants in the playtesting sessions, we conducted structured interviews with open-ended questions to learn about the players' attitudes and beliefs surrounding the voice communication feature. In the end, we asked the participants to fill a short survey to document their demographic data and to accumulate quantitative data regarding the usability of the voice communication feature.

The results of the usability evaluations showed that the voice communication feature is considered an important feature that can enhance the gameplaying experience and add more fun and enjoyment to a game. It is also helpful for achieving a good cooperation and collaboration between the players of a game. The results also showed that the feature is accepted by a large group of players and they are willing to use it in mobile games.

During the implementation and evaluation of the voice communication feature, we found some possible usability issues that might encounter players when using the voice communication feature. We also derived some of best practices and guidelines for implementing usable voice communication feature. We also summarized these issues and guidelines and presented them as a set of usability heuristics that can be used to evaluate the voice communication feature in a multiplayer mobile game. With the generated set of usability heuristics, developers and usability evaluators can easily test the voice communication feature in any real-time multiplayer mobile game using the well-known usability heuristics evaluation method.

Voice communication is an important feature that can be added to multiplayer mobile games. In this project, we explored the voice communication

feature in the context of real-time multiplayer mobile games. However, there is still lots of enhancements and future work that can be done in order to cover more details and aspects of voice communication usability in mobile games. For example, the feature needs to be tested with more participants in order to get more accurate results and feedback. Also, the feature needs to be explored on different types of games, especially with multiplayer games that support a larger number of real-time players. Moreover, the feature can be tested with other different forms of voice implementation.

REFERENCES

App Annie, March 2017, "App Economy Forecast: Mobile App Store Revenue to Exceed $139B in 2021", https://www.appannie.com/en/insights/market-data/app-annie-forecast-2017-mobile-app-store-revenue-exceed-139-billio-n-2021/(Accessed: 10 April 2018).

Babich, N., 2017, "The Top 5 User Testing Methods", https://theblog.adobe.com/the-top-5-user-testing-methods/**,** (Accessed: 5 May 2018).

Badar, M. and Nikhil, T., 2013, Development guidelines for mobile multiplayer games, Royal Institute of Technology, Stockholm, Sweden, 24 p.

Bevan, N., 1997,Quality and Usability: A New Framework, Achieving software product quality, Tutein Nolthenius, Netherlands.

Carter, M., Wadley, G. and Gibbs, M., 2012, Friendly! don't shoot!: how communication design can create novel social interactions, Proceedings of the 24th Australian Computer-Human Interaction Conference, Australia, pp. 72-75.

Daud, E., Mokhtar, S. and Mohd, F., 2016, Usability heuristics in the context of control features on mobile games, 2016 International Conference on Information and Communication Technology (ICICTM), Kuala Lumpur, Malaysia, 4p.

Desurvire, H. and Wiberg, C., 2009, Game usability heuristics (PLAY) for evaluating and designing better games: the next iteration, Online Communities and Social Computing, third international conference, Los Angeles, California, 11p.

Gibbs, M., Wadley, G. and Benda, P., 2006, Proximity-based chat in a first person shooter: using a novel voice communication system for online play, Proceedings of the 3rd Australasian conference on Interactive entertainment, Murdoch University, Perth, Australia, pp. 96-102.

Google Play Game Service, 2017, "Guides and Concepts for Real-time Multiplayer",https://developers.google.com/games/services/common/conc-epts/realtimeMultiplayer, (Accessed: 10 April 2018).

Halloran J, Fitzpatrick G, Rogers Y. and Marshall P., 2004, Does it matter if you don't know who's talking? multiplayer gaming with voice over IP, In Proceedings of CHI 2004, ACM Press, Vienna, Austria, 1215-1218 pp.

REFERENCES (continue)

Jiang, J.R and Chen, H.S., 2007, Peer-to-peer AOI voice chatting for massively multiplayer online games, Parallel and Distributed Systems International Conference, Cambridge, USA, 9p.

Johnston, A. and Burnett, D., 2014, "WebRTC: APIs and RTCWEB Protocols of the HTML5 Real-Time Web", Digital Codex LLC; 3 edition, 350p.

Korhonen, H. and Koivisto, E.M.I, 2006, Playability heuristics for mobile games, Proceedings of the 8th Conference on Human-Computer Interaction with Mobile Devices and Services, Mobile HCI 2006, Helsinki, Finland, pp. 9-16.

Korhonen, H. and Koivisto, E.M.I., 2007, Playability heuristics for mobile multi-player games, Proceedings of the Second International Conference on Digital Interactive Media in Entertainment and Arts, DIMEA, Perth, Western Australia, pp. 28–35.

McPeak, A., 2017 **,** "The 4 Best Usability Testing Methods", https://crossbrowsertesting.com/blog/visual-testing/methods-usability-testing/ , (Accessed: 10 May 2018).

Nacke, L., Drachen, A. and Göbel, S., 2010, Methods for evaluating gameplay experience in a serious gaming context, International Journal of Computer Science in Sport, 9(2), 1-12 pp.

Nacke, L. and Lindley, C.A., 2008, Flow and immersion in first-person shooters: measuring the player's gameplay experience, Proceedings of the 2008 Conference on Future Play: Research, Play, Share, New York, NY, USA, 81-88 pp.

Newzoo Q2, 2017, "The Global Games Market Will Reach $108.9 Billion in 2017 With Mobile Taking 42%",Global Games Market Report, https://newzoo.com/insights/articles/the-global-games-market-will-reach-108-9-billion-in-2017-with-mobile-taking-42 , (Accessed: 10 April 2018).

Nielsen, J., 1994, Enhancing the explanatory power of usability heuristics, CHI '94 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Boston, Massachusetts, USA, pp.152-158.

REFERENCES (continue)

Pierre, 2016, "Axure 8: A Comprehensive Review" , https://www.smashingmagazine.com/2016/07/a-deep-dive-into-axure-8-a-comprehensive-review/, (Accessed: 15 June 2018).

Pinelle, D., Wong, N., and Stach, T., 2008, Heuristic evaluation for games: usability principles for video game design, CHI 2008 Proceedings - Game Zone, Florence, Italy, 10p.

Pinelle, D., Wong, N., Stach, T., and Gutwin, C., 2009, Usability heuristics for networked multiplayer games, Proceedings of the 2009 International ACM SIGGROUP Conference on Supporting Group Work, GROUP 2009, Sanibel Island, Florida, USA, pp.169-178.

Polson, P., Lewis, C., Rieman, J., and Wharton, C., 1992, Cognitive walkthroughs: a method for theory-based evaluation of user interfaces, International Journal of Man-Machine Studies, v.36 n.5, p.741-773.

Sanchez, J.L.G., Zea, N.P. and Gutierrez, F.L., 2009, From usability to playability: introduction to player-centered video game development process, Proceedings of the 2009 First International Conference, HCD 2009, San Diego, CA, USA, 65-74 pp.

Simatic, M., Craipeau, S., Beugnard, A., Chabridon, S., Legout, M.C. and Gressier, E., 2004, Technical and usage issues for mobile multiplayer games, 5th CGAIDE. Reading, England, 6p.

Sensor Tower, Aug 2017, "Sensor Tower Quarterly Reports Q2-2017 Data Digest", https://s3.amazonaws.com/sensortower-itunes/Quarterly+Reports/-Sensor-Tower-Q2-2017-Data-Digest.pdf, (Accessed: 10 April 2018).

Soomro, S., Fatimah, W., Ahmad, W.F.W. and Sulaiman, S., 2013, Evaluation of mobile games with playability heuristic evaluation system, Information System International Conference 2013 (ISICO2013), Vol. 2, Malaysia, pp.2–7.

Stumpf, C., 2018 , "6 usability testing methods that will improve your software", https://www.infoworld.com/article/3290253/6-usability-testing-methods-that-will-improve-your-software.html , (Accessed: 12 May 2018).

Traczyk, M., 2016, "Methods and Types of Usability Testing", http://blog.uxeria.com/en/methods-and-types-of-usability-testing/, (Accessed: 12 May 2018).

REFERENCES (continue)

Triebel, T., Guthier, B., Plotkowiak, T., and Effelsberg, W., 2009, Peer-to-Peer voice communication for massively multiplayer online games, Consumer Communications and Networking Conference, 2009. CCNC 2009. 6th IEEE, Las Vegas, NV, USA, 5p.

Ülger, G., 2013, Playability heuristics for mobile games using touchscreen displays, M.Sc. thesis, Middle East Technical University, Ankara, Turkey, 153p.

Wadley, G., 2007, Mundane metaverses: communicating by voice in virtual worlds, International Workshop on Social Interaction and Mundane Technologies, Melbourne, 4p.

Wadley, G., Gibbs, M.R. and Benda, P., 2005, Towards a framework for designing speech-based player interaction in multiplayer online games, Proceedings of the 2nd Australasian conference on interactive entertainment, Creativity & Cognition Studios Press, Sydney, Australia, 223-226 pp.

Williams, D., Caplan, S. and Xiong, L., 2007, Can you hear me now? the impact of voice in an online gaming community, Human Communication Research, 33 (4), 397-535 pp.

Xenos, M., 2001, Usability perspective in software quality, Proceedings of 8th Panhellenic Conference on Informatics with international participation, Cyprus, Vol.2, pp.523-529.

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APPENDIX

Appendix A Survey Data

Appendix A: Survey Data

#	Age	Gender	Experience	Q2.1	Q2.2	Q2.3	Q2.4	Q2.5	Q2.6
1	20-30	Female	I rarely play.	4	5	3	2	2	3
2	20-30	Male	I rarely play.	5	3	2	3	4	4
3	20-30	Female	I rarely play.	4	5	4	3	3	5
4	20-30	Female	I play every day.	4	4	4	2	4	5
5	20-30	Female	I play once a week.	4	5	4	2	2	4
6	20-30	Female	I play every day.	3	4	5	3	4	3
7	20-30	Male	I rarely play.	4	4	4	4	4	4
8	20-30	Male	I play every day.	4	5	4	1	4	3
9	20-30	Female	I play every day.	3	4	4	2	5	3
10	20-30	Male	I rarely play.	5	4	5	4	4	3
11	20-30	Male	I rarely play.	5	4	5	4	5	4
12	20-30	Female	I rarely play.	3	2	4	3	4	4
13	20-30	Male	I play once a week.	4	4	4	3	4	5
14	20-30	Male	I play every day.	5	5	4	3	3	4
15	20-30	Male	I play every day.	3	5	5	4	4	4
16	20-30	Male	I play once a week.	5	5	5	4	5	4
17	20-30	Male	I play once a week.	5	4	5	4	5	5
18	20-30	Female	I play once a week.	4	2	4	2	1	5
19	20-30	Male	I play every day.	4	4	4	2	5	4
20	20-30	Male	I play every day.	5	5	4	3	5	4
21	20-30	Male	I play every day.	4	5	4	3	3	5
22	20-30	Female	I play once a week.	3	4	5	4	4	5
23	20-30	Male	I play every day.	4	3	3	1	4	4
24	20-30	Female	I play every day.	3	5	5	3	5	5
25	20-30	Female	I've never played a mobile game.	2	3	1	3	3	3
26	20-30	Male	I play every day.	4	4	5	4	4	5
27	20-30	Male	I play every day.	4	4	5	4	5	5
28	20-30	Male	I play every day.	4	5	5	4	5	5
29	20-30	Female	I play every day.	4	4	5	3	2	4
30	20-30	Male	I play every day.	4	4	5	4	5	5
31	20-30	Female	I play once a week.	3	4	5	4	3	5
32	20-30	Male	I rarely play.	3	5	3	3	2	3
33	20-30	Female	I play every day.	4	5	5	3	3	4
34	20-30	Male	I play every day.	3	5	5	5	5	5
35	20-30	Male	I play once a week.	5	4	3	2	4	4
36	20-30	Male	I rarely play.	3	2	4	4	3	2
37	20-30	Male	I play once a week.	4	5	5	3	4	3
38	20-30	Female	I've never played a mobile game.	5	3	2	1	2	4
39	20-30	Female	I play once a week.	4	4	3	3	5	3
40	20-30	Male	I play once a week.	5	5	5	5	5	4