**ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY**

# GAMIFICATION DESIGN PRINCIPLES IN HEALTHCARE: A STUDY ON VITAL SIGNS MEASUREMENT IN PEDIATRICS AT SELF-SERVICE HEALTH KIOSK

**M.Sc. THESIS**

**Eren GÖKGÜR**

**Department of Game and Interaction Technologies**

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**MARCH 2020**

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**Thesis Advisor: Assoc. Prof. Dr. Hatice KÖSE**

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**ISTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ**

# SAĞLIKTA OYUNLAŞTIRMA TASARIMI PRENSİPLERİ OTONOM SAĞLIK TERMİNALİNDE YAŞAM BULGULARI ÖLÇÜMÜ ÇALIŞMASI

**YÜKSEK LİSANS TEZİ**

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**Oyun ve Etkileşim Teknolojileri Programı**

**Tez Danışmanı: Doç. Dr. Hatice Köse**

**MART 2020**

Eren Gökgür, a M.Sc. student of İTU Graduate School of Science Engineering and Technology student ID 529181008, successfully defended the thesis/dissertation entitled "GAMIFICATION DESIGN PRINCIPLES IN HEALTHCARE: A STUDY ON VITAL SIGNS MEASUREMENT IN PEDIATRICS AT SELF-SERVICE HEALTH KIOSK" which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

| | | |
|---|---|---|
| **Thesis Advisor :** | **Assoc. Prof. Dr. Hatice KÖSE**<br>İstanbul Technical University | ..... |
| **Jury Members :** | **Assoc. Prof. Dr. Hatice KÖSE**<br>İstanbul Technical University | ..... |
| | **Assoc. Prof. Dr. Sanem SARIEL**<br>İstanbul Technical University | ..... |
| | **Assoc. Prof. Dr. Güven ÇATAK**<br>Bahçeşehir University | ..... |

**Date of Submission : 15 February 2020**
**Date of Defense : 11 March 2020**

***To my friends,***

## FOREWORD

My dissertation “Gamification Design Principles in Healthcare: A Study on Vital Signs Measurement in Pediatrics at Self-Service Health Kiosk”, is an applied study that aims to question the effectiveness of gamification design in healthcare. I wrote this thesis for the graduation of the Game and Interaction Technologies at İstanbul Technical Univesity. I have been writing this thesis from February 2019 to February 2020.

Due to my interest in the gamification field, the project was jointly decided with Arcelik Innovation Department, at the time I was employed, and Dr. Hüseyin Kutay Tinç, a reputable professor from my undergrad studies. We together with my supervisor in Arcelik, Uğur Halatoğlu, decided on my thesis topic. The hardest part of the research was to develop a practical experiment including developing the application and measurement setup to study the effectiveness of gamification in a proper way. It would not be possible without the help of my teammates in Arçelik, in the field of medicals and electronics.

I want to say thanks to my supervisor for his absolute interest and assistance during the writing of the thesis. I am thankful to all of the mothers and fathers of each participant; without their assistance, the analysis could not be possible. The greatest thanks go to my advisor assoc. prof. dr. Hatice Köse for her constant assistance and guidance.

February 2020 Eren GÖKGÜR

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**ABBREVIATIONS**

| | |
|---|---|
| **AI** | **:** Artificial Intelligence |
| **BP** | **:** Blood Pressure |
| **ECG** | **:** Electrocardiography |
| **GUI** | **:** Graphical User Interface |
| **HIS** | **:** Hospital Information Systems |
| **HR** | **:** Heart Rate |
| **MDE** | **:** Mechanics, Dynamics, Aesthetics |
| **LTC** | **:** Long Term Condition |
| **SPO2** | **:** Peripheral Capillary Oxygen Saturation |
| **UTP** | **:** User Datagram Protocol |
| **UX/UI** | **:** User Experience / User Interface |

**SYMBOLS**

**P Wave** **:** de-polarization of the atria

**QRS Wave** **:** de-polarization of the ventricles

**T Wave** **:** re-polarization of the ventricles

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## GAMIFICATION DESIGN PRINCIPLES IN HEALTHCARE: A STUDY ON VITAL SIGNS MEASUREMENT IN PEDIATRICS AT SELF-SERVICE HEALTH KIOSK

## SUMMARY

Studies on improving user experience through gamification have gained importance. Different sectors have been practicing with game-like factors to be successful in their sectors for many years. With the aid of digitalization in recent years, new possibilities raised in terms of seeing examples of gamification in various industries that have no game-related origin. We may give an instance, where we are witnessing the practices of the gamification field in Healthcare. Even there are focused studies taking advantage of gamification in particular health fields. Specifically, medical examination for pediatrics is an open area that may yield promising outcomes once enhanced with gamification. Medical examination, which is not part of children's daily routine, may often be associated with uncertainties, and thus with worrying experiences, and is one of the areas which can be improved through a gamification design approach.

This research examines the gamification design of a self-service health kiosk prototype to get vital signs measurements in pediatrics. Analysis of the effect of gamification design on the accuracy of the vital signs measurements while providing the child with a comfortable experience with playful design is the goal of the study. This thesis begins with the industrial origin of gamification, the theories that gamification is derived from, the disciplines that gamification taps into and its positive effect on children's health by promoting adherence, increasing the accuracy of the vital signs measurement and reducing stress.

The methods regarding testing our hypothesis involve an application, vital sign measurement devices in a self-serving health kiosk, analyzing of the results, comparison of the results with normal values and our observation on the participants as well as the participants' remarks.

As we are in pursuit of observing the positive effects of gamification of vital sign measurements on children's health, we would like to observe three things, those are, promoting adherence, increasing the accuracy of the vital signs measurement and reducing stress. With the data at hand and relying on our observations, we may come into some preliminary facts that in the healthcare domain, by using gamification design principles we can promote adherence, increase accuracy and reduce pediatric patience's stress.

Exceeding the patient interests, healthcare providers can also gain from gamification technology through gathering insights into patients, pulled from usage data, a better comprehension of preventive care requirements.

## SAĞLIKTA OYUNLAŞTIRMA TASARIMI PRENSİPLERİ

## OTONOM SAĞLIK TERMİNALINDE YAŞAM BULGULARI ÖLÇÜMÜ ÇALIŞMASI

## ÖZET

Oyunlaştırma alanında kullanıcı deneyimini geliştirme üzerine yapılan çalışmalar önem kazanmıştır. Farklı sektörler onlarca yıldır iş hedeflerine ulaşmak için oyunlarda kullanılan elementlerden faydalanmaktadır. Son yıllarda, oyunlaştırma farklı sektörlerinde bir trend olarak ortaya çıkması çeşitli alanlarda akademisyenlerin, eğitimcilerin ve uygulayıcıların dikkatini çekti. Oyunlaştırmanın bu kadar trend olmasının nedeninin, dijital dönüşümle beraber daha ucuz teknoloji, kişisel veri izleme, seçkin başarılar ve oyun ortamının yaygınlığı gibi bir dizi yakınsama faktöründen kaynaklandığı öne sürülebilir. Son yıllarda dijital dönüşüm aracılığı ile, oyunlaştırma, daha önce herhangi bir oyunla ilişkili olmayan endüstrilerde fayda sağlayabilecek yeni fırsatlar yarattı. Bu endüstrilerden biri olan sağlık, oyunlaştırma kavramıyla kısa süre önce tanışmış ve efektif bir şekilde faydasını görmeye yeni başlamış bir endüstridir. Hatta belirli sağlık alanlarında oyunlaştırmanın avantajlarını ele alan odaklanmış çalışmalar bile vardır. Özellikle, pediatri hastaları için tıbbi muayene, oyunlaştırma ile umut verici sonuçlar verebilecek gelişime açık bir alandır. Çocukların günlük rutininin bir parçası olmayan tıbbi muayene, genellikle belirsizliklerle ve dolayısıyla endişe verici deneyimlerle ilişkilendirilebilir ve oyunlaştırma yaklaşımı ile iyileştirilebilir.

Dünya çapında, sağlık hizmetlerinin sunumunda hem acil hem de geniş kapsamlı zorluklar bulunmaktadır. Birçok ülke için demografik değişimler, bakıcıların hastalara oranındaki değişiklikler, sağlık hizmetlerinin sunulma biçimini yeniden düşünmeye zorlamaktadır. Bu dönüşümü ele almak için otonom sağlık terminalinin kullanımına dayanan yeni bir sağlık teknolojisi türü ortaya çıkmıştır. Bu sistemler çoğunlukla sağlık hizmeti tavsiyesi sağlamak için kan basıncı ve EKG gibi hayati işaretlerin alınması için kullanılabilir. Çalışmada kullandığımız otonom sağlık terminali, insanların çeşitli tıbbi ölçümler yapması, verilerine ulaşabilmesi ve belirli konular

hakkında doktorlara danışmasını istemesi için tasarlanmıştır. Hastane içi kullanımda, muayene öncesi sağlık parametrelerini ölçmek, tıbbi geçmişi olan hastaların sağlık bilgilerini toplamak, analiz etmek ve hekimlere iletmek üzere tasarlanmıştır. Sağlık terminalleri her tıbbi alt uzmanlık alanı için değiştirilebilir ve hastanelerde, tıp merkezinde, sağlık ocağında veya eczanede ayarlanabilir. Tez çalışmasının konu edildiği otonom sağlık terminali pediatri hastalarına hizmet vereceği düşünülerek oyunlaştırma tasarımı kullanılmıştır.

Bu tezin konusu olan çalışma, pediatride yaşam bulguları ölçümlerini toplamak için bir otonom sağlık terminali prototipinin oyunlaştırma tasarımını araştırmaktadır. Bu çalışmanın amacı, çocuklara eğlenceli tasarım ile daha rahat bir deneyim sunarken, bu oyunlaştırma tasarımının yaşamsal bulgu ölçümlerinin doğruluğu üzerindeki etkisini analiz etmektir. Bu makale endüstriyel oyunlaştırmanın kökeniyle, oyunlaştırmanın türetildiği teorilerle, oyunlaştırmanın içine girdiği disiplinlerle başlar. Devamında, genel olarak ve özellikle sağlık alanında, oyunlaştırma kavramları üzerinden, yaşamsal bulgu ölçümünün doğruluğunu, tedaviye uyum sürecini ve stresi azaltarak çocukların sağlığı üzerindeki olumlu etkisini özetlemektedir.

Sağlık hizmetlerinin teşhisinde, izlenmesinde ve klinik karar almada fizyolojik önlemlerin potansiyel kullanımının göz önüne alındığında ölçüm doğruluğuna ihtiyaç vardır. Önlemlerin klinik standartlara uyması gerekir. Bu durum otonom sağlık terminalinde oyunlaştırma elementlerinin tasarımı konusunda zorluklar getirir, tüm sorunlara cevap verebilecek bir tasarım nadiren karşımıza çıkar. Bu zorlukları ele alırken, ölçüm doğruluğunu etkileyen faktörlerin dikkate alınması gerekir. Otonom sağlık terminali ölçüm süreci, birden fazla bileşeni olan insan ve makine arasındaki etkileşim olarak düşünülebilir. Antropometri ve biyomekanik ile karakterize edilen geleneksel fiziksel durumları içerir. Bu faktörler ölçüm doğruluğuna katkıda bulunur ve vücut duruşu, ölçüm cihazı yüksekliği, ekipmanın mekansal düzeni ve benzer unsurları içerir. Örneğin, farklı duruşlar ölçülen sistolik / diyastolik kan basıncında %20'den fazla bir değişime neden olabilir. Başka bir bileşen, oyunlaştırmanın hastanın hissiyatını ölçmek ve etkilemek için önemli bir rol oynadığı bireyin psikolojik veya zihinsel durumu ile ilgilidir. Ölçüm sonucunu etkileyen zihinsel durumun bir örneği kardiyovasküler ölçümlerde hasta psikolojisinin ölçüm sonuçlarını %20 kadar etkilediği yönündedir. Doğru bir önlem almak önemlidir. Bir araştırmaya göre, diyastolik kan basıncının 5 mmHg tarafından hafife alınması durumunda hipertansif

bireylerin neredeyse üçte ikisine morbidite önleyici tedavi verilmeyecektir. Tersine, sistolik basınç 5 mmHg ile fazla tahmin edilirse hipertansiyon tanısı konan kişi sayısı iki kattan fazla olur. Bu nedenle, bir otonom sağlık terminalinde yaşamsal işaretlerin okunması için etkileşimli oyunlaştırma tasarımının dikkatli bir şekilde düşünülmesi gerekmektedir. Dolayısı ile tezimizde sorguladığımız hipotezlerimizden biri oyunlaştırma tasarım ilkeleri esas alarak ölçüm doğruluğunu geliştirme perspektifinden değerlendirilir.

Ölçüm doğruluğu dışında, oyunlaştırmanın etkilerini araştırdığımız bir diğer alan ise dayanıklılığı ve hastalıklarla mücadele motivasyonunu artırarak hastaların sağlığı üzerinde önemli ve olumlu etkilere sahip olması ve tedaviye uyumu teşvik etmesidir. Ancak başarı eğlenceli geri bildirim yoluyla uzun vadede hastalara hitap etmesine bağlıdır. Oyunlaştırma, hastalara ilişkin içgörüleri elde ederken, pediatri hastalarına daha kişiselleştirilmiş deneyimlerini sağlayarak daha iyi uyum sağlamalarını kolaylaştırır. Çeşitli akademik çalışmalar, sağlık hizmetlerindeki oyunlaştırılmış uygulamaların daha yüksek uyum, katılım ve motivasyon sağladığını ve sonuç olarak hasta refahını artırdığını göstermektedir. Bu çalışmalarda "eğlence faktörü" ile katılım oranları arasında pozitif bir korelasyon olduğu gösterilmiştir. Biz de bu sebepten dolayı oyulaştırma tasarım ilkelerini tekrar esas alarak tedaviye uyumu desteklediği hipotezini sorgulayacağız.

Son olarak, etkileşimli oyunların iyimser duyguları ve ödül sistemini harekete geçirerek hastaların esneklik ve tedaviye verdiği cevabı güçlendirdiği kanıtlanmıştır. Eğlenceli oyun, çocukların hastanenin soğuk ve boğucu atmosferini unutmasını sağlamak için tasarlanmıştır. Bir ölçüm yapılmadan önce, çocuklara kendilerini rahat hissetmeleri için talimatlar ve bilgiler verilir. Hastalar sürecin tam olarak farkında olduklarında ve ölçümün ne zaman ve hangi koşulda gerçekleşeceğinden tam olarak sorumlu olduklarında, kontrolde olmanın rahatlığını, dolayısıyla özerkliği hissederler. Oyunlaştırılmış süreci anlatı biçiminde ve tematik bir kavramla sunmak, onlara hastalıkla savaşmak için net hedefler verir. Bu da, ölçüm yapılırken hastaların daha esnek ve daha az stresli olmasını sağlayacaktır. Biz de bu noktada oyunlaştırma tasarım ilkelerinin pediatri hastaların stresini yenmesi konusunda fayda sağlayabileceği konusundanki hipotezimizi sorgulayacağız.

Deneyi test etmek için kullandığımız ilgili yöntemler, ölçüm süreçlerini konu olan sıfırdan geliştirilmiş bir yazılım üzerinden, otonom olarak hizmet veren bir sağlık

terminalinde yaşamsal bulguların ölçülmesi, sonuçların analizini, sonuçların normal değerlerle karşılaştırılmasıdır. Ayrıca hipotezimizi doğrulamamıza destek olması için katılımcıları gözlemlerken aldığımız veriler ve katılımcıların yorumlarını da içerir.

Yaşamsal bulgu ölçümlerinin oyunlaştırılmasının çocukların sağlığı üzerindeki olumlu etkilerini gözlemlemeye çalışırken, tedaviye uyumu teşvik etmek, yaşamsal bulgu ölçümünün doğruluğunu artırmak ve stresi azaltmak gibi için üç argümanı gözlemlemek istiyoruz. Eldeki veriler ve gözlemlerimize dayanarak, sağlık hizmetleri alanında oyunlaştırma tasarım ilkelerini kullanarak tedaviye uyumu teşvik edebileceğimiz, ölçümün doğruluğunu artırabileceğimiz ve pediatri hastasının stresini azaltabileceğimiz bazı ön bulgulara ulaştığımızı dile getirebiliriz. Hasta yararlarının ötesinde, sağlık hizmeti sağlayıcıları, oyunlaştırdıkları bu dijital sistemlerin kullanım verilerinden yola çıkarak hastalara ilişkin öngörü elde ederek, koruyucu bakım ihtiyaçlarını daha iyi anlamak için bu teknolojisinden de yararlanabilirler.

## 1. INTRODUCTION

Using game design components in settings where no game element is present, that the main intention is to stimulate and enhance user engagement has increased in interaction design in diverse applications ranging beyond productivity, economics, health, education. Gamification, for the last decade [1,2] is the hyped word in terms of boosting user engagement and increasing user behaviors, social synergy, or quality and activities' productivity. [3]. The aspired models are thought to arise in consequence of positive, intrinsically motivating [4], "gameful" experiences [5].

Using game-like systems by companies from different sectors to accomplish their business goals for a couple of years. Nevertheless, digitalization in recent years has formulated new possibilities when it comes to transferring gamification to businesses beforehand not affiliated with any sort of game [6]. A great example of the awakening of the notion of gamification happens in Healthcare, that we currently witness. Many converging trends promote the advantage of gamification in the healthcare sector. Various research [7], have revealed that gamification can significantly affect, the wellbeing of patients by encouraging endurance, promoting adherence to care, and improving willingness to combat sickness.

It exists urgent and far-reaching hurdles to the stipulation of healthcare, globally. Lately, a unique set of healthcare technology has advanced. The use of self-service kiosks such as Higi and Pursuant Health (formerly, Solo Health) are the perfect examples of the norm. Mentioned above companies are examples of vital signs collection involving BP, ECG in order to give health guidance [8,9].

What counts as success is, nevertheless, in the long course appealing patients with fun among friends, and while delivering continuous juicy feedback through intuitive user-interface. Above the benefit of the patients, the other advantages are that gathering insights into patients, extracted from interaction and health data, a greater judgment of need for predictive health issues and increased user engagement to pediatric care.

Gamification field applications are closely connected to social media and mobile, which goes hand-in-hand with artificial intelligence. AI capabilities in the gamification field will continue to grow in the areas of following user statistics and interpreting them for a more comprehensive tailor-made experience for the patients. Specifically, one of the AI technologies, computer vision technology, enables us to recognize the user's emotional state during vital signs measurement. These emotional states are defined in the literature [10,11]. The mentioned primary emotions are defined by a common facial character created by pulled or loosened facial muscles. Measuring these attributes may help us to provide a better patient experience by designing the flow to give a positive contribution to children's health by promoting adherence to the measurement. In our experiment, we recorded the facial expression of the participants to analyze in a future experiment.

This thesis starts with the industrial origin of gamification, the theories that gamification is derived from, the disciplines that gamification taps into. In this thesis, you will find the outlines of gamification concepts in action particularly in the healthcare domain and its positive effect on children's health by promoting adherence and increasing the accuracy of the vital signs measurement as well as reducing stress.

## 2. GAMIFICATION & GAME DESIGN

### 2.1 Background of Gamification and Literature Research

The terminology of "gamification" dates back to 2008, followed by the practices in the field of technology and healthcare experts within the early months of 2010, incorporates a wide range of game-related components into the business [1]. The most generalized and widespread definition states "gamification is the use of game design elements in nongame contexts" [1]. Gamification is widely accepted and adopted by companies to strengthen the initiation phase and retention of aspired behaviors [12], on top of that, the estimation says 60% of health officials in workplaces, in present, incorporate gamification components. [13,14].

As it can be observed in literature research (over 47,200 papers on Google Scholar; over 1.500 on Science Direct database (accessed on March 10, 2019.) the studies in the gamification medium is quite popular. This may suggest:

1) that accurately created gamification designs have the ability to affect users,
2) that minimization of different biases via experimental design
3) that information gathering makes it the most reliable way to discover its effects or its restrictions [7].

Identical terms are in the market and fresh terms keep being brought alive, such as "productivity games" [15], "funware" [16], "playful design" [17], "behavioral games" [18]. Furthermore, we can assert that gamification is standardized as the common term. In the meanwhile, gamification term is also open to severe discussions, essentially within the industry of games and the studies of games. Restlessness with current practices, simplicities, and discussions have driven some people to invent modified terms. A good example of that is from an academician, she describes "Alternate Reality Games" as "a game you play in your real-life" [19]. On the other side, another practitioner suggested substituting the name "gamification" with "exploitationware" [20], that grammatical politics that would more accurately depict the exploitation that

gamification probably causes. He also asserts that gamification disregards games' secondary characteristics over the primary elements. Adding, it fatally abuses and disrupts games. There is a mistake that games' attraction for oversimplified ones directed to extrinsic motivations.

The current main usage of the term gamification fluctuates among two similar ideas. Primarily to grow engagement, and universality of games in daily life [21,22]. Secondly, the more precise concept is the reason that games are created for fun, and because it has demonstrated to drive them with exceptional depth and continuation. Game elements transform real-life cases, which don't incorporate gaming elements, more delightful and charming as well [23].

There are client-looking definitions existing, often pronounced by consultants to describe gamification, for instance, the wide use techniques in the non-gaming business [22], solving real-life issues by game design framework [24].

In time, some studies have investigated playfulness as a sought-after UX concept. Although there is a sizable literature, there is no common definition for the state of playfulness: Seldom, there are associations like "pleasurable experience" [25] or "fun" [26], or any work surpasses task concept [27, 28]. Considering this, a researcher proposed some norms "ludic design", "ludic engagement" and "ludic activities", explaining "activities motivated by curiosity, exploration, and reflection" [27]. According to another description, gamification is mainly, a design method dedicated to enhance or reconstruct real-life scenarios [1].

In outlining gamification, a group of researchers [5] asserts gamification summons the same experiences when we play games. Some researchers [1], in contrast, indicate that the elements used gamification identical to those in games.

In the last decade, gamification has appeared as a trend within various areas. Indeed, gamification is far from being a firsthand idea, there are prior implementations in marketing involving points badges and bonuses, grades, and degrees. [29]. The growth of gamification is made possible by a few uniting elements, involving technology becoming affordable, information availability, and the predominance of the games [30]. Game studies can be included in the list, which remains to explain a methodically examined framework, which brings about immersive experiences, feeling of fun. [31]. Therefore, a more complicated interpretation of gamification is [32] "behavioral

management technique". Alternatively, the gamification studies concentrate on the decisions, which are consolidated by a certain measure of consideration given to motivation and teachings extracted from game design.

In gamification, creating a particular outcome is the main intention such as increased learning [33], increased health [34]. Gamification is closer to game design studies, rather than games as a concept as its motivational as well as behavior outcomes [35]. This reasoning is the answer to understanding gamification studies. Designing a game where the play is relevant is not fundamentally a goal of the designer. There is the case that, fun is not the core aspect of gamification; for example, some researchers [36] asserted a user training activity can be improved by adding a narrative only. Cases like this, play is unnecessary.

Gamification may be characterized as a post-positivist concept of game studies that examines the different study methods, and matters applied to supplement existing real-world processes with game elements. A researcher [37], suggests a physical existence that is observed through subjective review. It would be right to say, gamification can be classified as a discipline under game science. It also shares literature research and game factors toolkit with various other disciplines, however, it has uniqueness in focusing on the design of gamification systems for altering real-life without designing a "fully-fledged" game.

Moreover, the elements of gamification are not as magical as caused by complete games [34]. Provided that, it is required to examine if progress bars affect a process, the people may be selected to experience progress bars or the nonexistence of progress bars and choose a meaningful outcome-based upon analytical tests regarding which test converged more into desired outcomes.

An additional description of the gamification system is an application, helps people to satisfy their needs, gives an order to their lives. In some examples, Gamification provides online health services to users and users are expected to nurture their health back faster by fulfilling systems [38].

### 2.2 Gamification as Game Design Methodology

The particular methods to alter the real-life process by adding game design elements to gamify are the primary aim of literature. The gameful design may be explained as

the method of “designing for gamefulness, typically by using game design elements” [1]. One of the methods of gamification is gameful design but is distinguished from the more general notion of gamification, involves the aim of designing for a target outcome, that creating a gameful activity, meanwhile, gamification may employ purpose. For instance, when non-game processes enriched with progress bars [39] cannot be considered gameful but employs gamification. This case is not appointed to perform the experiment in a gameful way. Alternately, this enables us to benefit from the motivational influences of progress bars to make the survey fulfillment behavior, differently. Some studies criticized and found manipulative or immoral when there is no gamefulness in gamification design. [40] In management field gamification systems, we see improved command over user behavior once we introduced points, badges and leaderboards which likely does not consist of gameful design.

A researcher reviewed [1] the extent gamification literature into a structure that involves components. They are separated according to intend. The first is the game interface, which is interaction components [41]. Stages, progress bars, competitive boards are examples of these cases. The second level basically game mechanics. [42]. The third level, game design principles that of gameplay and goals" [43]. Eventually, the most obscure one is the game design method, which involves, testing the gameplay and design that is centered on the gameplay [44,45]. Choosing the fittest gamification method differs from case to case and no common agreement on for such design is held [46] a several were suggested. For instance, using the tiniest distinguishable factors in the user’s abilities is called skill atoms.[47]. This practice applies as, continuous feedback circle of skill atoms of which can involve game elements. Therefore, the goal of each step in the design process is to facilitate changes in and progress toward achieving the designated goal. In a contradiction, some researchers [35] used a method [48] to introduce story, plot, scenario create levels in a real-life case to make it seem like a game. Once complexity in the real-life advances, the distinct area among the game and gamified system is more obscured. Lastly, we may say the structured type of play can be considered as games [49], however, the play is only a sub purpose of gamification.

Gamification sometimes doesn't include play however, in the game literature, the terms game/play are used correspondently [50]. It’s claimed that the unique form of play is called games under specific rules. There is an emphasis that play is associated with the

player and so the game with rules [49]. Rather, users of gamified systems sometimes don’t play and it may be a no-rule game. So, a gamified system would not surely focus on play to accomplish the proposed result except, the goal is explicitly defined as play.

# 3. HEALTHCARE

## 3.1 Self-Service Health Kiosk

Globally, there are both urgent and lengthy challenges for healthcare. For most of the world's population, evolving conditions on demographics, growth in LTCs (Long Term Conditions) and the ratio of healthcare professionals to patients keep us searching for a better way for the provision of healthcare. To address this transformation, healthcare technology is developed, which is to use autonomous terminals in other words kiosks [8,9]. Vital sign measurements involving BP and ECG are now done by specialized kiosks for advancing healthcare.

The self-service healthcare kiosk is designed for people to do various medical measurements and prompt them to consult physicians about particular issues. In-hospital use, it is designed to measure health parameters, collect, analyze, and convey health information of patients including the medical background to physicians before an examination. Kiosks can be modified for each medical subspecialty and set at hospitals, medical centers, health clinic, or pharmacy.

According to the research by Grand View Research, an estimation says ECG measuring devices to reach USD 7.63 billion by 2025, growing at a CAGR of 5.8% from 2017 to 2025 [51].

According to a HIS healthcare consultancy, healthcare kiosks will more than double by 2020. Referring to another research, the companies employ above half a thousand people, it's typical for 30% of them to have self-service kiosks in the US [52].

It's essentially a human factor engineering topic, whose literature has hundreds of applicable design rules, considering the physical characteristic of the self-service kiosks [53]. Every population has different statistical physical data, which engineers can use to apply to provide a solution for the target population [54]. These engineering methods as well as user interfaces are very rich in guides in the works of literature [55,56].

The self-service health kiosk is equipped with a smart voice and visual assistant function for people to guide them to carry out their measurements such as blood pressure, oxygen saturation measurement, respiration rate, weight and height measurements along with electrocardiography measurement. The results are printed out at the end of the gamified experience along with the rewards and badges earned. Patient identification by face recognition is also included in the kiosk.

### 3.2 Accuracy of Vital Signs Measurement

Addressing the mentioned above set of guidelines could be helpful in the design of self-service healthcare kiosks considering in mind the factors of both the environment and the users. This, however, may not always indicate that we have a 100% guarantee on the accuracy in terms of vital signs measurement.

There is a requirement for accuracy of the measurement provided that in measures of physiological characteristics under healthcare, monitoring, diagnosis and decision making. Measures need to follow clinical standards. This requires tests upon designing the gamification elements of the kiosk as no solution can cover all the issues. In approaching these difficulties, it assists delving deep into sub-problem, considering the factors that affect on measurement accuracy. The self-service kiosk measurement method may be viewed under the terms as an interaction among machines and humans, consisting of many elements. These elements incorporate regular physical aptitudes, as described by anthropometrics and biomechanics branch. These factors affect the accuracy of measurement and include features such as posture, the height of the device which makes measuring, the physical organization for tools. Such as, there is a report that asserts, systolic/diastolic blood pressure can take highly different values sometimes more than 20% when postures of the patients are not correct [57]. Gamification plays a substantial part to gauge and affects the patient's mentality which is very important when we think of an emotional state that can affect the outcome of the measurement. An example of a mental state affecting the outcome of the measurement is observed in a study on the cardiovascular department for cardiac-related measures, where the difference is above 20% [58].

Getting an accurate measurement is important. According to a study, If diastolic blood pressure is underestimated by 5 mmHg, almost two-thirds of hypertensive individuals will not be given morbidity prevention. Conversely, if systolic pressure is

overestimated by 5 mmHg, the number of people diagnosed with hypertension is more than double [59]. Accordingly, the form of an autonomous health terminal for the getting of vital signs requires thoughtful attention.

Once we speak about the UI, academicians often researched the core of ergonomics and effectiveness of practicing various interactive elements, to check tools; a relatively small number of them have studied how to optimize the features of tools, to maintain the measurement accuracy. Research on UI [60] and compared the effectiveness of different input modalities, for instance, touch screens usage versus hand-operated controls and physical factors [61], multimodal interaction techniques [62] and alternative structuring of task instructions [63]. The gamification design principles of self-service health kiosks are mainly evaluated for increasing measurement accuracy. Therefore, the measurement accuracy of the vital signs of the pediatric patients shall be compared and contrasted between the gamified solution implemented kiosk and kiosk with standard measurement procedure.

### 3.3 Promoting Adherence

Gamification is a crucial enabler when obtaining insights of patients, drawing usage data so as to reach improved adherence of pediatric patients by providing them a more personalized experience.

Various academic studies show that gamified practices in health care provide higher participation, participation, and motivation and consequently increase patient well-being. In these studies, it has been shown that there is a positive correlation between “fun factor” and participation rates [7].

HopeLabs developed an online game named, Re-Mission to help children fight with cancer. Players control a flying robot fight against cancer cells and tumors while using treatment techniques. The research shows that the emotional and motivational state of the players is activated by the game. This enables such behavior and emotions that improve users' commitment and willingness to treatment [64].

Founded in 2013, Oscar Health sets its aim for gamification fighting against chronic diseases. It’s a leading example of the company for future healthcare providers. The partnerships gave the company an upper hand when it comes to creating a variety of

games to increase health conditions. They cooperated with Misfit to provide wearables to promote healthy activities. Also, Oscar encourages the use of telemedicine [65] to observe the patient's health.

### 3.4 Reducing Stress

Endurance and activation of upbeat feelings can be achieved with games with rewards for patients, which is proven in research [66].

The playful experience is designed to make children forget the cold, suffocating atmosphere of the hospital. Prior to a measurement being taken, a set of instructions and information are provided to pediatric patients to make them feel relaxed. When the patients are fully aware of the process, and in charge of exactly when and on which condition the measurement would take place, they feel the comfort of being in control, therefore autonomy. Presenting the gamified process in a narrative format and thematic concept gives them clear goals to fight for. This, in turn, would enable the patients to be more resilient and less stressful while the measurement is taken.

# 4. UX/UI FOR CHILDREN

## 4.1 Comparison of Voice and Touch Interface

Self-service health kiosk is an automated medical measurement platform that enables pediatric patients to do various medical measurements with the help of the voice and visual assistants. Audiovisual auxiliary methods the output channels in UI. Visual is the preferred over audio. A study shows multiple auxiliaries is demanded [67]. We know that people rely more on visual feedback. As the patient journey in the self-service health kiosk presents itself as a single-task condition, meaning measures are taken in once at a time, it's convenient to put visual interface as primary and keep the voice as a second option.

## 4.2 Children Experience

Measuring vital signs requires an appropriate approach to the child's age and personality. In newborns, there are no problems with fear of strangers or examinations. However, to keep the child calm, talking with the child in a low voice and touching with a warm hand make the process easier. To show an object that will be of interest to a child in infancy, or to give the object to his hands, to talk to him, if he is overreacting, a significant portion of the measurement must be carried on the lap of the participant. In our experiment, I did not include this age group as our target group.

On the other hand, talking to pre-school children, asking questions that will attract their name and interest, giving them the equipment to be used during the examination and getting them to know them; and dialogue with school children and older children in a manner that caresses their pride [68]. When designing the content of the gamified system, I particularly paid attention to create an experience to fit the needs of pediatric patients.

Essentially, there is a requirement for the Graphical User Interface (GUI) to be considered separately. Apart from ergonomic design and external factors, the smoothness of intended operations relies on neatly considered GUI [53]. For example,

before the measurement starts, I designed a set of instructions for the user to guide him through the process by presenting a human hand-like figure showing how to grasp the ECG bar. GUI prepares pediatric patients (e.g. calms the patients before the operation). Sometimes, it very valid to give healthy living recommendations or educating patients in regard to staying in healthy conditions through the GUI.

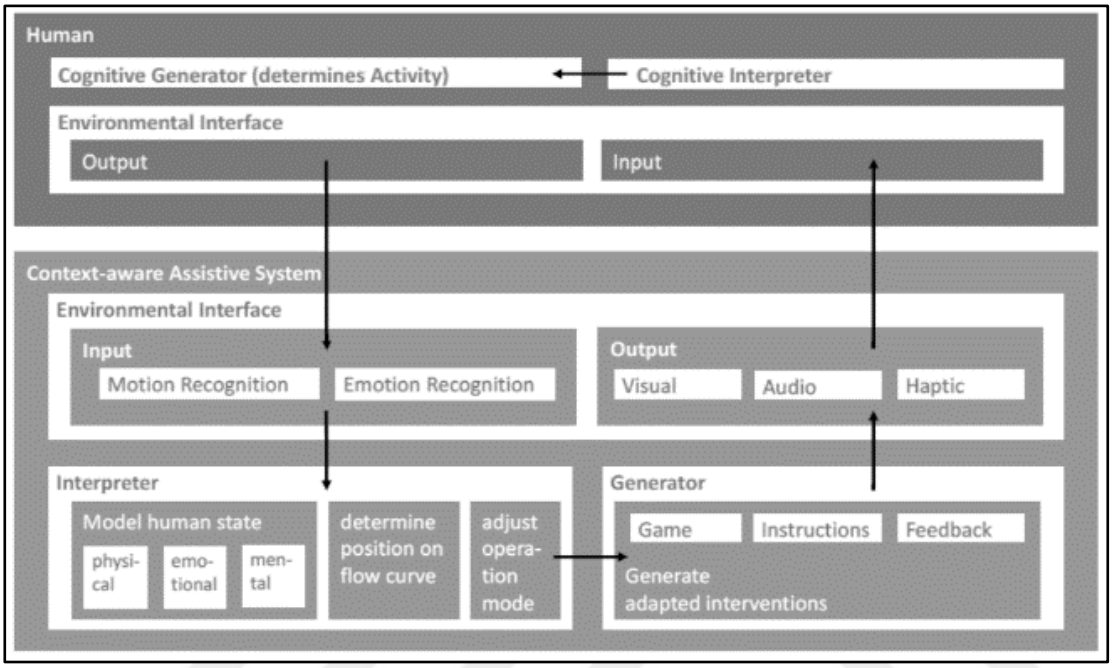


**Figure 4.1 :** CAAS framework

Context-aware assistive systems (CAAS) is a detailed model of using gamification framework in real-life scenarios (Figure 4.1) [69]. Flow is the intended goal of any gamification design, that is included in this framework. Csíkszentmihályi describes flow is a state of optimal experience characterized by being fully focused and engaged in an activity[70].

# 5. METHODOLOGY AND EXPERIMENT SETUP

## 5.1 Design

### 5.1.1 General Workflow

The general workflow mainly consists of getting the measurement order form HIS, taking the vital signs measurements, and sending the report of the measurements to HIS. HIS stands for Hospital Information System that handles everything related to electronic hospital records (Figure 5.1).

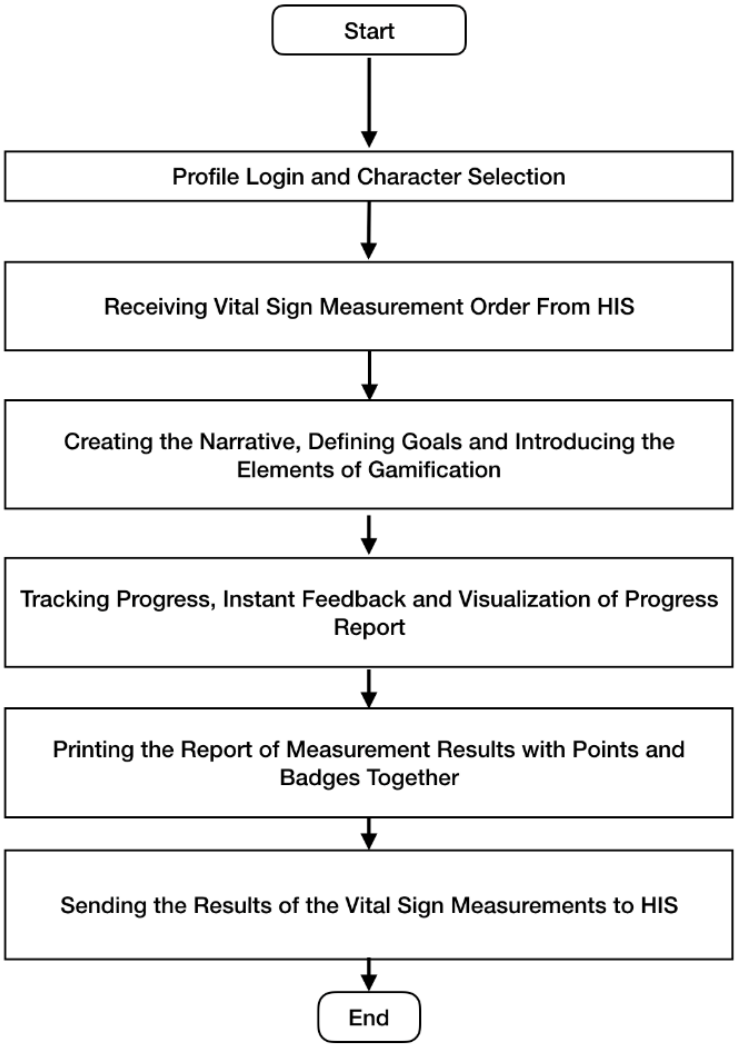


**Figure 5.1 :** General workflow

### 5.1.2 Gamified System Workflow

The self-service health kiosk employs various gameful sections, let's call these missions, for each measurement as well as the main section sitting as a meta-game between missions. The system has a total of 5 sections, as well as the main section listed below:

1. Main Section
2. ECG Section
3. SPO2 Section
4. Blood Pressure Section
5. Weight and Height Section

In the experiment, only the Main and ECG section are used to carry out the inspection. SPO2 and Blood Pressure are designed and implemented but were not used in this experiment due to keeping the focus on one single measurement.

#### 5.1.2.1 Main Section

At the beginning of the process, vital sign measurements are introduced to the pediatric patient with a moving narrative (Figure 5.2). This allows the patient to get a preliminary idea of the process to be experienced. The story employs the feeling of discovery in the patient while creating a clear goal (Figure 5.3). The goal gives the patient the feeling of self-determination enabling the patient to foresee what to expect.

In this section the patient is able to select an avatar, chose a nickname and plan the order of vital sign measurements, namely mission, he/she would like to take. For the ease of experiment, in our study with volunteers, we decided to make the selection of the avatar a nickname default as well as choosing the first and only mission as ECG section.


**Figure 5.2 :** Narrative

In this pursuit, the gameplay continues with the avatar selection. The avatar has a progression system that can evolve as a result of the measurements performed.


**Figure 5.3 :** Clear Goal

There is a progress in the patient's experience; It is aimed to give a feeling of success by employing game dynamics such as points collection, badge awards (Figure 5.4). The patient's realization of these steps with his / her consent and the narration of the process contribute to the preparation of a calm and comfortable measurement environment. Each of the vital sign measurement screens is enriched with a playful discover the island concept in the context of the story and theme.

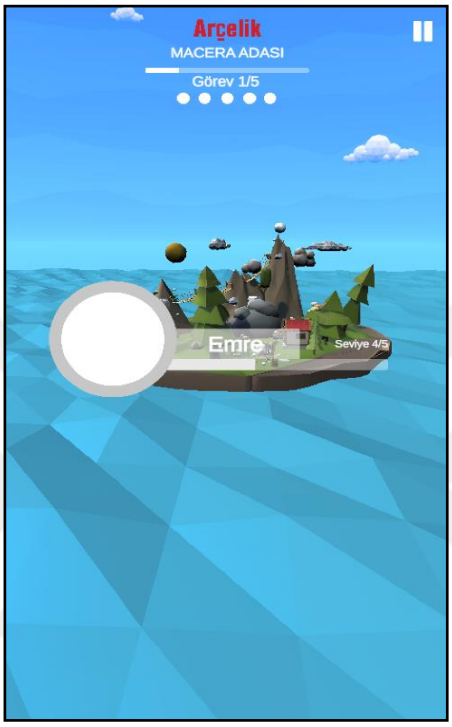


**Figure 5.4 :** Progress bar

Each measurement is defined as a task within the context of gamification and the experience score to be obtained if these tasks are completed (Figure 5.5). With the completion of the tasks, experience points are gained and the events are monitored by the progress bar. Then the progress is shown to the patient in the form of instant feedback.


**Figure 5.5 :** Awards

### 5.1.2.2 ECG Section

ECG section consists of an ECG (electrocardiography) measurement of the pediatric patient. This measurement is done through the patient putting hands-on 2 dry handle electrodes. This process takes 1 – 1.5 minutes and in a non-invasive way (Figure 5.6).


**Figure 5.6 :** ECG start

ECG workflow starts with narrating the aim of the mission. The patient is then, offered a choice to select the bike. This gives a feeling that the patient is in control of the process and the experience is tailored to the patient. Upon bike selection, the patient is instructed the desired behaviors. There are animated hand models that demonstrate the holding position to the ECG bars (Figure 5.7).

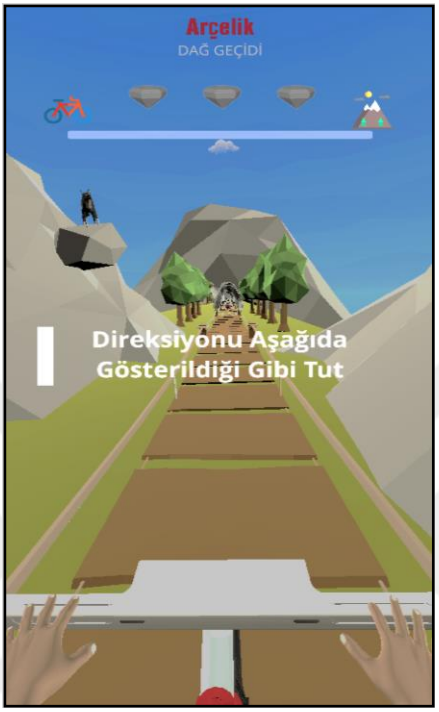


**Figure 5.7 :** Animation

Once the patient feels ready and holds the bars, the measurement starts as well as the cycling. So, the bike starts moving as the measurement is taken. As cycling and measurement are carried out, the progress bar illustrates how much of the activity is remaining. There are collectible diamonds on the way through the goal. There is a very subtle relaxing cycling sound while the bike moves on. This aims to keep the heart-rate of the patient in normal conditions. Once the bike makes it to the end of the bridge the measurement is finished. The whole section takes up to 1.5 minutes maximum.

While doing all that, I tried to present the introductions with simple instructions in 3D animations. Therefore, enabling the user to get what is going on and what to expect throughout the measurement.

At the end of the ECG measurement, the patient's ECG values are measured, experience points are collected and the game proceeds into the next mission. The figure below describes the ECG workflow (Figure 5.8).

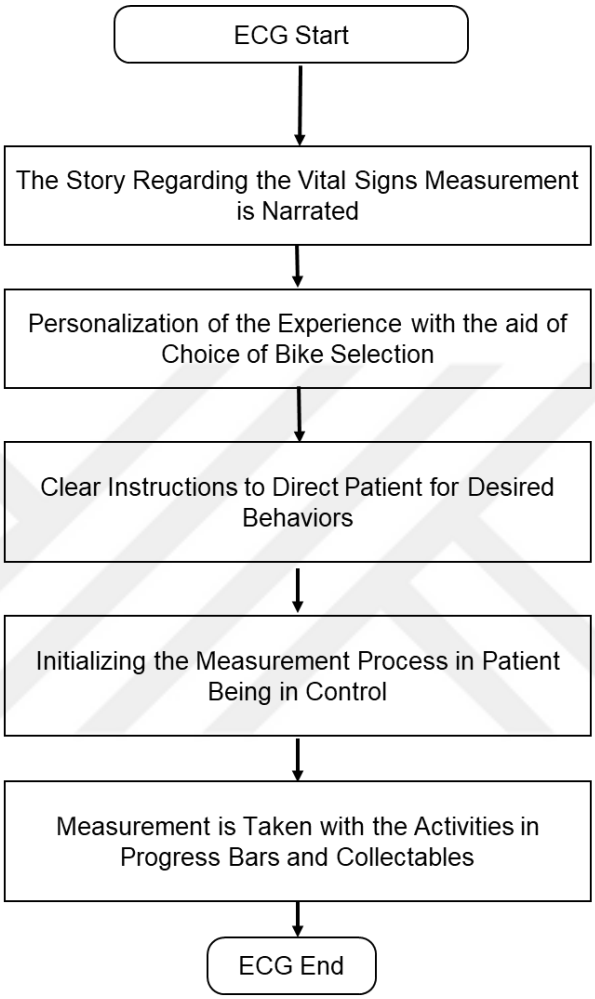


**Figure 5.8 :** ECG workflow

### 5.1.3 ECG Sensor: Max30003

It's worth mentioning the technical underlying of the measurement system's logic. The ECG sensor used in the experiment is Ultra-Low Power, Single-Channel Integrated Biopotential Max30003 component. The chip is greatly performant for the clinic side and sports purposes, including energy saving. The powering-up sequence guarantees no harm done on itself. The single-lead sensor is used for ECG measurement and Arrhythmia Detection. Below is the illustration of the functional diagram of the sensor chip (Figure 5.9).

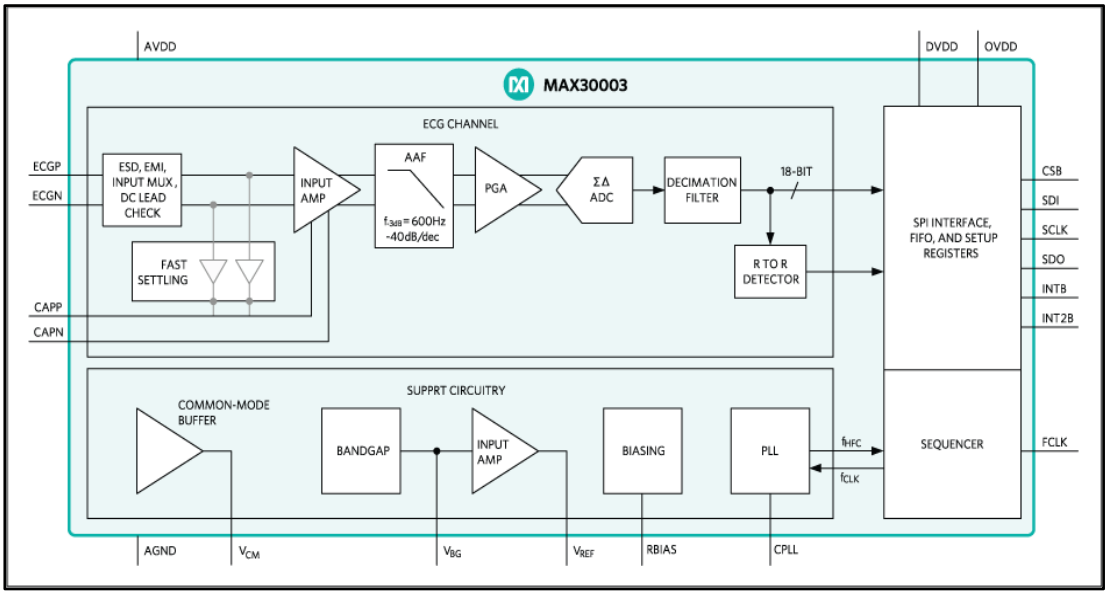


**Figure 5.9 :** ECG sensor chip

In broad terms, the sensor reads the voltage difference of both hand palms in the millivolt unit. The voltage difference is read 120 times in a second. Then a specific algorithm analyses the measurement and draws the graph of the values. The algorithm addresses the arrhythmia if there is any.

### 5.1.4 Game Engine: Unity

All the environment is created in Unity 2018.2. As the patient holds the ECG bars, the sensor signals ‘leads on’ information so the program understand measurement can be taken. As the ‘leads on’ information are communicated through UDP connection, Unity handles the received information and activates the physics component of the bike game object. As long as there are the ‘leads on’ signal received from the sensors, a specific physical force is exerted that enable the bike to move. When there are no ‘leads on’ signal is received from the ECG sensor, meaning that the patient is not holding the bars, therefore measurement is not taken, the physics component gets deactivated and the bikes stop. The measurement stops once the required amount of ECG values is collected, in other words, the bike gets to the finish line (Figure 5.10).

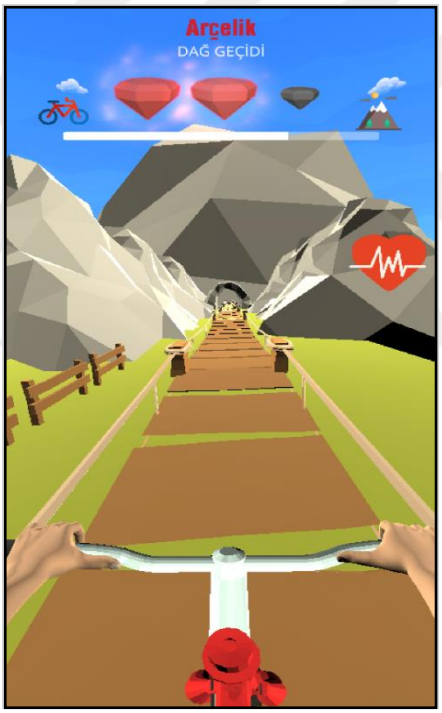


**Figure 5.10 :** ECG collectibles

### 5.1.5 Fixing External Factors

I did not intend to hinder the influence of all the external factors but instead aim to keep them constant. In other words, I tried to assess the effects of the gamified system while keeping all the other parameters so as to say external factors fixed.

### 5.1.6 Utilizing Avatars

The study shows avatar feedback is very effective particularly those that are customized for us makes us do harder exercise while watching the avatar lose weight [71]. In the study, the participants who had personalized avatar feedback did almost ten times more exercise than those you did not have an avatar.

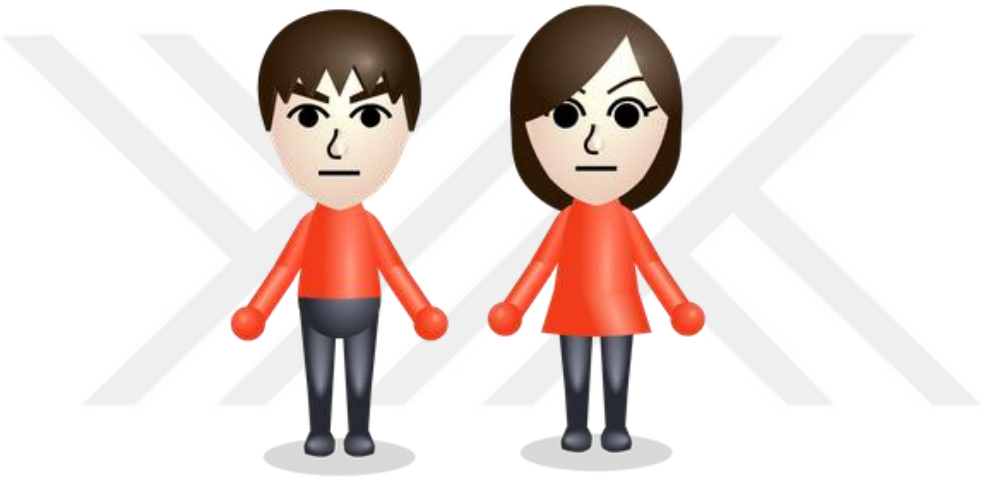

**Figure 5.11 :** Wii avatars

That bodes well for the potential use of Mini-like avatars at home or at gyms, where people are more likely to work out in front of screens (Figure 5.11). (And, in fact, many home fitness games, including Wii Fit and EA Sports Active, use avatar feedback to engage players in harder workouts.) The researchers theorized that seeing virtual versions of themselves doing a positive activity stimulated memories of the subjects' own real-life positive experiences, making them more likely to reengage in the activity.

This is a good choice to use cute avatars. Wii and EA Sports, are great examples of using avatars to get the people into action (Figure 5.12). In the studies, it is argued that watching virtual avatars, contributes to the overall experience.


**Figure 5.12 :** EA Sports Active avatars

An academician has put forth a claim that there is an emotional bond to virtual avatars. The avatars appear to be adorable defenseless actors, that are modified to seem in that way, incite a designed human want to sustain and think about them. “Time spent playing with them feels like care-taking, an act of responsibility and altruism,” she explains. She argues, we develop compassion for them and spend resources on their prosperity [72]. We feel more like caregivers when we make our avatar characters happy.

The feedback of our avatar’s wellbeing is not apparent as badges, coins, and accomplishments. As we keep on figuring out how to inspire ourselves by applying the best structure techniques of games, we will learn more [39].

Considering the findings mentioned above, I included avatar selection at the beginning of the flow which accompanies patients throughout the vital sign measurement journey. That being said, I introduce using personalized avatars as an element of a gamification design principle for our case.

# 6. TEST AND RESULTS

## 6.1 TEST

The execution of the experiment is done with 3 children aged 5,7 and 11. They all seemed to be at their very normal metabolism. The measurements were done in the R&D office in Arçelik in the ITU Teknokent office. Therefore, the environment was not similar to those at the hospital where this kind of gamified product may take place in the future rather than the office environment.

Measurements of the patients are carried out on a sequential basis where they had the environment to see each other's measurements as it's likely to be that way in the hospital environment. As we observed, watching other patients playing the game, created anticipation and excitement (Figure 6.1).

**Figure 6.1 :** Measuring Environment (First Participant)

During the experiment, I captured the participants' faces for further studies in regard to analyzing the correlation by detecting their feelings and ECG values. However, for this stage of the thesis, we chose to limit our observation to the accuracy of vital sign measurements, promoting adherence and reducing stress.

The experiment started with the first child aged 5. Without giving any prior information, I asked the children to sit in the kiosk and told him, we will play a game. His sister, aged 7, and other child aged 11 was among the audience where they can observe what is going on. As the child was not capable of reading and writing, I voiced over the sentences appearing on the screen. As the visuals and animations were self-explanatory, the child aged 5 almost completed the measurement with non-to little external direction. He seemed quite enjoying the experience and showed no indication of stress. At the end of ECG measurement, he was very insistent to try it again which was a promising indicator of high adherence rates.


**Figure 6.2 :** Second Participant

The second participant aged 11 had read and writing competency, and the bigger sister of the first participant. She seemed quite eager trying for the measurement for the first time. Observing her brother playing the game, built up excitement for her, that was very obvious. This time, I did not interfere, and she got her measurements taken without anyone stepping in. I also recorded her getting the measurement for further analysis of her feelings by facial impressions (Figure 6.2).

**Figure 6.3 :** Third Participant

The last participant was aged 7, female, capable of reading and writing. She also watched other participants experience the process so very content with trying on her own. In her case, we did not run into any complication, the procedure went as planned and we took the measures. She was the only one, who understood that while she was playing the game, we took her measurements. We saved her ECG values; I again recorded her video for further analysis (Figure 6.3).

## 6.2 RESULTS

### 6.2.1 ECG Measurements

We measured the ECG values of the 3 participants. After the initial measurement, we collected raw values of voltage difference of both hand palms in millivolt unit 120 times per second. Considering, for every child, the measurement took place for 1.5 minutes, we collected roughly discrete 7.500 raw voltage difference values (Figure 6.4).


```
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{"command": "ecg-data", "data": {"index": 7527, "value": 591.7685170167886}}
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{"command": "ecg-data", "data": {"index": 7537, "value": -359.918311922432}}
```


**Figure 6.4 :** Raw ECG values

Following, an algorithm, which is uniquely developed in Arçelik Innovation Department, analyzed the raw values to draw the graph of ECG values and show some other indicators in milliseconds such as;

- Heart Rate (HR)
- SDNN: Standard deviation of beats or N-N internals. In other words, the difference in the duration among heartbeats.
- PR: Duration between P and R beats
- QT: Duration between Q and T beats
- QRS: Duration between Q-R-S beats

The algorithm addressed the arrhythmia if there is any.

### 6.2.2 Analyzed Results of the Measurement

Before sharing the analyzed results of the ECG measurement of the 3 participants, it's worthwhile to explain the PQRST waves in general for better understanding (Figure 6.5).

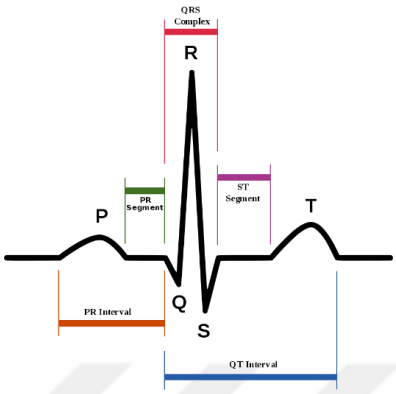


**Figure 6.5 :** PQRST beat

- P Wave stands for de-polarization of the atria
- QRS Wave stands for the de-polarization of the ventricles
- T Wave stands for the re-polarization of the ventricles.

With that being mentioned, here are the analyzed results of ECG measurements;

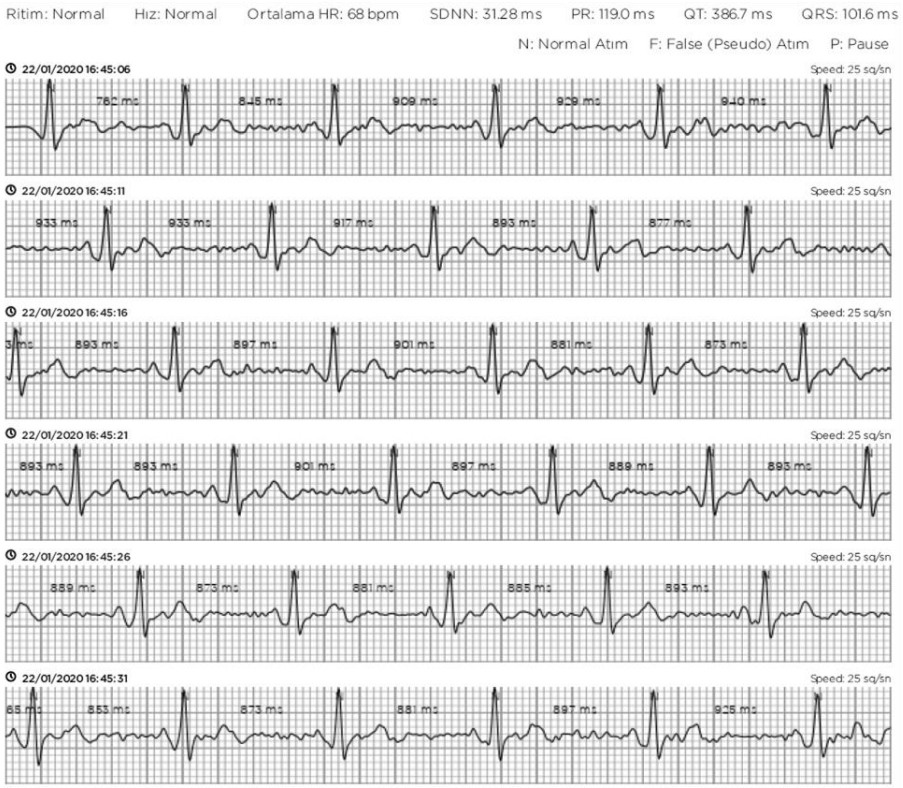


**Figure 6.6 :** ECG Analyzed Result of Participant-1

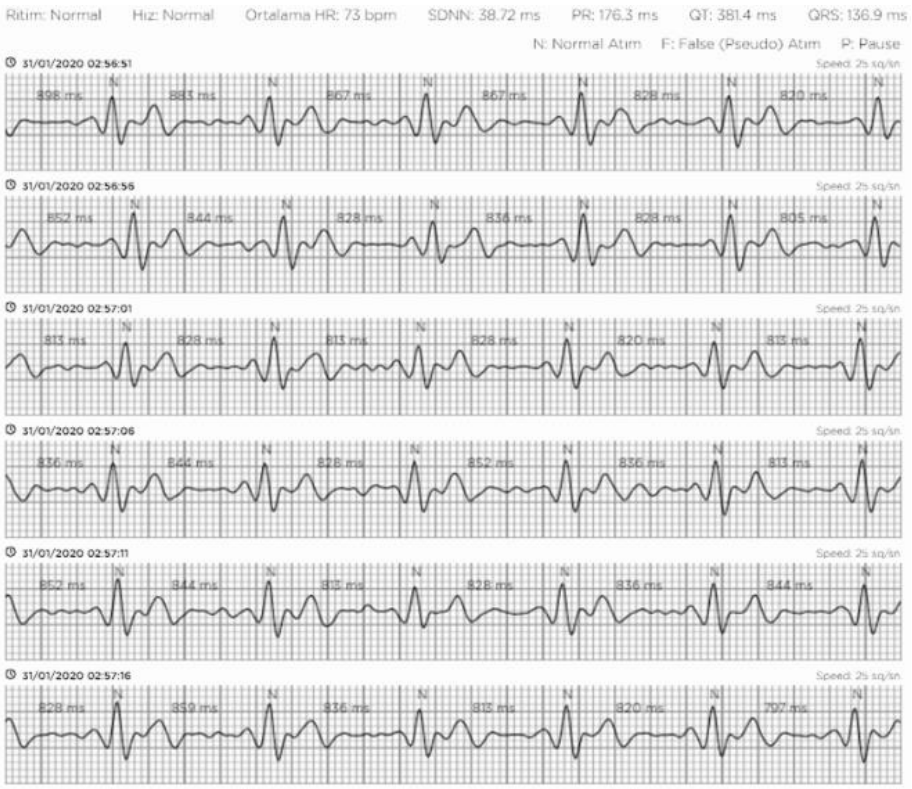


**Figure 6.7 :** ECG Analyzed Result of Participant-2


**Figure 6.8 :** ECG Analyzed Result of Participant-3

# 7. CONCLUSION

## 7.1 Conclusion of the Experiment

As we are in pursuit of observing the positive effects of gamification of vital sign measurements on children's health, we would like to observe three things, those are, promoting adherence, increasing the accuracy of the vital signs measurement and reducing stress.

### 7.1.1 Accuracy of Vital Signs Measurement

Reading the ECG of pediatric patients is hard. Due to special conditions in measuring ECG of pediatric patients as well as these cases presents itself very seldom, the process is prone to errors. According to research, there is a huge variation in the interpretation of ECG measurements in terms of accuracy up to 32% [73,74].

As we mentioned before, the mental state of the individual effects the outcome of the measurement is a discrepancy in ECG measures up to 20% [58]. So, by using gamification elements to we brought the heathy kids, into a playful mental state.

Under these circumstances, the analyzed results of the experiment show us, the outcomes sit between normal values of pediatric patients aged 5-12 [75].

On its own, we can't make an assumption that accuracy is higher than the normal one, however, it still, give us the right to say we can argue, this measurement as accurate as standard ECG measurement. The various metrics comply with the normal values, such as HR, SDNN, and QRS intervals. Therefore, it strengthens our hypostasis that the measurement is accurate.

### 7.1.2 Promoting Adherence

As we observed in the experiment, children aged between 5-12 show considerable interest in games not only playing but also watching some other people playing. According to what we inspected, watching other patients playing the game, created anticipation and excitement for the children. In the experiment, participants were keen

on playing the same game (taking measurements) over and over again and also the other games which are SP02 and Blood Pressure measurement. At the end of each measurement, they were quite insistent to try the other measurements. Based on these indicators, we may assert that gamification in healthcare would promote adherence rates for pediatric patients as they would like to keep coming back especially with updated content.

### 7.1.3 Reducing Stress

As we stated earlier, interactive games help the kids feel empowered by activating optimistic emotions and the reward system, after observing the kids during the experiment, we saw no sign of stress. Considering the environment is an office, still, a child is prone to be resistant and scared towards uncertainty and medical devices. However, providing a set of information in a narrative format before the measurement is taken, made the kids relaxed, resilient and feel in control. By providing kids with a playful environment, we not only reduce stress but also made things more entertaining, interesting and fun.

## 7.2 Further Things to Study

The experiment took place in Arçelik Innovation Headquarter, that is an office environment. It would be sound to carry out the experiment in a hospital environment. We didn't have the chance to move the health kiosk due to regulatory and logistical issues in a hospital environment. However, given the chance to make it, the experiment in a hospital environment with the same gamified system would be definitely beneficial in terms of reduced stress and promoting adherence.

Apart from that, the study can even be deepened if carried out with a control group. So, the comparison of the results of the measurements between the gamified version and the non-gamified version of the system would likely yield more detailed findings to discuss.

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