A PROCEDURE PROPOSAL FOR DEVELOPING NOVEL IDEAS FOR MILITARY PRODUCTS: DOMAIN EXPERT KNOWLEDGE TRANSFER THROUGH DESIGN BY ANALOGY

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ABSTRACT

A PROCEDURE PROPOSAL FOR DEVELOPING NOVEL IDEAS FOR MILITARY PRODUCTS: DOMAIN EXPERT KNOWLEDGE TRANSFER THROUGH DESIGN BY ANALOGY

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When future soldier programmes are examined, especially from product design perspective, it is clearly seen that they embody various products from different domains. Some products used in military systems are originally commercial products which are integrated to military systems. These products which can be used for both commercial and military purposes are defined as “dual-use technologies”. Such integrated military systems are open for new ideas especially in the concept generation phase in terms of product variety. This type of ill-defined concept generation process makes it difficult to produce solid solutions and this situation leads designers to the process of reproductive thinking. To overcome this problem, there are many Design-by-Analogy (DbA) methods, tools and techniques in the literature. Practicability and efficiency of these methods, tools and techniques are highly questionable due to their experimental nature. These DbA methods, tools and techniques present design knowledge to designers who have no knowledge in this domain. However, DbA literature predicts that this may not be enough to lead designer to innovation. To achieve innovation and cross domain knowledge transfer, transferring knowledge between experts is important. In this respect, study aims to involve designers who have domain knowledge. In order to increase the efficiency of DbA process the procedure of Expert Knowledge Transfer Through Design-by-Analogy (DEKT-DbA) is developed. Before conducting the study, situational awareness concept was determined as a design problem to be resolved, by military experts. In the process, individual workshops and semi-structured interviews were made with 20 product designers from different domains. These 20 designers were able to create 76 design solutions to increase situational awareness of military personnel. The design solutions were firstly categorized under the subsystems of soldier modernisation programmes and then evaluated by juries who are experienced product designers in defense industry. The efficiency of DEKT-DbA is evaluated with these scored concepts. In addition, the knowledge of designers on design by analogy and other methods or tools and techniques in terms of cross-industry innovation was also examined.

Key Words: Future Soldier, Design-by-Analogy, Dual-used Technology, Cross-Domain Knowledge Transfer

ÖZ

ASKERİ ÜRÜNLER İÇİN ÖZGÜN FİKİRLER GELİŞTİRİLMESİNE YÖNELİK BİR PROSEDÜR ÖNERİSİ: ANALOJİ YOLUYLA TASARIM İLE UZMANLIK ALANI BİLGİSİ AKTARIMI

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Dünyadaki askeri modernizasyon çalışmaları ürün odaklı incelendiğinde, çalışmaların birçok farklı sektörden, birçok farklı ürüne bağlı olarak gelişmekte olduğu görülmektedir. Askeri sistemlerde yer alan bazı ürünler, ticari kökenli ürünlerin askeri alana entegre edilmesi ile ortaya çıkmaktadır. Bu şekilde hem sivil hem de askeri alanda kullanılan ürünler ilgili alanyazında "çift kullanımlı teknolojiler" olarak adlandırılmaktadır. Bu şekilde farklı alanlardaki ürünlerden oluşan askeri sistemler, özellikle konsept geliştirme aşamasında ürün çeşitliliğinin sağlanabilmesi için, yeni fikirlerin geliştirilmesine açıktır. Eğreti tanımlanmış bu tarz konsept geliştirme süreçleri, süreci zorlaştırmakta ve tasarımcıları yaratıcı düşünme süreçlerine yönlendirmektedir. Alanyazında birçok analoji yoluyla tasarım yöntem, araç ve teknikleri önerilmektedir. Bu yöntem, araç ve tekniklerin deneysel doğaları gereği, uygulamadaki pratiklikleri ve etkenlikleri sorgulanmaktadır. Alanyazındaki analoji yoluyla tasarım yöntem, araç ve tekniklerinde, sektörel bilgisi olmayan tasarımcılara farklı alanlara ilişkin tasarım bilgisi sunulur, ancak, bu süreç tasarımcının yenilikçi çözümler üretmesi için yeterli değildir. Yenilikçilik ve alanlar arası bilgi aktarımını sağlamak için farklı alanlardaki uzmanların bir araya gelerek bilgi aktarımı gerçekleştirmesi önemlidir. Bunları göz önünde bulundurarak, çalışma sektörel bilgisi olan tasarımcıların sürece dâhil edilmesini amaçlar. Analoji yoluyla tasarım sürecinin etkinliğini artırmak amacıyla, çalışmada Analoji Yoluyla Tasarım ile

Uzmanlık Alanı Bilgisi Aktarımı olarak adlandırılmış prosedür geliştirilmiştir. Çalışma öncesinde askeri uzmanlar ile görüşülmüş ve tasarım problemi olarak "durumsal farkındalık" belirlenmiştir. Süreç boyunca farklı sivil sektörlerden 20 ürün tasarımcısı ile bireysel çalışmalar ve görüşmeler yapılmıştır. Çalışmada 20 tasarımcı, durumsal farkındalığı arttırmayı hedefleyen toplamda 76 tasarım çözümü sunmuştur. Çözümler ilk önce literatürde belirtilen modernize piyade alt sistemler başlığında gruplanmış ve daha sonrasında savunma sanayinde deneyimi olan bağımsız bir jüri grubu tarafından değerlendirilmiştir. Puanlanan konseptler ile Analoji Yoluyla Tasarım ile Uzmanlık Alanı Bilgisi Aktarımı prosedürünün etkinliği değerlendirilmiştir. Ayrıca çalışma kapsamında ürün tasarımcılarının analojik tasarım ve ya diğer yaratıcılık yöntem, araç ve teknikleri hakkında bilgileri sorgulanmış ve bunları tasarım süreçlerine dâhil edip etmedikleri incelenmiştir.

Anahtar Sözcükler: Geleceğin Askeri, Analojik Tasarım, Çift Kullanımlı Teknoloji, Sektörler Arası Bilgi Transferi

To My Family

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CHAPTER 1

INTRODUCTION

1.1 Background and Motivation of the Study

In today's world, like every other aspect of our life, armed forces have also been transforming rapidly with emerging technologies. Apart from technological advancements, scenarios of the battlefield are getting so complex that the infantryman needs integrated command and control (C2) systems to adapt to them. However, most of the systems that are designed so far have not been adapted to real user scenarios as fully integrated future soldier systems (Valpolini, 2013). At the Royal United Services Institute (RUSI) Land Warfare Conference in London, US Army Chief of Staff, Gen. Mark Milley warned that %90 of the population will be living in cities which will be a real threat for modern armies lack of modernized units to adapt to that type of battlefield (Donaldson & White, 2016).

The perception of future soldier is not a new concept for military. Especially after the Second World War, the great powers of its period designed military concepts against nuclear and biological weapon threads. Nowadays, not only these powers have been developing future soldier concepts, but also the rest of the world is developing future soldier systems. The member states of NATO which have been developing future soldier systems can be listed as Canada, Croatia, Czech Republic, Denmark, France, Germany, Holland, Italy, Norway, Poland, Spain, UK, USA and Turkey. Other countries that have no membership to NATO but developing Soldier Modernisation Programmes (SMPs) can be counted alphabetically as Australia, Brazil, China, Finland, India, Russia, Serbia, Singapore, Sudan, Sweden, Switzerland and Japan. Among both member states of NATO and non-NATO countries, USA, Russia and

China are the leading countries in terms of military expenditure to Soldier Modernisation Programmes (Merklinghaus, 2014; Öztoprak & Arda, 2016).

The researcher has been working as an industrial designer since 2015 for Aselsan A.Ş, which is a defense industry company of Turkish Armed Forces Foundation. He has worked in many defense industry projects including land and naval weapon systems, command and control systems and future soldier concepts and products. Among these fields of study, CENKER, which is a wearable command and control suite, has allowed him to explore the potential of design concepts that comes together as a system from different products which are belong to different domains (Figure 1.1). CENKER's end product version officially launched at International Defence Industry Fair (IDEF) 2017. CENKER system is designed for both military personnel deployed in field and command echelon. System provides inter-patrol and intra-patrol voice and communication and lets military personnel to have advantage over threats with electro-optical, infrared cameras and laser designators. By taking operation durations into consideration, system provides an intelligent power management and harvesting infrastructure. Furthermore, command echelon may monitor personnel's health indicators, activity and position in the field (Donaldson & White, 2016).

This type of integrated systems is open for new ideas, from products developed in different domains and areas. Such type of interactions with different domains can trigger innovation, especially in the concept phase. Furthermore, some of these various components has not been specifically designed for military context from scratch but has a substructure of commercial applications or products. For instance, NETT Warrior programme of USA adopts a 178-gram Samsung Galaxy Note I which is a commercial off-the-shelf (COTS) product (Valpolini, 2013). With the help of literature published about cross-industry innovation, this occasion lead the researcher to think industrial designers from other industries may enrich the concept of future soldier with an appropriate tool of Design-by-Analogy (DbA). Cross-industry innovation defines as transferring an approach from other industry domain. Even though many mechanical engineering and architecture literature published about DbA methods and tools to increase innovation potential of the projects, literature on product design have not much contributed to the field of DbA. Therefore, this study is designed for examining the potential contribution of non-military domains of product design within the borders of military product and concept development.

Figure 1.1 CENKER - IDEF 2017

As stated above the concept of SMPs consist of various products and technologies which creates a large number of possibilities to combine them as an integrated system. Developing such a system with an unclear structure and fuzzy initial requirements leads to tackling with ill-defined (or wicked) design problems with an unknown number of solutions (Casakin, 2010). Akin (1990) explains that, this type of ill-defined problems make producing solid solutions difficult and this situation leads designers to the process of reproductive thinking. Among the creativity enhancement methods, tools and techniques, design-by-analogy (DbA) is claimed to be an effective method which triggers innovation by using similar solutions from other domain fields to produce solutions (Fu et al., 2015).

Analogical thinking exists within the structure of DbA. Basically, the term analogical thinking refers to transferring an information or a concept from known situation to the problem area. Known situation is called as “source or base” while the problem area is called “target” (Casakin & Goldschmidt, 2000). Explaining these terms with an example would be valuable to embody the concepts. Owen Maclaren who is a retired aeronautical engineer used the concept of retractable landing gear to develop foldable baby buggy (Vulling & Heleven, 2015). In this case the retractable landing gear is the “source” while the foldable baby buggy is the “target”. The distance between the source and the target defines analogical distance. As far as the similarities between source and target are diminished, it was called as far-field analogy. On the contrary case, it is called near-field analogy. Fu et al. (2013) claimed that field of analogy could be too far, or near in terms of domain, which inhibits establishing a connection. They stated that there is a sweet spot in terms of analogical distance for creating innovative ideas.

Considering that achieving innovation is the most desirable outcome of the design process, the use of creative enhancement methods, tools and techniques and DbA appears as a powerful source to any profession. Despite the use of these methods, tools and techniques is a highly valuable for supporting design process by areas such as architecture and mechanical engineering, these concepts are executed within experimental setups (Casakin, 2005; Fantoni et al., 2013; Fu et al., 2015; Linsey et al., 2012; Akrami et al., 2017). Practicability and the efficiency of these methods, tools and techniques are highly questionable due to their experimental nature. DbA methods, tools and techniques like AskNature (Deldin & Schuknecht, 2014), IDEA-INSPIRE (Chakrabarti, et al., 2004), Biomimetic Design Through Natural Language Analysis

(Cheong, et al., 2008), Engineering-to-Biology Thesaurus and Function-Based Biologically Inspired Design (Nagel, et al., 2010), Design by Analogy to Nature Engine (DANE) (Vattam, et al., 2010) and TRIZ-Based Methods for Bio-Inspired Design (Craig et. al, 2008) present design knowledge designers who have no knowledge in this domain and thus aim to inspire the designers. However, it is predicted that this may not be enough to lead to innovation (Yargın, Firth, & Crilly, 2017). For achieving innovation and cross domain knowledge transfer, transferring knowledge between experts is important. In this respect, study aims to involve the designer who has domain knowledge, in order to present the field knowledge to the designer as an inspiration.

Designing complex systems like future soldiers requires different approaches (Tack, 2006). To design a future soldier concept, also many specializations may be needed in terms of product design including electronic appliances, human engineering and ergonomics, apparel design and wearable technologies, and so on. For this reason, this study aims to explore innovation potential of transferring knowledge from other fields of product design.

1.2 Aim and the Scope of Research

In the light of the discussions in this chapter, this study aims to make contribution to the concept generation phase of military products and systems that includes dual-use products by integrating design-by-analogy approach to it. In this study, a new approach is proposed which uses visual displays involving within domain and between domain inspiration sources to aid design activity. Between domain sources represent the expert knowledge, while within domain sources represent the target domain. Proposed DbA procedure embodies within and between domain sources. Between domain sources are provided by domain experts which transferring their knowledge to other domain. Proposed tool is entitled as “Domain Expert Knowledge Transfer through Design-by-Analogy” (DEKT-DbA). Harris (2012) explains dual-use technologies as products which have a potential to be used in both military and commercial applications. As military design concepts encourage dual-use products which are based on civil industries, this study aims to find out the possible contribution of product designers from other domains.

1.3 Research Questions

The thesis aims to answer following questions in two categories: sub-questions and main questions which are listed below.

Main questions of the study:

- How can cross-industry innovation be supported through design by analogy within the context of military products?

Sub-questions of the study:

- Soldier Modernisation Programmes (SMPs) have a rich product line which depends on many dual-used products and dual-used technologies. Considering equipment of SMPs also supported by dual-used products and cross-industry innovation, through employing DEKT-DbA, what can be the potential contribution of a designer out of defense industry to defense products and concepts?

- How does industrial affinity effect industrial designers in a creative process?

- How do industrial designers use design-by-analogy tools, methods and techniques to enhance creativity in their professional life?

- How does cross-industry innovation take place in industries that industrial designers work?

1.4 Structure of Thesis

This thesis consists of five chapters. This chapter intends to introduce the subject of the thesis. The main and sub-question of the research are presented after describing the motivation, the aim and the scope of this study. In conclusion, structure of the thesis is displayed.

Chapter 2 introduces the result of reviewed literature about the concept of Soldier Modernisation Programmes (SMPs), classification of sub-systems of SMPs, definition of dual-used technologies and cross-industry innovation and their relations with the product and system development of SMPs. Chapter continues with introduction of Design-by-Analogy tools, methods and techniques and supportive creativity enhancement methods, tools and techniques for Design-by-Analogy. At the end of this chapter, contribution of this study to the literature is argued.

Chapter 3 present the research methodology which involves an applied design-by analogy task followed by a semi-structured interview with participants. The DEKT-DbA procedure explained by referring to the regarding literature.

Chapter 4 examines the findings of the study and semi-structured interview. Concepts that were developed by participants is examined one-by-one and scoring of the jury is presented. Through the chapter, both quantitative and qualitative analysis were executed to answer research questions.

The last chapter presents the conclusions for the study by mentioning its implications, limitations and what possible future studies can be conducted about this subject.

CHAPTER 2

LITERATURE REVIEW

This chapter introduces literature about the concept of Soldier Modernisation Programmes (SMPs), classification of sub-systems of SMPs, definition of dual-used technologies and cross-industry innovation, DbA and its relation with the process of product and system development of military systems.

2.1 Background: Soldier Modernisation Programmes

The development of modern technology we know, begins to change our daily life in many fields. One of the major advancement in technology is powerful computing capacities we achieve with handheld devices. Even most of us are unaware that, our smartphones can perform instructions 120,000,000 times faster than an Apollo era computer which lead human race to the Moon in 1969 (Puiu, 2017). This shocking example points out the devastating development done in a little while compared to the existence of humankind. This logarithmic growth in computing capacity also contributes to the evolution of military field in many ways. Starting from early examples of traditional armaments[1], to today's armies using Unmanned Aerial Vehicles (UAV) and smart systems to reinforce individual soldier in the field (Herr, 2013). Changing technology and risk perception of military, demands more situational awareness (SA) and more connectivity between soldiers which leads armies to the Soldier Modernisation Programmes (SMPs). After the concept comes in sight, the progress is so flashing, some projects had to move back to the starting point because sudden progress outdated them already.

[1] The term of traditional armaments includes all wieldable armaments while excluding firearms.

SMPs are mostly built on NATO's five concepts of capability enhancement (Harašta, 2009):

(1) Command, Control, Communications, Computers and Intelligence (C4I): C4I concept aims to provide effective transfer of orders and information among individual soldiers to maximize combat efficiency.

(2) Lethality: Lethality concept aims a higher accuracy in fire power.

(3) Mobility: Mobility concept aims to provide a lower load for total weight of equipment that soldier carries during an operation. Also, the concept of mobility aims to provide better navigation systems in the field.

(4) Survivability: Survivability concept aims to provide a ballistic protection, camouflage, CBRN (chemical, biological, radiological and nuclear) and combat identification

(5) Sustainability: Sustainability concept aims to provide equipment and military products with higher life-cycles

These capabilities aim to satisfy needs of the complexity of modern military operations. Modern military operations are different than conventional warfare that history of mankind is used to. Lind, Nightengal, Schmitt and Sutton (1989) classifies how the concept of warfare has changed in five stages and Gürcan (2011) updated the peak point of third generation wars and added a fourth one which involves contemporary military operations. Compilation of these sources can be seen in Table 2.1.

Table 2.1: Evolution of Warfare (Lind, Nightengal, Schmitt and Sutton, 1989)

Stage I	**Wars before nation-states**
Stage II	**First generation wars:** Classic wars (1648-1830) **Notable Peak Point:** Napoleonic Wars
Stage III	**Second generation wars:** Full Scale Wars (1830-1918) **Notable Peak Point:** I. World War
Stage IV	**Third generation wars:** Maneuver Warfare (1918-1948) **Notable Peak Point:** Gulf War (1991)
Stage V	**Fourth generation wars:** Unconventional Warfare (1948-today) **Notable Peak Point:** Occupation of Afghanistan and Iraq

The concept of conventional warfare refers to traditional warfare that occurs between nation-states. These conventional conflicts depend on legal sanctions like Geneva Conferences (Astan, 2015). On the other hand, the modern warfare we observe mostly consists of asymmetrical threats[2] which triggered the need of SMPs for every single nation. Asymmetrical threats lead the generation of SMPs concepts to overcome different combat scenarios apart from usual occasions. These scenarios may vary but are mainly constructed for urban areas because currently, world's urban population has reached to 54.298% with an expected 1.63% growth rate per year between 2015-2020 (International Bank for Reconstruction and Development [IBRD], 2016). These

[2] Asymmetrical threat, or asymmetrical engagement, a concept of conflict between a professional army and a resistance. The term commonly known as "terrorism" or "guerilla warfare".

data sets are completely overlapping with the theory, which claims that the world is in the fourth generation of war era.

Even if it is clear that warfare is leading to another way, equipment of SMPs are not completely deployed for individual soldiers. Donaldson (2013) states that the concept of SMPs are easy to explain but hard to achieve in many ways. The main concern that delays these technologies to appear in the field is extraordinary human-computer interaction that occurs in extreme stress levels in battlefield which differentiates military products from consumer products. Apart from differences in human-computer interaction styles between these product groups, harsh environment conditions and requirements related to device mobility and power supply are other main factors that puts pressure on designers in terms of developing military products for SMPs. Besides technical problems, countries are trying hard to prove their capabilities to the world and are highly influenced from the needs of soldier in Afghanistan and Iraq campaigns which led future soldier programmes to satisfy all needs at once (Donaldson & White, 2016).

There are more than 40 countries which have announced that they are working on a soldier modernisation programme (Donaldson & White, 2016). Despite the progress and announcement of these systems in this field, none of these modernization concepts has been integrated fully to the field. According to Valpolini (2013) only France, Germany and USA has an integrated suit which is currently deployed while Britain has some components of FIST (Future Infantry Soldier Technology) system on the field which are mostly related to sighting and targeting.

2.2 Classification of Sub-systems of Future Soldier Systems

To understand SMPs concept, first it is a necessity to completely perceive what elements form a future soldier and what the primary source of these elements are. These sub-systems of SMPs are formed from various product groups. Since the area of wearable technologies highly depends on commercial products, most of these products of SMPs can be defined as *dual-use products*. Dual-use products can be explained as products which has a potential to be used in both military and commercial applications (Harris, 2012). Dual-use products have three type of concepts in terms of design intend. In the first scenario, dual-used products are designed for a specific field, but it has been integrated to military or civilian fields without any modifications, because they were meeting the requirement of the other field already. In the second scenario, dual-use products need to be modified before being used in particular military and civilian scenarios because they do not fulfill the requirements of the other field. In the third and last scenario, dual-used products are designed considering both fields at the very first moment of design process. (Molas-Gallart, 1997). Dual-used technologies are broadly divided into ten categories by the U.S. Department of Commerce (Examples of Dual Use Items, n.d.):

a) Nuclear

b) Materials, Chemicals, Microorganisms and Toxins

c) Materials processing

d) Electronics

e) Computers

f) Telecommunications and Information Security

g) Lasers and Sensors

h) Navigation and Avionics

i) Marine

j) Propulsion Systems, Space Vehicles and Related Equipment

The policies on dual-use technology tend to increase in recent years. Mollas-Gallart (1997) explains the increase in trends of dual-use technologies in three main reasons. These reasons can be listed as:

The significant decrease of defense expenditures of NATO countries after the peak point in 1987.

- Cost of military systems and products tend to grow logarithmically, while military systems and products become more complex.

- The dominance of military technologies over civilian technologies is changing with the continuous growth of civilian technologies.

Examining military products, which forms the future soldier concept, verifies that wearable technologies contain many dual-use products. Astan (2015) decomposed future soldier systems to seven sub-systems. Sub-systems are sorted alphabetically at below:

I. Command, control, communications, computers, combat systems, intelligence, surveillance, and reconnaissance (C5ISR) sub-systems

II. Equipment and protection sub-systems

III. The Human

IV. Lethal and non-lethal weapon sub-systems

V. Power and energy sub-systems

VI. Sensor (Detection) sub-systems

Since this study focuses on the product section of the SMPs, the "human" as a sub-system is not introduced in detail. Also, because "lethal and non-lethal weapon subsystems" are not applicable to the definition of dual-used products, they are not elaborated on in this thesis. The rest of the four sub-systems are introduced in depth hereinafter for both expressing the frequency of dual-use technologies and products that have been already used and to understand the elements of a complete future soldier.

2.2.1 C5ISR sub-systems

C5ISR is a concept that aims to increase situational awareness of a soldier by sharing real time data from the field. C5ISR can be considered as a central component of SMPs due to containing the base components such as personal computer, transponder, GPS devices, aerials and software that are running on these devices (Astan, 2015).

C5ISR systems became an important part of the SMPs as the concept of warfare evolves through integrity of human and unmanned vehicles in the field. Therefore, the global C5ISR market is expected to reach $1,350,700 by 2023 with approximately %23 growth comparing to 2016 (Global C5ISR Market Outlook 2017-2023, 2017).

Components of this subsystem can be listed by Astan (2015) as:

a. Transponder Unit
b. Personal computer Unit
c. Antenna Unit
d. GPS Unit
e. Navigation Unit
f. Display Unit
g. HUD Display
h. Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Software

2.2.2 Equipment and protection sub-systems

As SMPs lands to the field for dealing with different kind of threats, their load continues to rise with advanced equipment. Equipment and protection sub-systems provide mobility, survivability and ability to execute operation to soldier on the field. Protective equipment categorized among to their protection levels from the least protective to the most, protection levels named as Unencumbered (UE), Full Fighting Order (FFO), FFO plus ballistic protection (FFO+). The heaviest configuration, FFO+ reaches to 25.7 kg (± 1.0) with ceramic plates (Bossi, Jones, Kelly, & Tack, 2016).

Components of this subsystem can be listed as (Astan, 2015):

a. Uniform

b. Ballistic helmet

c. Ballistic vest

d. Assault vest

e. Back pack

f. CBRN (Chemical, Biological, Radiological, and Nuclear) equipment

2.2.3 Power and energy sub-systems

Similar to equipment and protection sub-systems, there is also significant development in changing needs and new electronics. As new electronic equipment are introduced to the concept of future soldier, many different type of batteries are needed. This occasion led the SMPs to a logistic struggle. At the early 1980's Land Warrior system announced a new approach which supplied all electronic components from a single battery (National & Press, 2004).

Dean (2003) states that average mission durations may vary between 48-72 hours. To meet these operation durations, besides carrying backup batteries, energy harvesting technologies have also been integrated to the SMPs. Despite this, energy harvesting technologies are mostly seen as immature due to their low power generation.

Components of this subsystem can be listed as (Astan, 2015):

a. Batteries

b. Battery Charging Units

c. Power Distribution Systems

d. Power Control System

e. Central Power Control Systems

2.2.4 Sensor (Detection) sub-systems

Modern soldier systems have active and passive sensor sub-systems to collect data during combat situations and to monitor soldiers. Most of wearable sensor studies concentrates on transferring health conditions of military personnel including heart rate, respiration, level of injury, fatigue, hydration level and physiological state (Top 5 Vendors in the Global Military Wearable Sensors Market, 2017).

Components of this subsystem can be listed as (Astan, 2015):

a. Thermal Sensors

b. Infrared (IR) Sensors

c. Optical Sensors

d. Binoculars

2.3 Designing Future Soldier Systems

Designing for military domain mostly requires multidisciplinary approach to ensure the different requirements of products and systems (Mitchell & Samms, 2012). Also, taking previous chapter into account, we can argue that military and civil domains are integrated and there is a bidirectional flow in terms of product, system and software design.

Designing product is an explorative activity. There are many process a designer can follow. Traditional design process has a series of stages. It begins with defining the systems. This definition designates the needed functions of the product.

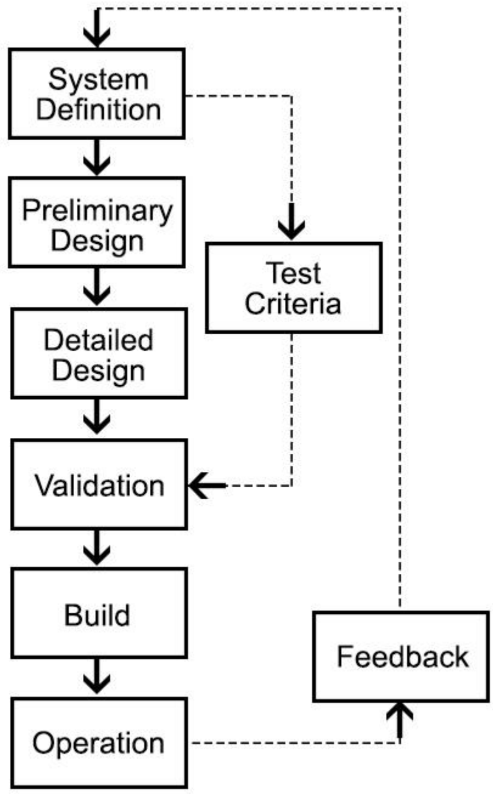

Figure 2.1: Traditional Design Process (Tack, 2006, p.3)

After definition of needed functions, design process continues with preliminary design stage in which concept design takes shape. As the preliminary design takes shape, concept may be prototyped for evaluation. Evaluation and tests lead design to the detailed design stage. Validated design is completed with manufacturing and distribution of product. As traditional design process may appear as a linear process, in real cases these stages may overlap (Tack, 2006).

Tack (2006) suggests an integrated design process for Research and Development (R&D) projects for defense industry through an example of Soldier Integrated Headwear System (SIHS). This design process aims to adapt an iterative R&D process, which encourages creativity.

On the whole, design process consists of three non-linear stages. System has stages of system definition, design cycle and evaluation process. As it is in the traditional design process, it also starts with the definition of a design problem which arises from the stages of technological review, requirement of specifications, design constraints, operational conditions of use and technology review.

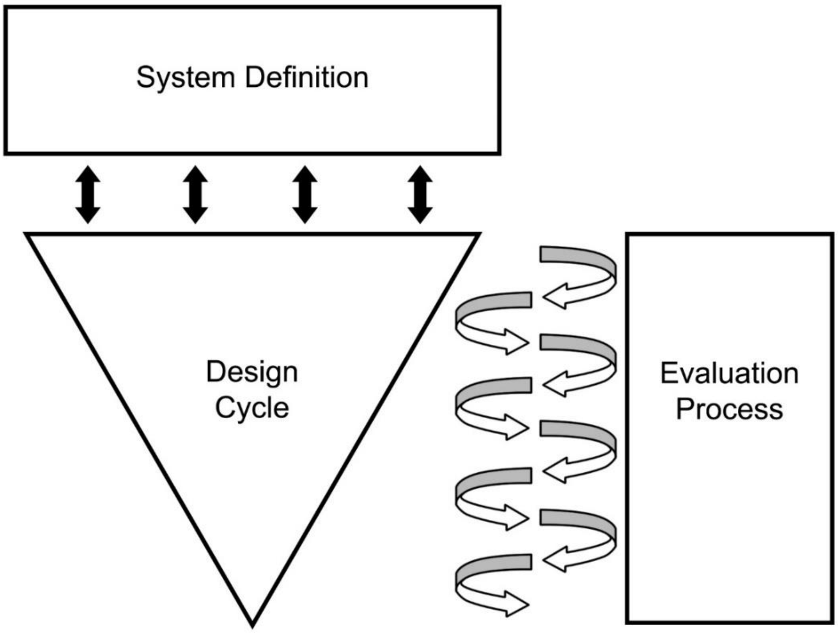

Figure 2.2: Integrated Design Process (Tack, 2006, p.4)

As a distinct from traditional design process, concept development, digital modelling, building physical mock-ups and functional prototyping activities take part under the title of design cycle as an integrated whole. As it is shown in Figure 2, design cycle has a wide spectrum of design concepts at the beginning without limiting the design options within limitations of the project. In the early stages of design cycle Tack (2006) stated that creativity enhancement methods, tools and techniques should be used to create undetailed ideas and concepts which are free from judgment in terms of feasibility. Output should be examined after the process of ideation ends. Then potentially feasible ideas begin to shape as digital models and physical mock-ups. As it combines with the tools of evaluation process, final concept is determined and functional prototypes are built to be tested in usability evaluations (Tack, 2006). Usability evaluations and feedbacks of the user are an important part of the process that lead product to final state. For example, Tack and Gaughan (2006) conducted a research about a military medical bag design. In the evaluation phase, users demanded an emergency release, which allows the user to drop his backpack in an emergency scenario. This feedback led researchers to make modifications on the final design before finalizing the process.

Idea generation is pointed as a key phase of military and civil design process for generating new ideas and finding solutions to a distinct design problem (Tack, 2006; Wilson, 2013). DbA is an important issue in the idea generation phase for developing dual use technologies and products, mainly because it involves solution transfer from one domain to the other. For this reason, the next section explains methods, tools and techniques that focus on DbA.

2.4 Design-by-Analogy

In this section, literature on design-by-analogy (DbA) is reviewed. DbA is a practice which has a great potential for improving concept generation process. This concept generation phase intends to lead designers to innovative solutions and products. Today's products and services mostly benefit from DbA to create more innovative solutions and these examples can be seen through many industries.

Gentner (1983) defined analogy as associating the relations of objects in cognitive linguistics. These relations transferred from *base domain* to *target domain* in the structure-mapping theory. This mapping occurs with metaphors in linguistics. To understand another concept in base domain, target domain is used. Apart from the linguistics terms, the term of analogical thinking refers to transferring an information or a concept from a known situation to the problem area in the design process. Known situation is called as "source or base" while the problem area is called "target" (Casakin and Goldschmidt, 2000). The distance between the source and the target defines analogical distance. Source analogies can be found both in a similar field, which is called close-domain, and a distant field which is called as cross-domain (Fantoni, Gabelloni, & Tilli, 2013). In some sources same concepts are referred as far-field analogy and near-field analogy (Fu et al., 2013). Analogical distance defines the functional similarities of the design problem. Close-field analogies tend to shares more similarities while cross-domain share little or none (Fu et al., 2013). A popular example for cross domain innovation is BMW’s interface design which is called *iDrive.* Designers of the BMW Group used gaming industry as a domain to transfer a gaming controller to car industry which allows the user to navigate through the car’s interface. The idea behind this concept is to let user control hundreds of functions with a single button as gaming controllers do (Automotive meets gaming, n.d.; Echterhoff, Amshoff, & Gausemeier, 2013).

Figure 2.3: Gaming controller analogy to BMW's controller system iDrive (Automotive meets gaming, n.d.)

According to literature on DbA, it is obvious that DbA is a beneficial method for creating innovative solutions for design problems. The problem pointed by Linsey, Markman and Wood (2012) is some of these methods lack of systematic approaches when it comes to application and teaching of these influential methods. Because of this uncertainty there are no certain approved categorization of DbA found in literature. According to Jeong and Kim (2014), “The design-by-analogy system can be divided into four; a case-based analogy system, a theory-based analogy system, a patent-based analogy system, and a term-based analogy system” (p. 3606). All four DbA analogy systems have advantages and limitations. All analogy systems require too much interpretation to achieve design solutions.

Case based analogy systems uses specific fields as analogy sources. One of the most known cased based analogy system is biomimicry. Instead of focusing on a spesific case, theory-based analogy systems rely on a defined solution pattern. As an example, TRIZ appeared as a well-accepted theory-based analogy system. Besides the advantages, defined patterns are appeared as limiting. Patent-based analogy systems are using user-defined patents as an analogy source. The last analogy system is called term-based analogy system. Term-based analogy system uses terminologies as an analogy sources. One of the most attention-grabbing term-based analogy system is WordTree.

System type	Information source	Process of analogy
Case-based analogy system	Organized cases in a specific domain	Similar functions to find design cases
Theory-based analogy system	Patterned solutions in various domains	Similar problems to find solution patterns
Patent-based analogy system	User-defined patents	Similar functions to find solution cases
Term-based analogy system	Systematized term relations	Similar terms to find new ideas

Figure 2.4: Design-by-analogy systems (Jeon & Kim, 2014, p.3607)

Nature is a remarkable inspiration source for imitating or transferring its solutions to design problems. Paola, Grandas, Yang and Wood (2015) classified DbA methods referring on if they are based on nature or not. They named these methods of DbA as:

1. BioX-driven analogies

2. Non-BioX driven analogies

BioX-driven analogies are based on design processes inspired by biology. Foundation of biomimetic dates back to the 16th century with Leonardo da Vinci who designed machines with inspiration from nature (Fu, Moreno, Yang, & Wood, 2014; Paola, Grandas, Yang, & Wood, 2015). Fu et al. (2014) categorize bio-inspired tools as (1) Biomimicry and AskNature (Deldin & Schuknecht, 2014), (2) IDEA-INSPIRE (Chakrabarti, et al., 2004), (3) Biomimetic Design Through Natural Language Analysis (Cheong, et al., 2008), (4) Engineering-to-Biology Thesaurus and Function-Based Biologically Inspired Design (Nagel, et al., 2010), (5) Design by Analogy to Nature Engine (DANE) (Vattam, et al., 2010) and (6) TRIZ-Based Methods for Bio-Inspired Design (Craig et. al, 2008). Bio-inspired methods are easy and intuitive to use but too much interpretation is needed and all of these tools do not provide insufficient aid to apply on real cases or required special database to execute. (Linsey et al., 2012; Jeong & Kim, 2014).

One of the most common Non-BioX driven analogy method is WordTree Method (Linsey et al., 2012). WordTree Method is a systematic way of finding analogies and analogous domains which is mainly constructed on linguistic approach for creative innovation ideas for design problems (Linsey et al., 2012). WordTree method begins with defining key problem descriptors which may be a function or customer need for a specific design brief. According to Linsey, Markman and Wood (2012) key problem descriptors must be constructed on these features:

1. Single word describing the overall function of the device (often in the Box Black)

2. Critical or difficult to solve functions

3. Important customer needs transformed into single action verbs. (p.3)

After defining key descriptors, method combines rotational brainwriting and online database which is called WordNet (https://wordnet.princeton.edu/) to complete creative cycle. WordNet is an online tool to find direct troponyms and direct hypernyms of a verb which can be used to enrich participants' WordTrees. Marshal, Crawford and Jensen (2015) defined hypernym as synonyms of a word with more general meaning, while defining troponym as synonyms of a word with a more specific meaning. These WordTrees can be defined as branches of words arranged from general to specific meaning. Specific meanings of a word are potential innovation zones for WordTree method because specific meaning of a word can lead its participant to an analogous domain which is the key of coming up with an innovative idea. Besides that, according to Segers, De Vries and Achten (2005), "Hypernym- and hyponym-relationships are often too abstract and therefore more likely to be useless" (p.643).

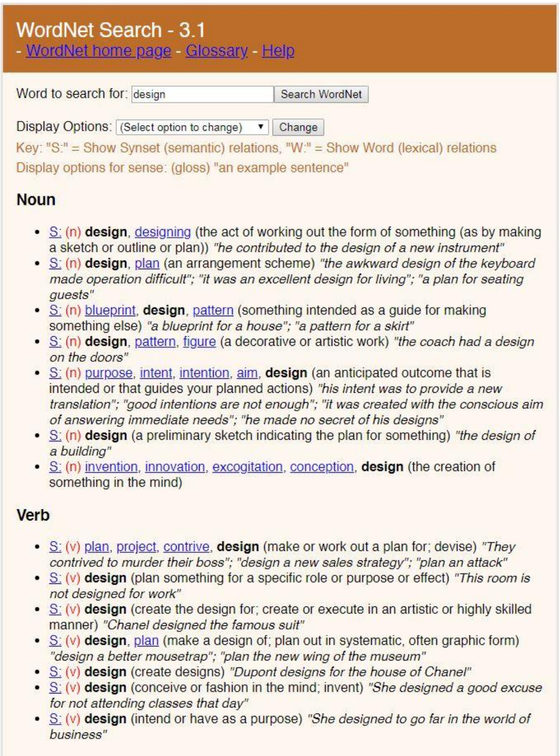

Figure 2.5: Interface of WordNet 3.1

The next phase of WordTree method is rotational brainwriting. In this phase, each participant has three pieces of paper for developing different WordTrees to each of them. Each user has a period of 10 minutes to create these WordTrees. To generate new approaches to the problem, participants rotate their papers clockwise, letting others to develop a WordTree in 5 minutes. At the end of the session participants of the group evaluate the potential analogies and analogous domains with the help of patent analysis which may assist in the design process by having a potential solution or functional similarities. In this phase, patent analysis aims to examine patented ideas for transferring those to other domains. WordTree method uses patent databases for this purpose. Patent analysis is an approach that uses published patents from various domains to derive information from it (Daim, Rueda, Martin, & Gerdsri, 2006).

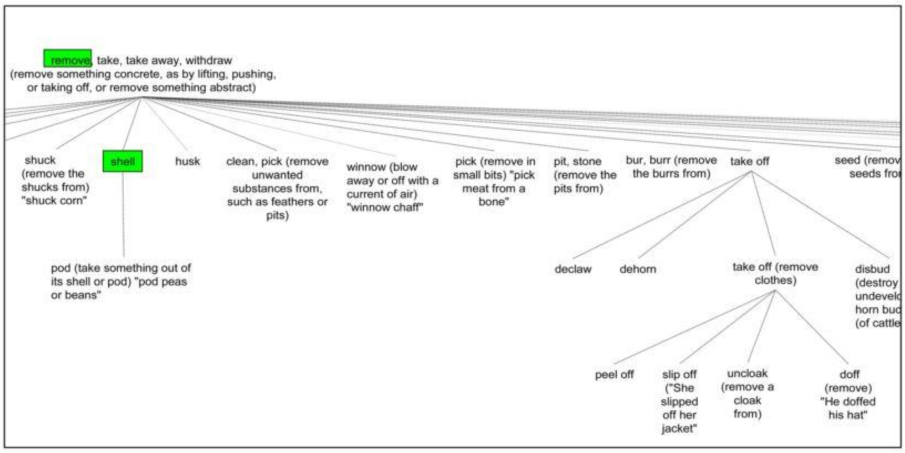

Figure 2.6 WordTree Example (Linsey, Markman, & Wood, 2012)

Another Non-BioX driven DbA method, Patent Analysis may appear as a standalone method but in some cases it may also appear as a part of WordTree methodology. Many companies are patenting many innovative and brand-new technologies but commercialization may not occur directly. Jeong and Kim (2014) give an example on a certain case why market analysis may not be enough to build analogies without patent analysis:

> Many companies are trying to create patents on the new technology. For instance, about 113 applications of patents related to magnetic resonance battery charging technology were filed before 2010 (KIPO., 2011), even though the technology had not been commercialized in 2012 (p.3605)

There is also a similar method to WordTree which is called *The Idea Space System* (ISS) which is mainly constructed for architectural design (Segers, 2004). ISS also uses WordNet and combines it with one of the key element of design: sketch.

One of the most frequently applied Non-BioX driven DbA method in literature is visual analogy method which is used by many design related occupations including architecture, engineering and product design (Casakin & Goldschmidt, 2000). Like other DbA tools visual analogy also identifies problem sets. Problem sets are divided to two as well-defined and ill-defined (or wicked) problems. Well-defined problem sets have specific requirements and design goals to fulfill while ill-defined problems have no strict requirements with numberless solution sets. Considering the difference between well-defined and ill-defined problems, ill-defined problems more open to creative thinking sessions (Casakin & Goldschmidt, 2000; Casakin, 2005; Casakin, 2010). In the same sense as DbA's concept of distance, visual analogy method categorized distance as within-domain and between-domain regarding if visual display sources has similarities to the target area, or not (Casakin, 2004).

To apply visual analogy method, there are various techniques in literature. The main idea behind these tools is to provide visual display sources in two ways: between-domain and within-domain. Some literature suggests that dividing visual analogy sources at two as between domain and within domain is not sufficient, and therefore, they add a third one: medium domain. Medium sources domain assumed as midpoint between near and far which is preferred by expert (Chai, Cen, Ruan, Yang, & Li, 2015).

2.4.1 Creativity methods, tools and techniques supporting DbA

Product and process innovations are a vital game changer for most prosperous companies around the world in many industries and various business segments. Achievements of these companies also inspire many other companies and organizations to endeavor designing cutting edge products and systems. This statement was proven with increasing number of trademarks for both technological and non-R&D-based innovations (OECD, 2011).

All methods have advantages and disadvantages when compared among themselves. But the main concern with these tools is that they are argued to be complex and the outcomes may be unpredictable enough to hinder application in every single case (Wilson, 2013). For that reason, increasing its efficiency many creativity-enhance methods, tools and techniques have been developing.

In this section, creativity methods, tools and techniques that can support DbA activity are reviewed to understand their strong and weak sides. According to Mazursky and Goldenberg (2002), creativity methods may be different in terms of approaches. They classified methods as; methods try to generate random associations or methods which generates analytical associations. Another classification is made from the scope of methods. Some methods are constructed for generalized occasions while others are specific. They argue that specific methods constructed for problem solving are stronger in terms of creating innovation for product development.

Developing new ideas has always been a challenge for mankind. Considering the momentum of advancement in production and industry, it forces companies to find unique solutions and design innovative products and systems (Motyl & Filippi, 2014). Although innovation is an important aspect for being a successful organization, it is hard to achieve it. Genco, Holtta-Otto and Seepersad (2010) argue that current engineering design processes help designers to create good products, but they lack of creative enhancement tools that will help them to ease the process for designing commercially successful and innovative products.

In this section, the methods, tools and techniques that referred frequently in the literature , according to Goldenberg and Mazursky (2002), are reviewed and discussed, namely brainstorming, lateral thinking, six thinking hats and TRIZ.

2.4.1.1 Brainstorming

The most common tool that has been used in many occupations is brainstorming. Brainstorming is a creative enhancement method which can be used by an individual or a group to find solutions to problems (Wilson, 2013). Alex F. Osborn is the founder of this technique. He studied on creativity techniques and problem solving starting from 1939 (Osborn, 1957). The method that Osborn developed is emerged from the need of creative ideas on an advertising campaign for both individuals and groups. Although its origin of this technique does not rely on design profession, throughout time, it has started to be implemented in the design process. Today, brainstorming is still counted as a valuable tool to generate creative ideas but apart from that, brainstorming can also be seen as a stage for other creativity enhancement methods, tools and techniques. For example, it is also used as a part of WordTree method (a type of DbA method), while generation WordTrees (Linsey et al., 2012).

Osborn (1957, 1963) believes that brainstorming technique must not contain self-criticism and criticism by others in order to encourage generation of large number of ideas. The idea beneath this understanding is believing that the larger the number of ideas people have, the more potential they have for having a valid solution. Osborn (1963) set four rules for brainstorming:

> [1] ***Criticism is ruled out.*** Adverse judgment of ideas must be withheld until later.
>
> [2] ***Free-wheeling' is welcomed.*** The wilder the idea, the better; it is easier to tame down than to think up.
>
> [3] ***Quantity is wanted.*** The greater the number of ideas, the more the likelihood of winners.
>
> [4] ***Combination and improvement are sought.*** In addition to contributing ideas of their own, participants should suggest how ideas of others can be turned into better ideas; or how two or more ideas can be joined into still another idea (p. 84).

The rules may seem simple to have a successful brainstorming. According to Wilson (2013), “Good brainstorming is rare, and in many cases what people consider ‘good brainstorming’ is often seriously deficient” (p. 4). For both individuals and groups, a certain amount of experience may be needed to overcome dynamics of process and social pressure (Wilson, 2013). Social pressure mostly appears in group brainstorming because of the fear of evaluation by other members of group (Camacho & Paulus, 1995).

Another important issue in studying brainstorming activity is understanding how individual and group brainstorming varies. Taylor, Berry, and Block (1958) conduct a research study in Yale University to understand the effects of group brainstorming. They generate two groups consisting of four people. One is a nominal group, which is a type of a group where people generate individual ideas but all ideas are voted at the end to decide on ultimate approach for a problem (O. Goldenberg & Wiley, 2011). The other group is an interacting group who let participants to discuss idea generation process face to face. Interacting and nominal groups have the same brief about a certain topic and they are asked to generate ideas. As a result, they concluded that nominal groups are acting better than interacting groups which is the opposite idea that Osborn pointed (Taylor et al., 1958). Osborn (1953, 1957) predicts that interacting groups have a superiority over nominal groups. They found out that, number of generated ideas of the nominal group is significantly larger than the interacting group's which is the opposite of Osborn's prediction. In addition, Taylor et al. (1958) find out quantity, quality, feasibility and uniqueness of proposed ideas are far better than interacting group's ideas. This points out that social pressure is an important fact while generating an idea, developing ideas individually with feedbacks stands out for idea generation process.

The development of technology also changes the concepts of creativity enhancement methods. Kerr and Murthy (2009) argued that computer-mediated methods can eliminate the weak points of interacting groups in brainstorming sessions which is mentioned before how psychology effecting brainstorming. This hypothesis emerged as a concept of electronic brainstorming (EBS). In EBS sessions participants are connected electronically to each other and they generate ideas to a common knowledge pool. Participants can download others' ideas from this pool to contribute to their ideas or developed a new idea. Research shows the potential of EBS with its positive effect on the process when it is compared to conventional brainstorming sessions (Wilson, 2013). Besides that, it is also seen as contradictory in terms of pros and cons, because inhibition of social encounters is seen as a negative feature of this method while elimination of distraction is beneficial for participants.

2.4.1.2 Lateral thinking

Lateral thinking which was developed by Edward de Bono is another method that is accepted by many occupations. Bono (1970) suggests that the working model of our minds combines the information we are trying to learn with the old patterns we have already experienced. To generate innovative ideas we need to escape from constraints of old patterns which is possible with creating new ones.

Lateral thinking differs from vertical thinking in terms of scope. The nature of vertical thinking is selective while lateral thinking is generative. The main difference between them is, vertical thinking selects an exact pathway and exclude others, while lateral thinking evaluates the possible advantageous alternative pathways to solve problem and selects the best solution in the end. According to Goldenberg and Mazursky (2002), “The philosophy behind this approach may be conveyed by the analogy of digging a hole. While structural thinking is analogous to digging down in depth, lateral thinking is analogous to the search for a new spot to start digging.” (p.53). Lateral thinking stands out as an important design thinking tool by reason of being core idea of DbA.

Even Edward de Bono suggested this constructed later thinking for managerial problems, he points the potential benefits of lateral thinking on designing products or services with help of analogical thinking and defined the patterns that can be used to select an analogy.

2.4.1.3 Six Thinking Hats

Another creative-enhancement method develop by Edward de Bono, is Six Thinking Hats. It is also not a design specialized method but it is seen as a constructive feedback method. It is currently used by many occupations, mostly in teaching. It has correlation with lateral thinking but the method is mostly concentrated on group thinking process.

This method chooses six different modes of thinking during a group discussion. Black, Blue, Green, Red, White and Yellow hats represent a different way of thinking. During sessions, hat’s color is announced by leader who decides the modes of thinking. When the red hat is announced, participants may speak about their personal feelings and emotions (Bono, 1985).

As a constructive feedback method for product development, Six Thinking Hats method is appeared as a critique session. At the end of the Six Thinking Hats session, product that discussed has many feedback from different perspectives. Different colors of hats represent different point of view for these critique sessions.

2.4.1.4 TRIZ

Design is a complex activity which leads scholars and industry partners to study on systematic process and methods. One of the early methods is created by German cult which is known as Functional Decomposition and Morphology (FDM). In fact, the FDM method appeals to academy more than industry. This gap between theory and execution leads Genrich Altshuller, who is a Soviet engineer, to create a more industrial based approach which he called TRIZ (Teoriya Resheniya Izobretatelskikh Zadach). The meaning of TRIZ can be directly translated as “"theory of the resolution of invention-related tasks" (Fiorineschi, Frillici, & Rotini, 2018).

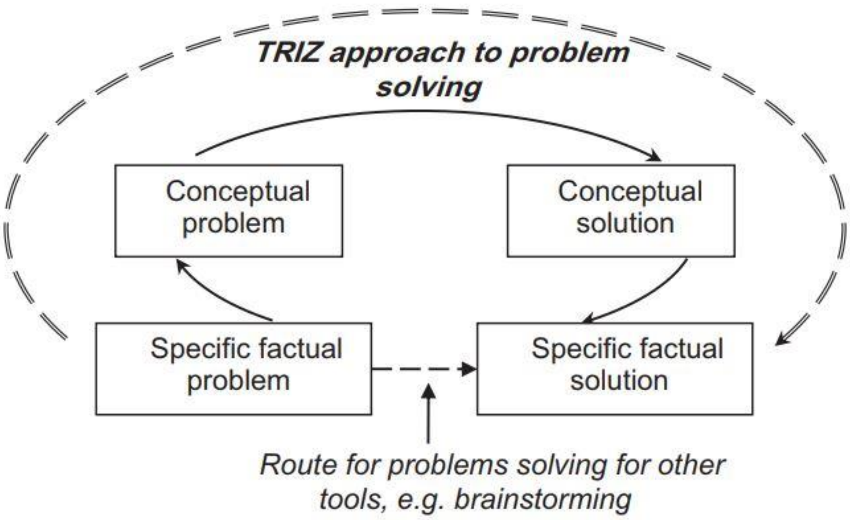

Figure 2.7 Systematic Approach Scheme of TRIZ (Ilevbare, Probert and Phaal, 2013, p.31)

According to Altshuller, one of the basic problems that leads a design activity to dead-end is trial-and-error which pushes him to study on a systematic problem solving and innovation tool (Gunes, 2009).

Within the process, TRIZ identifies concept solutions and leads them to a technical solution. Altshuller has three main concepts for problem solving process which are (1) contradiction, (2) ideality and (3) evolution patterns. First concept; contradictions show opposite features within a system. Contradictions are categorized as technical and physical contradictions. Second concept; ideality, designates how a system can possibly perform at its best. Ideality of a system is called as ideal final result (IFR). Last of the concepts is called patterns of evolution of a system. The concept of evolution is about predicting how a system will evolve and what possible solutions may be generated for specific solutions in the way of evolution (Altshuller, 1999; Ilevbare, Probert, & Phaal, 2013).

2.5 Summary

The chapter of literature review started with defining and telling the background of future soldier concept and soldier modernisation programmes (SMPs). After introducing how SMPs evolved in the context of future conflict concepts, the components and sub-systems of SMPs were presented in detail. Importance of identifying all elements of SMPs is to point out how dual-used technologies frequently take place in SMPs. Literature review of dual-used technologies explained how civilian technologies continuously grow in terms of dominance between civilian and military technologies (Molas-Gallart, 1997). As dual-used technologies are getting popular for military domain, it makes military field a potential field to apply cross domain innovations.

Creativity methods, tools and techniques need to be occupied to reveal this innovation potential. Design-by-analogy is a creativity practice which has a great potential for improving concept generation process. This concept generation phase intends to lead designers to innovative solutions and products. Classification of design-by-analogy methods and methods accepted by the literature are examined. Despite the use of these methods, tools and techniques is a highly valuable for supporting design process by areas such as architecture and mechanical engineering, these concepts are executed within experimental setups (Casakin, 2005; Fantoni et al., 2013; Fu et al., 2015; Linsey et al., 2012; Akrami et al., 2017). Practicability and the efficiency of these methods, tools and techniques are highly questionable due to their experimental nature. DbA methods, tools and techniques like AskNature (Deldin & Schuknecht, 2014), IDEA-INSPIRE (Chakrabarti, et al., 2004), Biomimetic Design Through Natural Language Analysis (Cheong, et al., 2008), Engineering-to-Biology Thesaurus and Function-Based Biologically Inspired Design (Nagel, et al., 2010), Design by Analogy to Nature Engine (DANE) (Vattam, et al., 2010) and TRIZ-Based Methods for Bio-Inspired Design (Craig et. al, 2008) present design knowledge to designers who have no knowledge in this domain and thus aim to inspire designers. However, it is predicted that this may not be enough to lead to innovation; for achieving innovation and cross domain knowledge transfer, transferring knowledge between experts is important (Töre Yargın, Firth, & Crilly, 2017). In this respect, study aims to involve designers who has domain knowledge. This procedure is presented at Chapter 3.

Chapter 2 has reviewed literature of SMPs, dual-used technology, cross domain innovation and creativity enhancement methods, tool and techniques. After examining literature of these topics, this study aims to search the potential of design-by-analogy tool, which is called visual analogy method, on military products or military system concepts development in context of SMPs.

CHAPTER 3

METHODOLOGY

This study aims to understand how Domain Expert Knowledge Transfer through Design by Analogy (DEKT-DbA) can be employed when developing innovative military products or military system concepts. Study focuses on product designers who work in civil industries and how knowledge of these designers can be transferred to generate innovative military design concepts that contains dual-use products and technologies. In addition, this study also aims to understand whether product designers have already adopted such creativity enhancement methods, tools and techniques in order to achieve innovation on their product design cases and processes in their professional life. Another motivation of this study is, while DEKT-DbA appears as a solid inspiration method for ill-defined design problems for constructing a concept design, product design literature does not contribute to literature as would expected.

After introducing SMPs in detail and reviewing the DbA, previous chapter also explains how DbA can be adapted to ill-defined concept generation phase of military systems. This chapter introduces DEKT-DbA procedure and presents the methodology on how its effectiveness is evaluated. At first, DEKT-DbA procedure is presented in detail including questionnaire and study phases. Finally, participant sampling data collection and the process of analysis are presented.

3.1 DEKT-DbA Procedure and Materials Used in the Procedure

Study aims to explore the potential of visual analogy method, which is employed by designers from other domains, for designing innovative military products or military system concepts. Stages of the study is shown in Figure 3.1.

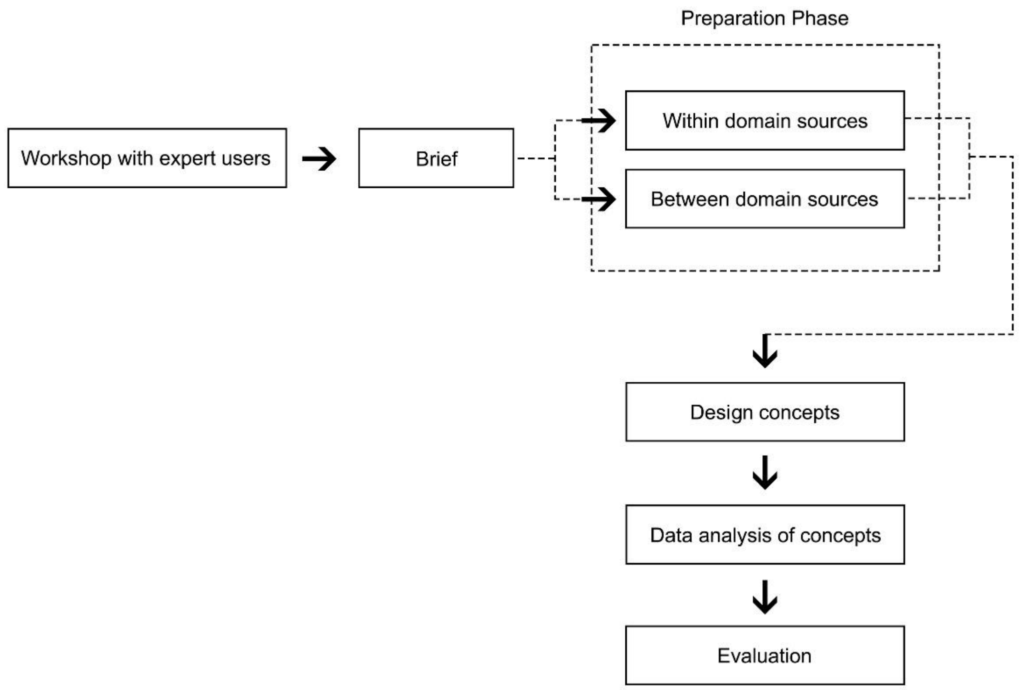

Figure 3.1 Stages of the study

This procedure uses visual displays as DbA to develop concepts transferring expertise of other domains. The visual display part of this procedure is developed based on the DbA procedure called “design aided by visual displays” proposed by Casakin (2005) to find creative paths for ill-defined (or wicked) design problems related with the field of architecture. In Casakin’s study, use of visual displays in analogical design is examined in terms of its contribution to the early stage of design. Casakin (2005) compares their usage for both ill-defined and well-defined design problems. The major difference between well-defined and ill-defined design problems is well-defined problem sets have specific requirements and design goals to fulfill while ill-defined problems have no strict requirements with numberless solution sets. This major difference makes ill-defined problems more open for creative thinking sessions (Casakin & Goldschmidt, 2000; Casakin, 2005; Casakin, 2010). Similar methods that are derived from Casakin’s method, also use visual analogy method to solve design problems related with the field of architecture and product design (Chai et al., 2015; Akrami, Faizi, & Moradi, 2017).

By taking into account designing a complex military system is rated as an ill-defined problem, DbA tools, methods and techniques stand out amongst other creativity tools, methods and techniques. Therefore, this study is designed to examine the potential contribution of product design domain experts to military concepts.

The design brief is constructed by the two separate workshop groups that researcher took place with the military experts who are interested in soldier modernisation programmes. Military experts emphasized the importance of situational awareness and informed the project team that dismounted soldier lacks situational awareness on the field which is a crucial need for current needs and contemporary military scenarios.

In order to reach aims of the study, subjects are expected to participate in a concept generation session. Study is conducted with one subject at a time in a quiet and comfortable room. Before the study no training programs are held. Procedure of this study is explained before starting the study. Throughout the session, interaction was avoided with participants except for questions asked by participants about within domain image set. In concept generation session participants were given A3-size papers to sketch their ideas. In view of the fact that every product designer has a sketching and idea generation style different kinds of drawing pens and pencils are provided. At sketching phase, participants were asked to sketch one idea per paper and pass on another paper for a different idea. The procedure took approximately 45 minutes in total. Concept generation took 30 minutes while the interview that takes place after concept generation phase took 15 minutes.

Figure 3.2 Materials and Environment of the Study

At the start of the study, a consent form presented to the participant (Appendix A). After that subjects were given instructions about the concepts of the study and detailed brief about an ill-defined design problem (Appendix B). Respectively, the concepts of dual-use technology, design-by-analogy and cross-industry innovation are disclosed. During the sessions, concept generation phase was video recorded while the interview phase that takes places after the concept generation was voice recorded.

Considering the limitations of current technologies and their maturity level to be an end product, creativity becomes a key concept for creating simple, robust and feasible solutions for products that provide situation awareness. For this reason, design problem of this study has been presented to participants as:

> *One of the most crucial ability of future soldier systems are "situational awareness". The ability of situational awareness allows military personnel to get real time data about the field the user is deployed. The real time data can be illustrated as:*
>
> - *Exact or approximate position of friend and foe*
> - *Global position of user and geographic north*

- *Map and geographical formations of the field that user deployed*
- *Weather conditions and weather forecast*
- *Health status and current posture of user*
- *Alert status for informing user for upcoming events*
- *Tracking ammunition that user had*

Critical information sets which are delivered to user visually or auditory increases the effectiveness of military personnel. You are expected to create product solutions or concepts that solve at least one problem from these examples given to you. The product solutions and concepts that relays information need to consider that user is in a military engagement. Therefore, it should engage the user physically and mentally as little as possible.

I will now present you two A3-size paper with 24 visual sources on them. Visual sources consist of 12 within domain and 12 between domain sources. On these papers you will find within domain solutions related to the brief I have just read and the between domain sources you have delivered to me before study. By using these visual analogy sources, you are expected to develop design concepts within 30 minutes. You can use as much time as you like to read and think about the design problem before you start developing design alternatives.

As it was explained in the design brief, two A3-size papers were provided that contains within domain and between domain image sets:

- Within domain image set is shown in Figure 8. Within domain image set consists of products for maintaining situational awareness that were already available in the market. Product set contains helmet mounted display, reconnaissance drone and bot, e-textile vest, larynx and bone-conduction microphone, wearable display, sight systems and virtual reality tactical maps. Detailed explanation and usage scenario of every single product is provided under every image. Images set is selected by researcher who has experience in soldier modernisation programmes.

- Between domain image set is unique for every participant. Before executing study, participant was asked to bring 12 images for between domain image set to the study. It was asked to select at least 6 images directly related with their field of expertise. The rest of the images can be selected whether participant's field of expertise or other fields that participant uses as an inspirational source while designing a product. An example image set selected by P10 is shown in Figure 9.

At the end of the study, the following questions were asked to acquire further information about both the study that participant completed and recognition of design-by analogy methods. Before starting to conduct the study, the researcher prepared a guideline for the semi-structured interview part of the study (Appendix B). This guideline intends to lead interview while have a more personalized data about the participant's experiences.

First question aims to learn further explanations of design concepts that participants developed. The main idea to ask this question is to understand how participants relate source images to and the target ones.

I. Let's talk about your concept generation session that you've completed. Could you explain how your design solutions are related with analogical resources?

II. I introduced the design-by-analogy methods in the literature before starting the study. Have you previously employed any design-by-analogy method to your design process in your academic or professional life?

   - If the participant answers "yes",

   II.I. Which design-by-analogy method you have had experienced?

II.II. Comparing the method you employed through your design process, what are the advantages and disadvantages of visual analogy method?

- If the participant answers "no",

II.III. Do you think, you are applying similar methods instinctively even you have never used a design-by-analogy method systematically in your design process?

III. Can you explain the advantages and disadvantages of this method when you compare the design by analogy methods that you have already experienced in your both academic and professional life?

IV. Have you ever experienced a cross-industry innovation in your domain?

- If the participant answers "yes",

IV.I. Could you explain the process of cross-industry innovation you have experienced?

IV.II. Was a specific methodology used to transfer or was it experimentally done?

Askeri havacılıkta önemli bilgilerin transparan ekrana yansıtılması, head-up display (HUD).

Kaska monteli HUD uygulaması ile durumsal farkındalığın arttırılması.

Keşif maksadıyla kullanılan mini insansız hava aracı.

Saate entegre ekran ile dost-düşman pozisyonların gösterimi.

Taktik yeleğe entegre tablet ile operasyon alanının gösterimi.

Kaska entegre termal, gündüz ve gece görüş kamerası.

Olay mahaline fırlatılarak kullanıcısının güvenli mesafeden görüntü almasına izin veren drone.

Alçak sesle haberleşmeyi sağlayan gırtlak ve kemik iletimli mikrafonlar.

Silaha monteli lazer mesafe ölçer ile çevredeki tehditlerin mesafelerinin saptanması.

Tekstile entegre edilmiş ve bu sayede kablo miktarını ve ağırlığını azaltan konnektör yapısı.

Bileğe takılabilen askeri tablet.

VR uygulamalar ile sanal taktik saha üzerinde stratejilerilerin planlaması.

Figure 3.3 Within Domain Analogy Sources

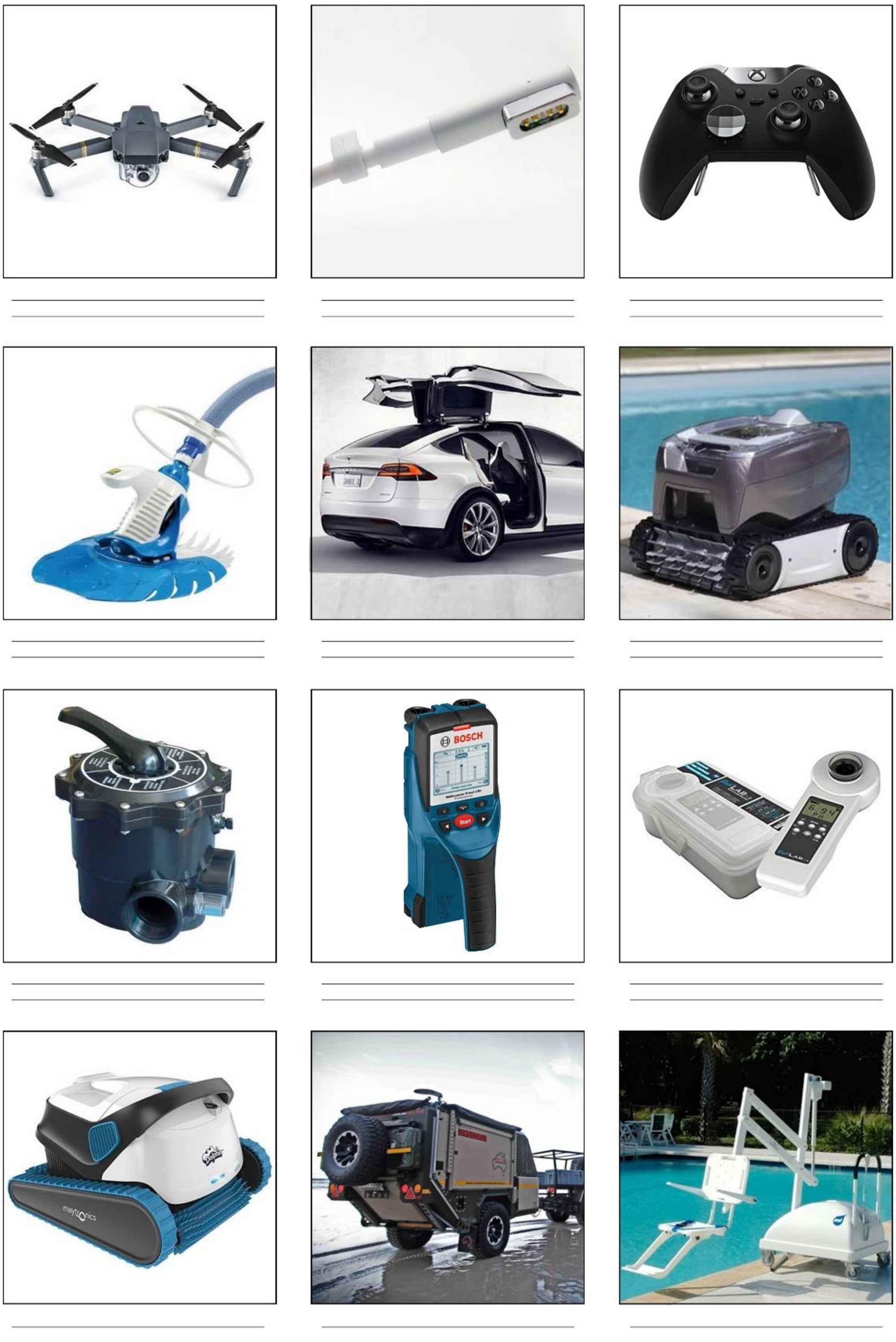

Figure 3.4 Between Domain Analogy Source Example Created by P10

3.2 Participants and Sampling

To conduct this research, data was collected from 20 product designers (mean year of experience 2.78 years, SD=1.64) who work in various civil industries. Distribution of the designers' expertise and their experience in this industry is shown in detail at Table 2. Classification of expertise of designers are based on Locarno Classification which classifies industrial design to 32 classes (Locarno Classification [LOC], 2013). To understand the efficiency of method depending to the distance of domain, participants are chosen to cover a wide range of industries including automotive, furniture, health appliances, home appliances, civil transportation, wearable products etc.

Purposive sampling was done to choose participants. Purposive sampling is a non-probability sampling method which relies on researchers judgment while selecting participants of the study (Dudovskiy, 2016). Selection criteria of designers is depending on various factors. The most important criterion is that the participant should not be working in the defense industry. This criterion is added to ensure that evaluation process is done objectively regardless from participants' domain experiences. Minor experiences like participating in a design contest about defense industry or contributing a short-term defense industry project was allowed. Participants with minor experience in the field of defense industry was used as a control group. The aim here is to understand how such an experience influences the quality of concept creation process.

Another selection criterion of participants is experience of designers. Participant should be working for at least 1 year and mostly 5 years in a specific field of design. Study conducted among novice designers, because Ozkan (2011) states that expert designers show signs of convergent thinking while novice designers show signs of divergent thinking. Through the study that Ozkan (2011) executed, expert designers used near domain sources while novice designers tried to build connection between generally distant source and target domains. Also Jansson and Smith (1991) state that expert designers struggle connecting source and target within the borders of inter-domain analogy. Inter-domain analogy is a concept where source and target domains are in the different conceptual domain (Bonnardel & Marmeche, 2004). These findings of literature directed the researcher to execute a study with novice designers to increase the efficiency of DbA session.

At the start of the study, participants were asked about their academic and professional experiences. Participants had an undergraduate degree from various universities: Middle East Technical University (9), Izmir University of Economics (5), Gazi University (3), Istanbul Technical University (2) and Anadolu University (1) (see Table 3.1).

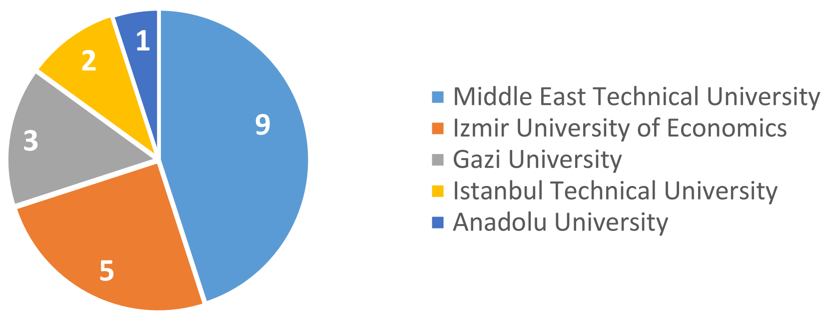

Figure 3.5 Distribution of Participants according to the University of the Undergraduate Degree

17 participants had an undergraduate degree while 3 had a master’s degree While 9 of the 17 designers who had an undergraduate degree are continuing their master’s degree education, 3 designers who had a master’s degree are continuing to their PhD degree education.

Participants were asked if they have any minor experience about defense industry in terms of product design. 14 participants stated that they don’t have any experience in the field of defense industry. 6 participants stated that they have minor experiences in the field of defense industry (see Table 3.2). This experience set includes

- Design competitions organized by private defense industry organizations,
- Design competitions organized by governmental defense industry organizations,
- Short-termed professional projects.

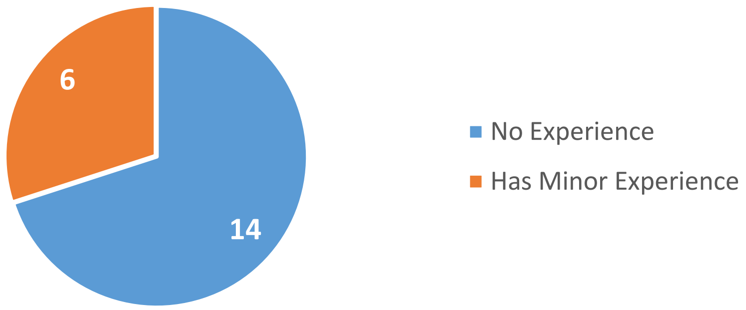

Figure 3.6 Distribution of Participants According If They Have Any Knowledge About Defense Industry

3 of 6 designers that had minor experiences about defense industry stated that they worked on (1) unmanned ground vehicle and (2) infantry fighting vehicle as part of design competitions. 1 of 6 designer stated he had a short-termed professional project about (3) command and control console. Only 2 of 6 designers stated that they had short-termed projects about (4) wearable technologies related with soldier modernization programmes. Outcome of these six designers are used as a control group through the analysis of the study.

Table 3.1 Distribution of Participants In Terms of Expertise

	Locarno SubClass	Experience (year)
P01	Gymnastics And Sports Apparatus And Equipment (21-02)	3.0 years
P02	Construction Machinery (15-04)	4.5 years
P03	Motor Cars, Buses And Lorries (12-08)	3.5 years
P04	Locomotives And Rolling Stock For Railways And All Other Rail Vehicles (12-03)	2.0 years
P05	Communications Equipment, Wireless Remote Controls And Radio Amplifiers (14-03)	1.5 years
P06	Apparatus And Equipment For Doctors, Hospitals And Laboratories (24-01)	2.0 years
P07	Apparatus And Equipment For Doctors, Hospitals And Laboratories (24-01)	5.0 years
P08	Beds (06-02)	2.5 years
P09	Signs, Signboards And Advertising Devices (20-03)	1.5 years
P10	Steps, Ladders And Scaffolds (25-04)	6.0 years
P11	Washing, Cleaning And Drying Machines (15-05)	2.0 years
P12	Apparatus And Equipment For Doctors, Hospitals And Laboratories (24-01)	4.0 years
P13	Games and Toys (21-01)	1.0 years
P14	Refuse And Trash Containers And Stands Therefor (09-09)	1.0 years
P15	Instruments, Apparatus And Devices For Checking, Security Or Testing (10-05)	1.0 years
P16	Seats (06-01)	2.0 years
P17	Apparatus And Equipment For Doctors, Hospitals And Laboratories (24-01)	2.0 years
P18	Cooking Appliances, Utensils And Containers (07-02)	1.0 years
P19	Public Lighting Fixtures (26-03)	4.0 years
P20	Data Processing Equipment As Well As Peripheral Apparatus And Devices (14-02)	6.0 years

3.3 Analysis of the Findings

Analysis of the findings embodies two methods of analysis: qualitative analysis and quantitative analysis. Combining both quantitative and qualitative data aims to increase the efficiency of research to understand the potential of visual analogy method in the field of defense industry. Analyzing qualitative data in the light of quantitative data increases the chance of accurate interpretation of results for complex real world scenarios (Kemppainen, Hein, & Manser, 2017).

The major difference between qualitative and quantitative analysis is the type of data. While qualitative research focuses on understanding of underlying reasons, opinions and motivations that cannot be explained mathematically, quantitative research focuses on generating numerical data to understand occasions statistically (DeFranzo, 2011). The methods of quantitative and qualitative analysis are introduced in the following sections.

3.3.1 Quantitative Analysis

Linsey et al. (2011) state that good metrics are important to evaluate output of idea generation process. Similar design metrics are defined to distinguish concepts in terms of idea generation success in various studies (Girotra, Terwiesch, & Ulrich, 2010; Linsey et al., 2011; Moreno et al., 2014). To evaluate the proposed concepts, metrics of the study are defined as:

[1] quantity of ideas

[2] quality of ideas

[3] novelty

[4] variety

3.3.1.1 Quantity of Ideas

Quantity of ideas is defined as number of concepts that participants are developed during the method of visual analogy session. All ideas generated by participants are listed in spreadsheet in Microsoft Excel. Any sketch, diagram or statement that participant creates in a A3 paper that was provided during the study defined as an “idea” (Moreno et al., 2014). Total number of ideas defined with equation specified below:

$$quantity\ of\ ideas\ =\ non-repeated\ ideas+repeated\ ideas$$

3.3.1.2 Quality of Ideas

During the study, participants generated 76 product concepts based on the brief about increasing situational awareness of military personnel deployed in the field. Scoring the quality of proposed design solutions are done by two industrial designer judges who have at least five year of experience in defense industry. The jury was chosen on the basis of volunteerism. Judges of this study do not have any further information about the design process that was conducted by participants.

There are several concepts for defining quality in terms of scoring. Some concepts may be found in literature as technical feasibility, relevance, specificity, etc. (Moreno et al., 2014). However, these concepts are highly related with practicability which can be applied to a well-defined design problem. The design brief aims to create innovative and creative solutions for an ill-defined design problem which directs participants to propose not fully solved design ideas. Casakin (2005) suggests that because ill-defined problems have a wide solution set, scoring of ideas should be done on a wide scale. A scale of 1 to 5 is defined for this study. A score of 1 to 2 is considered that design requirements are not met while a score of 3 to 5 is considered the proposed design solution is more satisfying.

After the scoring of judges, Cronbach’s Alpha is used to measure the interrater reliability of deliberately chosen judges. Cohen’s kappa varies from 0 to 1 in terms of agreement level of jury for the same case (Glen, 2014). To analyze agreement level of jury, numeric range of Table 3.2 is used.

Table 3.2 Rule of Thumb for Cronbach's Alpha (Glen, 2014)

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3.3.1.3 Novelty of Ideas

To calculate the variety and novelty of the product concepts, 76 product concepts was listed to a spreadsheet in Microsoft Excel. Researcher of the study grouped similar product concepts that designed by participants (Figure 3.3). After similar concepts was grouped, the novelty was calculated for the whole study (Jansson & Smith, 1991). Novelty of product solution is calculated using the equation specified below:

$$novelty \ = 1 - \frac{number\ of\ similar\ concepts}{total\ number\ of\ concepts}$$

3.3.2 Qualitative Analysis

Qualitative data analysis aims to support quantitative data analysis and to give an answer for both main and sub-question of this research. As it is mentioned at previous section, study concluded with a semi-structured interview that takes place at the end of the study. Questions intend to acquire further information about both the study that participant completed and recognition of design-by analogy methods.

As conversation during an interview is transferred to text, words may lose its true meaning. That is why, although transcription may seem a straightforward process, it is one of the most compelling phases of qualitative data analysis (Bazeley, 2015). While semi-structured interviews were audio recorded, concept generation activities were video recorded. Both audio and video recorded data requires qualitative data analysis. Audio recordings of the interview were transcribed to be used for qualitative analysis. Transcription was done in Microsoft Word.

To conduct qualitative analysis, a computer assisted qualitative data analysis (CAQDA) which is called Atlas.ti was used. All data including video records, audio records and transcripts of audio records are processed to Atlas.ti. During the process, these features that Gibbs (2011) explained were used for coding:

[1] the construction, modification and maintenance of code lists,

[2] the use of these to code documents,

[3] ways of dealing with case-based data

Coding scheme is categorized according to the requirement of study. Categories are [1.1] *DbA in academic life*, [1.2] *DbA in professional life*, [1.3] *use of analogy for functional purposes*, [1.4] *use of analogy for styling purposes*, [2.1] *instinctive use of DbA*, [2.2] *methodological use of DbA*, [3.1] *cross-industry innovation*. These codes aim to understand awareness level of product designer in the field of DbA and how product designer using DbA in their professional flow.

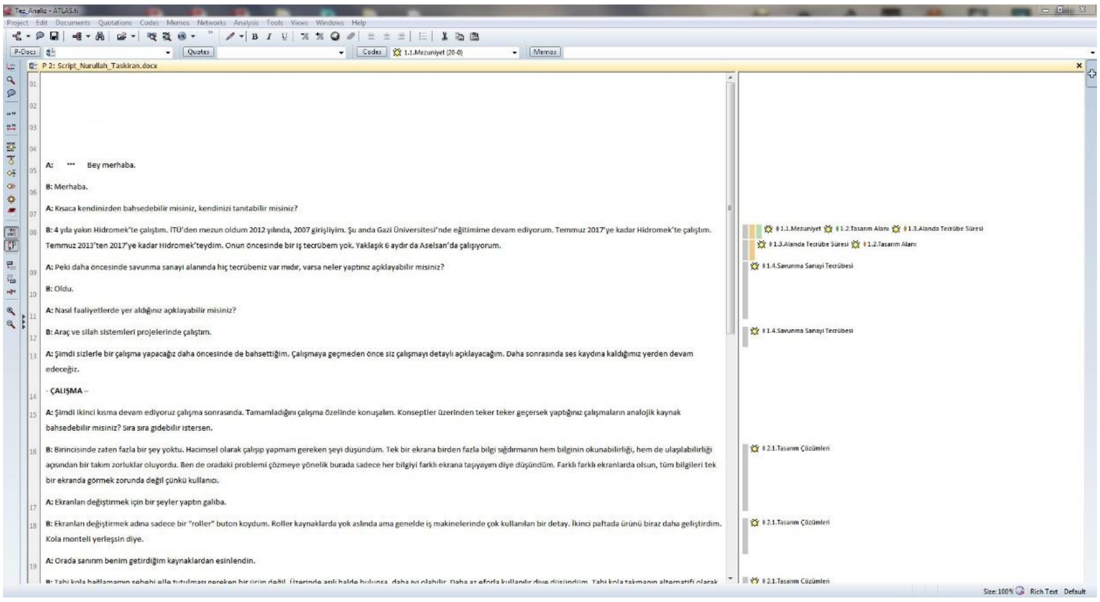

Figure 3.7 Interface of Atlas.ti

3.4 Summary

This chapter explained the DbA procedure proposed in this thesis and how it is evaluated. Throughout the chapter process of DEKT-DbA, semi-structured interview that takes place after study and their qualitative and quantitative data analysis is explained.

During the study empirical data was collected from 20 product designers (mean year of experience 2,78 years, SD=1,64) who work in various civil industries including automotive, furniture, health appliances, home appliances, civil transportation, wearable products etc.

Before the study two workshops were held and the brief was defined. According to brief, within domain sources were defined. On the other hand, between domain images set is unique for every participant. Before executing study, participant was asked to select 12 images for between domain image set which are related with their field of expertise.

With the preparation of within and between domain sets, first stage of the study which is called visual analogy session was conducted. After the study semi-structured interview was held to gather more information about the study and usage frequency of creative enhancement tools by product designers. To analyze the data of the study whole process was video and voice recorded.

At the following chapter, results of the study are presented.

CHAPTER 4

RESULTS

In this chapter, both quantitative findings of the study and qualitative findings of the semi-structured interview are presented. Following the order of interview and semi-structured interview outcomes of the study are examined on an individual basis through both qualitative and quantitative ways. Finally, the effect of DEKT-DbA as a tool to enhance creativity for a distant domain will be examined.

4.1 Quantitative Analysis of the Study

In this section, quantitative analysis of the study is presented. During the study, participants generated 76 product concepts based on the brief about increasing situational awareness of military personnel deployed in the field. 76 product concepts were classified as 30 “C5ISR”, 22 “Equipment and protection sub-systems”, 10 “Sensor (detection) sub-systems”, 2 “Power and energy sub-systems” and 12 “Autonomous and RC sub-systems”. Originally, classification of future soldier sub-systems does not include “Autonomous and RC Sub-systems” (Astan, 2015). Both the regarding literature and concepts generated by participants, point the importance of supportive systems so that while classifying the concepts, “Autonomous and RC Sub-systems” was added to the classification. Zajac and Bober (2017) state that autonomous systems are becoming key players of the field with their ability to decrease casualty risks and their surpassing performance compared to humans.

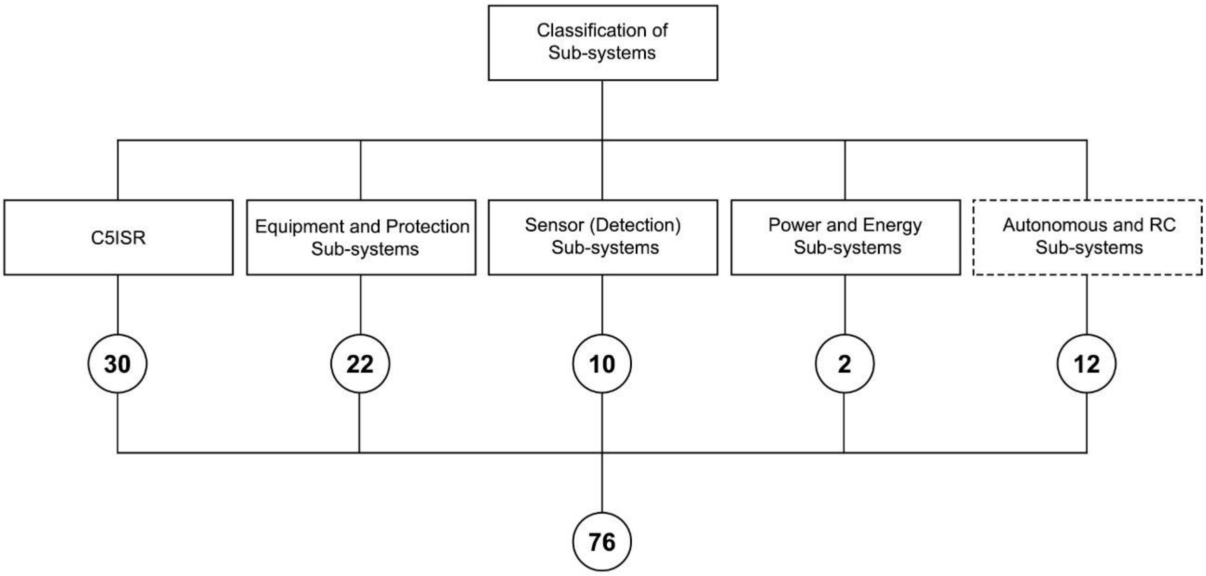

Figure 4.1 Distribution of Concepts among the Sub-Systems

Participants developed 30 concepts for C5ISR and 22 concepts for Equipment and Protection Sub-systems. These two fields contain various product groups and graphic user interfaces. However, Sensor (Detection) and Power Sub-systems and Energy Sub-systems have a technological infrastructure compared to other fields. Distribution of concepts points out that product designers preferred sub-systems which are considered as near-fields for product design profession. Participants prefer developing product and graphical user interface concepts (Equipment and Protection Sub-systems, C5ISR) rather than technology depended fields (Sensor Sub-systems, Power and Energy Sub-systems)

4.1.1 Novelty of Ideas

Novelty of product concepts was calculated for entire study based on every product solution that participants proposed (Jansson & Smith, 1991). To calculate novelty of the study researcher examine all product concepts and classified according to Classification of Sub-systems (Figure 4.1) (Appendix I). Jansson and Smith (1991) proposed the equation below to calculate originality of concepts. The novelty was calculated as 0.79 for this study.

$$novelty \ = 1 - \frac{number\ of\ similar\ concepts}{total\ number\ of\ concepts}$$

$$novelty = 1 - \frac{17}{76} = 0.79$$

Based on equation, maximum novelty is equal to 1. Novelty of the study was observed satisfactory (r=0.79). Novelty is an important metric to observe the efficiency of idea generation methods, tools and techniques.

4.1.2 Quality of Ideas

The design brief for the study aims to create innovative and creative solutions for defined problem which can lead participants to propose ideas not fully solved in terms of design. For assessing quality of ideas, a scale of 1 to 5 is defined for this study. A score of 1 to 2 is considered that design requirements is not met while a score of 3, 4 to 5 is considered that proposed design solution is more satisfying (Casakin, 2005).

Two jury members, who have at least five years of product design experience in the field of defense industry, evaluated 76 solutions proposed by 20 participants. During that process, jury members were not informed about the conditions of the study. The scoring of the concepts was conducted independently by each member, so that they could not affect each other's decisions. After the scoring of product concepts, average quality of all participants was calculated as 3.06/5 (see Table 4.1). According to Casakin (2005) average score is rated as "satisfying" in terms of design.

Table 4.1 Average Score of Every Participant According to Juries

Participants	Number of Concepts	Jury 1	Jury 2
P 1	4	3.25	3.50
P 2	4	1.75	1.50
P 3	7	2.14	1.86
P 4	5	4.00	3.60
P 5	6	2.67	2.67
P 6	7	2.86	2.57
P 7	4	3.25	2.75
P 8	3	2.33	2.67
P 9	3	3.67	3.00
P 10	2	3.50	3.50
P 11	5	4.20	4.20
P 12	3	3.00	2.67
P 13	2	4.00	3.50
P 14	5	3.60	3.40
P 15	3	2.33	1.33
P 16	2	3.50	3.50
P 17	5	4.20	3.80
P 18	2	2.00	1.00
P 19	2	4.00	4.00
P 20	2	3.50	3.50

To understanding the effect of domain-knowledge, participants who has a minor knowledge in the field of defense industry were divided and the average score calculated separately (see Table 4.2). The rest of the participants were also divided, and the average score calculated in terms of comparing (see Table 4.3).

Average score of participants who had a domain-knowledge about defense industry calculated as 2.52/5 (see Table 4.2). On the other hand, average score of participants who do not have experience in defense industry calculated as 3.29/5 (see Table 4.3). In Table 4.2 and Table 4.3, participants who had a score above the group's average are shown in orange color.

Table 4.2 Average Score of Participants Who Had Domain-Knowledge

Participants	Average Score of Participant
P 2	1.63
P 3	2.00
P 5	2.67
P 8	2.50
P 12	2.83
P 20	3.50
Average	**2.52**

Table 4.3 Average Score of Participants Who Had Not Have Domain-Knowledge

Participants	Average Score of Participant
P 1	3.38
P 4	3.80
P 6	2.71
P 7	3.00
P 9	3.33
P 10	3.50
P 11	4.20
P 13	3.75
P 14	3.50
P 15	1.83
P 16	3.50
P 17	4.00
P 18	1.50
P 19	4.00
Average	**3.29**

In this study, participants who had no domain-knowledge in defense industry performed better than participants who had a domain-knowledge in defense industry. Considering that participants who had no domain-knowledge in defense industry performed better in this study, the results may match with the concept of Resistance to Change (RTC). RTC defines as resistance of a designer to change. Higher RTC level for a designer mostly indicates the lower creativity level (Kemppainen, Hein, & Manser, 2017).

After the scoring process, Cronbach's Alpha was calculated as 0.94 which indicates that internal reliability of jury was "excellent" according the Rule of Thumbs (see Table 3.2) (Glen, 2014).

4.2 Examination of Ideas

In that section, 76 ideas are examined to understand the analogy transfer route of participants in terms of how they generate analogies while developing their design solutions. To visualize idea generation flows, an approach is introduced which is called "Analogy Reflection Diagram". Analogy Reflection Diagrams has two columns (see Figure 4.2 for an example of it). Right column shows the "Within Domain Analogy Sources" (see Figure 3.5) provided by the researcher to both introduce future soldier concepts to participant and creating a "target" field to project their ideas. Left column shows "Between Domain Analogy Sources" (see Figure 3.6) that were created by participants related with their field of work.

In most of the cases (27 cases), participants use an image from "Between Domain Analogy Sources" and constructed an analogy with an image from "Within Domain Analogy Sources". In several cases (2 cases) participants did not use a source while generating concept.

In "Analogy Reflection Diagram", use of image is presented in two states. Blank squares points participant used no image to construct an analogy, while the squares with images points that participant used an image to construct an analogy.

In the following sections, idea generation flows of each participant are explained in detail together with their Analogy reflection Diagrams.

4.2.1 Participant 1

Participant 1 (P1) has 3 years of experience in the field of Games, Toys, Tents and Sports Goods - Gymnastics And Sports Apparatus And Equipment (Class 21, Subclass 02) according to Locarno Classification. He does not have any design experience in the field of defense industry. During the study, he generated 4 concepts.

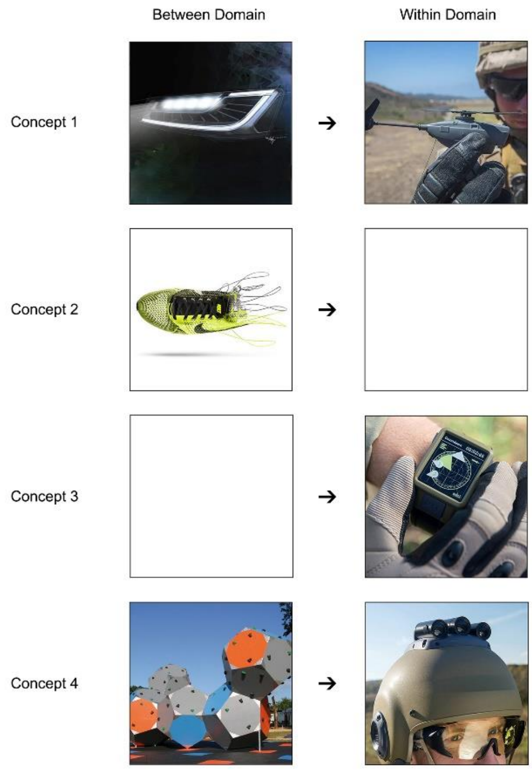

Figure 4.2 P1's Analogy Reflection Diagram

[1] At the first concept, participant inspired from an automotive LED light. He projected this inspiration to the field of unmanned aerial vehicle (UAV). Participant

proposed to add LED lights to increase the efficiency of night operations and tracking motion of UAVs.

[2] At the second concept, participant inspired from knitted shoe design. Participant uses no target image to project but developed a concept about preventing bleeding. He proposed intelligent sleeve set for various parts of the body to prevent bleeding even if military personnel are not able to interfere the wound.

[3] At the third concept, participant uses no source image to inspire but he detects a potential problem area on target image set. He explains that the size of the displays at wrist are not proper to deliver complex data to the end user. Also, he pointed that light discipline is an important issue for night combat. Participant proposed a simplified watch which is easier to understand while in the battlefield. The watch has several small LEDs on it which informs end user with different colors according to warning level.

[4] At the fourth concept, participant directly inspired from his field of work. He proposed a modular camera set. Every module has a mechanical interface which creates the possibility to combine every module from various combinations. Also, he proposed that a single battery unit may feed the whole system via that working principle.

See Appendix C, Figure C.1 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.1 to see example sketch developed during study.

4.2.2 Participant 2

Participant 2 (P2) has 4.5 years of experience in the field of Machines - Construction Machinery (Class 15, Subclass 04) according to Locarno Classification. He has design experience in the field of defense industry. He participated to a design competition organized by governmental defense industry organization. The brief of the competition is about designing an autonomous military vehicle. During the study he generated 4 concepts.

Figure 4.3 P2's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from his field of work. He was inspired from an interior of a heavy-duty equipment. Participant states that roller button is a common interface that is used in interior design of heavy-duty equipment. Instead of using a touch-screen or multiple buttons in wearable displays he proposed a single roller button. Interface of the watch contains separate screens for every information set so that it is easier to understand and easy to use with roller button.

[2] At the second concept, participant uses no source image. He tries to explore alternative ways to carry wearable displays to increase its ergonomics.

[3] At the third concept, participant uses a robust product example to transfer its features to wearable displays. He pointed that light discipline and robustness is an important issue for military operations. He proposed adding a lid for wearable displays

to have protection against environmental factors and provide light discipline when it is not in use in night combat.

[4] At the fourth concept, participant directly inspired from his field of work. He proposed a collapsible Helmet Mounted Display (HMD). Military personnel may fold HMD over the helmet when the device is not in use to prevent blocking the Field of View (FOV).

See Appendix C, Figure C.2 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.2 to see example sketch developed during study.

4.2.3 Participant 3

Participant 3 (P3) has 3.5 years of experience in the field of Means of Transport or Hoisting - Motor Cars, Buses and Lorries (Class 12, Subclass 08) according to Locarno Classification. She has design experience in the field of defense industry. She participated to a short-termed project related with the military vehicles. During the study, she generated 7 concepts.

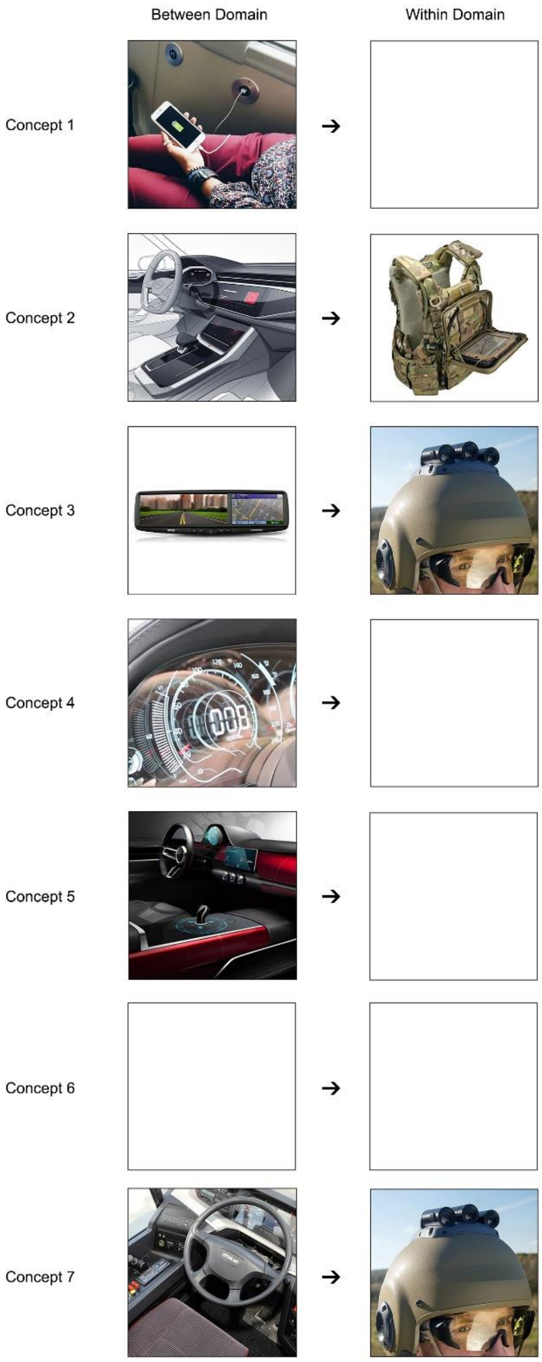

Figure 4.4 P3's Analogy Reflection Diagram

[1] At the first concept, participant inspired from her field of work. She explained that as intelligent gadgets start playing a part in our life, battery life of these devices become an important problem. As a result, public transportation introduces built-in chargers for vehicles. Based on this, she proposed mount solar panels on assault vest.

[2] At the second concept, participant directly inspired from her field of work. She explained that panels that are used in interiors of vehicles are mostly assembled without using fasteners but with close fits. She proposed using the same principle for mounting equipment to a vest.

[3] At the third concept, participant inspired from her field of work. She explained intelligent rear-view windows allow users to gain situational awareness (SA) about traffic conditions. Starting from this point, she proposed a rear camera that projected to HMD which would help user gain SA.

[4] At the fourth concept, participant inspired from a layered indicator design from her field of work. She proposed a mechanical layering system for HMD's to provide superiority to user considering different environmental factors.

[5] At the fifth concept, participant inspired from an interior sketch. She explained that contemporary interiors of vehicles have many mechanical and digital interfaces. Starting from this point, she proposed a voice activated system for modernized infantry to focus on the real task on the field.

[6] At sixth concept, participant used neither a source image nor a target image to transfer. She explained that modernized infantry systems became software dependent. When single system is seized by enemy this could endanger the whole system. She proposed a hard button for deleting the whole software.

[7] At sixth concept participant directly inspired from her field of work. She explained a mechanical detail used in automobiles to connect buttons to a dashboard and proposed using the same logic for ballistic helmets to integrate other equipment on them.

See Appendix C, Figure C.3 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.3 to see example sketch developed during study.

4.2.4 Participant 4

Participant 4 (P4) has 2 years of experience in the field of Means of Transport or Hoisting - Locomotives and Rolling Stock for Railways and All Other Rail Vehicles (Class 12, Subclass 03) according to Locarno Classification. He does not have any design experience in the field of defense industry. During the study, he generated 5 concepts.

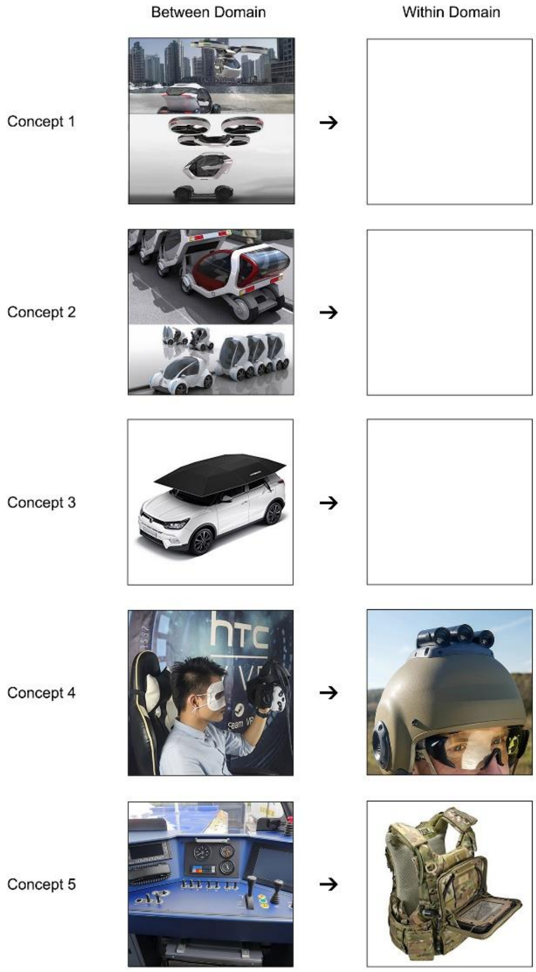

Figure 4.5 P4's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from his field of work. He was inspired from a concept transportation project. Participant proposed a stretcher which may be integrated with both unmanned aerial vehicles (UAV) and unmanned ground vehicles (UGV).

[2] At the second concept, participant directly inspired from his field of work. He was inspired from a stackable car concept. He proposed a modular UAG concept consisting of 9 units. All units may move together or independently while performing different types of missions. Also, they may execute reconnaissance missions for providing SA.

[3] At the third concept, participant directly inspired from his field of work. He proposed a solar panel mounted on a frame which is attached to the backpack of personnel. Also, he proposed that the same frame could carry a flexible display which would reflect the texture of the ground to provide camouflage for soldier.

[4] At the fourth concept, participant inspired from disposable pads of VR sets. Using the same principle, he proposed that helmets may have disposable pads to provide hygiene.

[5] At the fifth concept, participant directly inspired from his field of work. He stated that fiber reinforced plastic (FRP) consoles that are used in locomotives have a generic hole on them for applying to different combinations of user interface. He proposed modular plates for assault vests which are similar with FRP consoles. These modular plates may be customized for special needs of soldiers and different type of missions.

See Appendix C, Figure C.4 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.4 to see example sketch developed during study.

4.2.5 Participant 5

Participant 5 (P5) has 1.5 years of experience in the field of Recording, Communication Or Information Retrieval Equipment - Communications Equipment, Wireless Remote Controls And Radio Amplifiers (Class 14, Subclass 03) according to Locarno Classification. He has design experience in the field of defense industry. He contributed to a short-term project from defense industry. The brief of the project is designing a wearable equipment. During the study he generated 6 concepts.

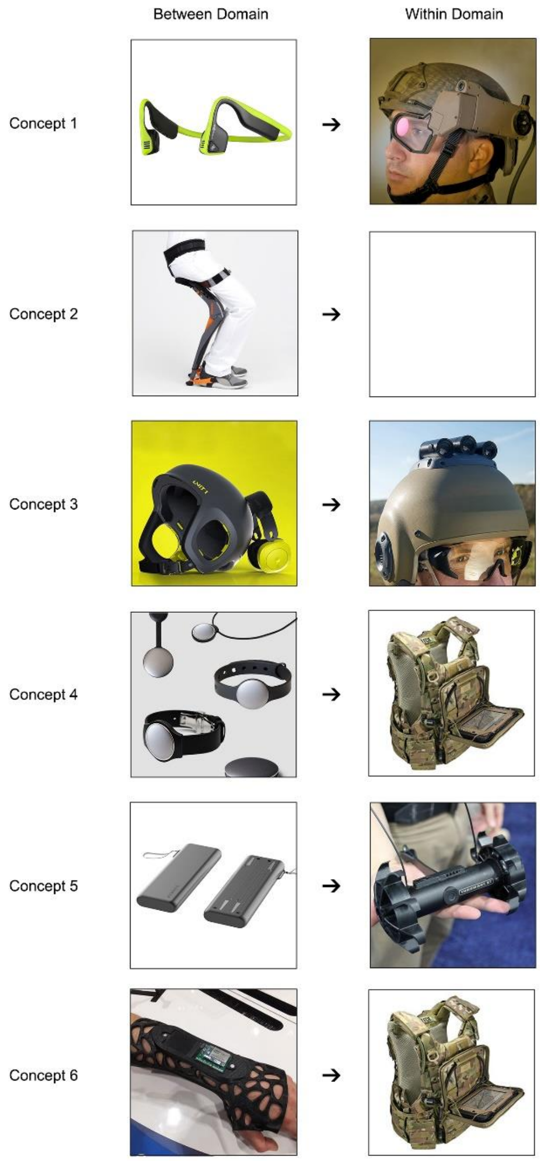

Figure 4.6 P5's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from his field of work. He explained that he has already had experience on bone conducting headphones. Considering the physical size of HMDs, he said both products can be integrated into one.

[2] At the second concept, participant directly inspired from his field of work. He was inspired from a product that he designed for assembly lines. He proposed a wearable

“chairless chair” concept for military personnel who use stationary equipment on the field.

[3] At the third concept, participant directly inspired from his field of work. He proposed a ballistic helmet which has some cavities on rear areas. These cavities let integration of different military headphones to the helmet. Also, when headphones are not integrated, these cavities may be covered with military graded armor.

[4] At the fourth concept, participant inspired from a product which he introduced in his sources. Using a similar function, he proposed a universal mounting unit for displays which lets users to integrate their display on both wrist and assault vest.

[5] At the fifth concept, participant directly inspired from his field of work. He was inspired from a product that he has developed. Product has telescopic grills which let users to collapse the whole product when it is not in use. He proposed using the same principle for throwable reconnaissance robots. He proposed an inflatable system which triggers with an impact.

[6] At sixth concept, participant inspired from his field of work. He was inspired from a wearable product that uses “voronoi diagram”. He proposed that, these voronoi diagrams may be used as mechanical joints for assault vest to mount different kinds of equipment.

See Appendix C, Figure C.5 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.5 to see example sketch developed during study.

4.2.6 Participant 6

Participant 6 (P6) has 2 years of experience in the field of Medical and Laboratory Equipment - Apparatus and Equipment for Doctors, Hospitals and Laboratories (Class 24, Subclass 01) according to Locarno Classification. He does not have any design experience in the field of defense industry. During the study, he generated 7 concepts.

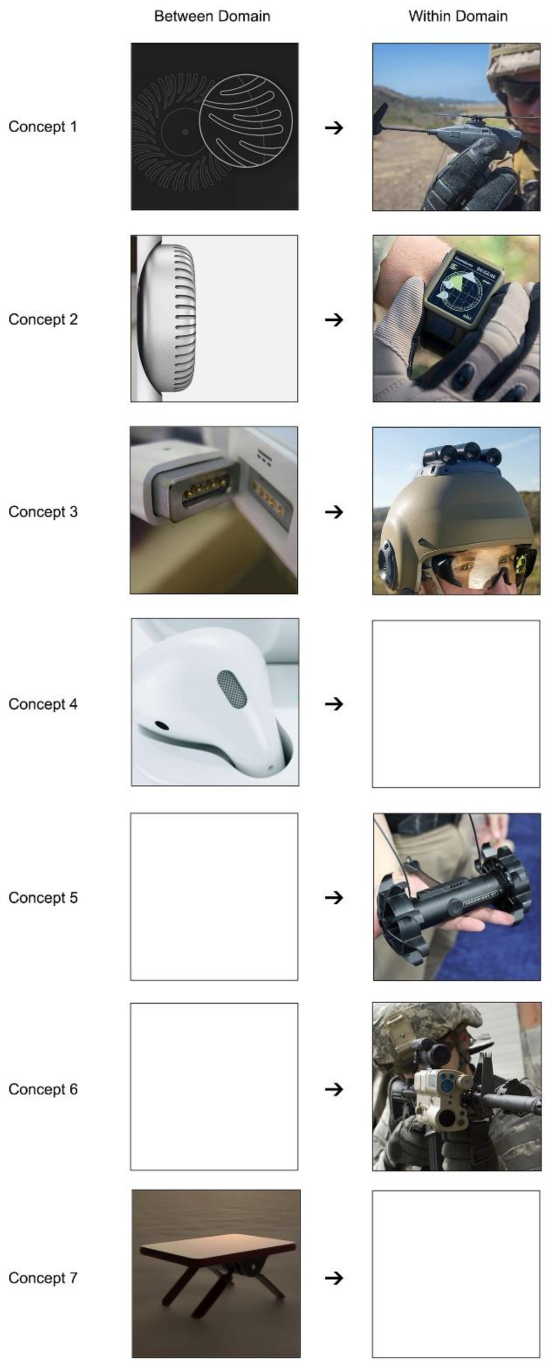

Figure 4.7 P6's Analogy Reflection Diagram

[1] At the first concept, participant inspired from a fan design from his field of work. He explained that asymmetrical fan design decreases the noise generated by fans. He proposed an asymmetrical propeller design to decrease the noise of drones.

[2] At the second concept, participant inspired from a roller button from his field of work. He explained that wearable displays that are used in military have many hard buttons on them. He proposed a roller button for the interface to create a user-friendly wearable display.

[3] At the third concept, participant inspired from a magnetic connector from his field of work. He explained that in most military systems batteries are integrated to the assault vest. Starting from this point, he pointed that a cable between the equipment on ballistic helmet and battery is needed which inhibits the head movement of user. He proposed a magnetic cable which allows user to remove his helmet easily when it is required.

[4] At the fourth concept, participant inspired from a directional microphone technology from his field of work. Using a similar working principle, he proposed a directional microphone design which eases communication on the field.

[5] At the fifth concept, participant uses no source image. He proposed a telescopic mechanism for throwable reconnaissance robots. He proposed an inflatable system which is triggers with an impact.

[6] At sixth concept, participant uses no source image. He proposed a weapon mounted product which provides face-recognition and ballistic correction. He suggested that with this addition any weapon would be an “intelligent” system.

[7] At seventh concept, participant inspired from a furniture design. He explained infantry may need complex PCs or other equipment which are heavy. He proposed a collapsible table which provides a horizontal plane in every condition.

See Appendix C, Figure C.6 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.6 to see example sketch developed during study.

4.2.7 Participant 7

Participant 7 (P7) has 5 years of experience in the field of Medical and Laboratory Equipment - Apparatus and Equipment for Doctors, Hospitals and Laboratories (Class 24, Subclass 01) according to Locarno Classification. She does not have any design experience in the field of defense industry. During the study, she generated 4 concepts.

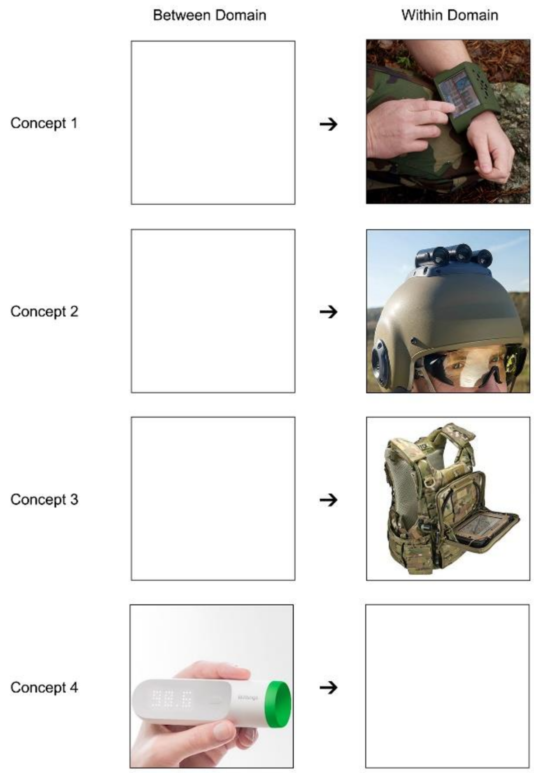

Figure 4.8 P7's Analogy Reflection Diagram

[1] At the second concept, participant uses no source image. He proposed a bracelet that projects the interface to user’s wrist.

[2] At the second concept, participant uses no source image. She explained separated modules that are designed for ballistic helmet impair the integrity of helmet design. She proposed an integrated ballistic helmet which includes laser rangefinder, multiple cameras, HMD and headphone.

[3] At the third concept, participant uses no source image. She proposed a mounting unit that is designed for tablet PCs or rugged phones. She explained that when removed from the assault vest, the mounting unit can also be used as a stand for product.

[4] At the fourth concept, participant inspired from a source image. She explained screens used in military conditions need special protection from the environmental effects. Instead of using LED display, she proposed a downgraded digital display with a simple interface. Also, she suggests this kind of display has an advantage of providing light discipline to user.

See Appendix C, Figure C.7 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.7 to see example sketch developed during study.

4.2.8 Participant 8

Participant 8 (P8) has 2.5 years of experience in the field of Furnishing - Beds (Class 06, Subclass 02). She has design experience in the field of defense industry. She contributed to a short-term project from defense industry. The brief of the project is designing a radio handset. During the study she generated 3 concepts.

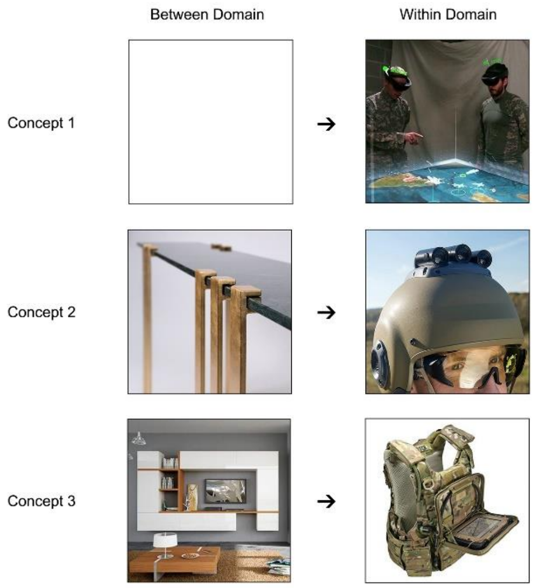

Figure 4.9 P8's Analogy Reflection Diagram

[1] At the first concept, participant uses no source image. She stated contemporary VR sets are not designed considering the need of military user's working environment. She proposed some ergonomic improvements for VR sets deployed to the battlefield.

[2] At the second concept, participant directly inspired from her field of work. She inspired from a mechanical joint of a furniture. She proposed a rail which has a similar working principle. With this rail, user can mount and easily adjust their equipment.

[3] At the third concept, participant directly inspired from her field of work. She explained every design has a visual balance within its design elements. She proposed that assault vests used by military personnel could be designed considering this design principle. She proposed several mechanical joints for integration of user's equipment to the user to assault vest.

See Appendix C, Figure C.7 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.7 to see example sketch developed during study.

4.2.9 Participant 9

Participant 9 (P9) has 1.5 years of experience in the field of Sales and Advertising Equipment, Signs - Signs, Signboards and Advertising Devices (Class 20, Subclass 03) according to Locarno Classification. She does not have any design experience in the field of defense industry. During the study, she generated 3 concepts.

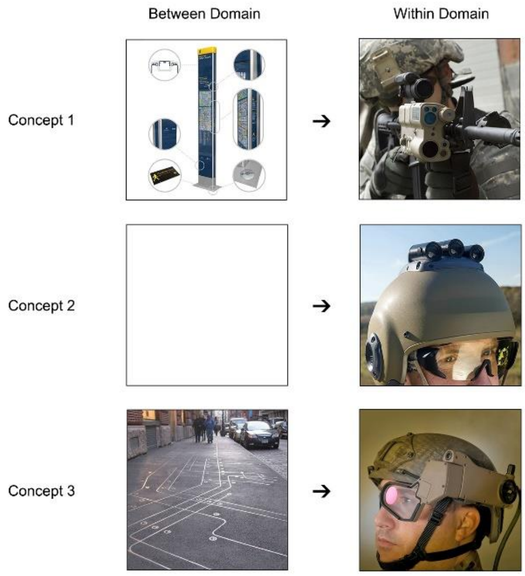

Figure 4.10 P9's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from her field of work. She explained that modular signboards that are used in urban design have essentially the same logic with laser rangefinders. She proposed that bracelets may have proximity sensors on them and use these sensor to collect data to map the environment.

[2] At the second concept, participant uses no source image. She explained that wrist may not be the proper place to collect environmental data. She proposed that helmets may be a more suitable place for collecting spatial data.

[3] At the third concept, participant inspired from her field of work. She explained that in many big cities, urban design helps people to reach touristic locations with two dimensional patterns. Inspiring from this idea, she proposed that concept two may merge with way-finding systems integrated to a HMD. This would help military personnel build awareness about environmental factors.

See Appendix C, Figure C.9 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.9 to see example sketch developed during study.

4.2.10 Participant 10

Participant 10 (P10) has 6 years of experience in the field of Building Units and Construction Elements - Steps, Ladders And Scaffolds (Class 25, Subclass 04) according to Locarno Classification. He does not have any design experience in the field of defense industry. During the study, he generated 2 concepts.

Figure 4.11 P10's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from his field of work. He inspired from a staircase design that he designed. Staircase has a dynamic graffiti inside the cone. Inspiring from the function “dynamic”, he proposed a dynamic camouflage which is projected from a camera to the uniform.

[2] At the second concept, participant directly inspired from his field of work. He stated that two-dimensional patterns on handrails create a third-dimensional feeling. Using the same principle, he proposed that layered uniforms can be designed.

See Appendix C, Figure C.10 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.10 to see example sketch developed during study.

4.2.11 Participant 11

Participant 11 (P11) has 2 years of experience in the field of Machines - Washing, Cleaning and Drying Machines (Class 15, Subclass 05) according to Locarno

Classification. He does not have any design experience in the field of defense industry. During the study, he generated 5 concepts.

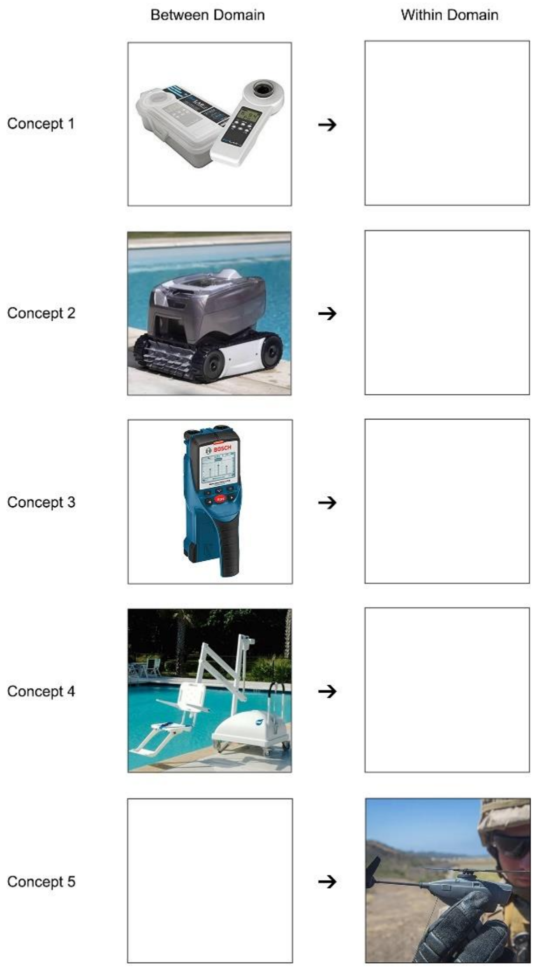

Figure 4.12 P11's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from his field of work. He explained that pool analyzing tools are portable devices which detects the quality of water. Inspiring from that concept he proposed a flask that analyzes water to determine if it is potable.

[2] At the second concept, participant directly inspired from his field of work. He inspired from tracked pool cleaning robots. He explained that using its suction, these robots can move in every axis inside the pool. Inspiring from that concept, he proposed

an unmanned vehicle which uses a similar approach to move on the field and rescue wounded personnel.

[3] At the third concept, participant inspired from a wall scanner. He proposed a wall scanner for detecting threats inside a building to gain situational awareness before door breaching.

[4] At the fourth concept, participant directly inspired from his field of work. He was inspired from disabled access lift for pools. He explained that lifts can move in five axes. Using the same principle, he proposed a lift for maintenance crew to reach every corner of sizable vehicles.

[5] At the fifth concept, participant uses no source image. He proposed a drone with integrated speakers and cameras. This drone may be used for reconnaissance, warning civilians to evacuate area and making propaganda to discourage opponents.

See Appendix C, Figure C.11 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.11 to see example sketch developed during study.

4.2.12 Participant 12

Participant 12 (P12) has 4 years of experience in the field of Medical and Laboratory Equipment - Apparatus and Equipment for Doctors, Hospitals and Laboratories (Class 24, Subclass 01). He has design experience in the field of defense industry. He participated to a short-termed project about wearable technologies related to soldier modernization programmes. During the study, he generated 3 concepts.

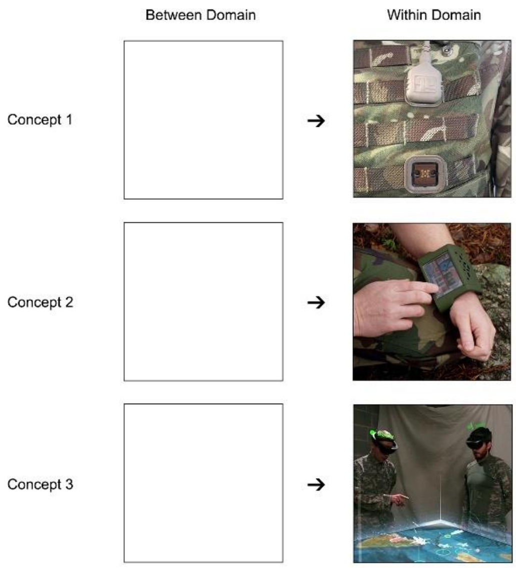

Figure 4.13 P12's Analogy Reflection Diagram

[1] At the first concept, participant uses no source image. Using his design experience on wearable technologies, he stated that electronic components on ballistic helmets needs coiled cables for both data and energy transfers. He explained that coiled cables obstruct head motions which is a crucial motion while gaining situational awareness. He proposed an integrated ballistic helmet which belongs to the uniform. Using a structure similar to an astronaut suit, he attached the helmet to the uniform which allows data and energy transfer through that fixed connection.

[2] At the second concept, participant uses no source image. He proposed a bracelet that projects the interface to user’s wrist.

[3] At the third concept, participant uses no source image. He proposed applying VR technology for both reconnaissance and guiding bomb disposal robots.

See Appendix C, Figure C.12 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.12 to see example sketch developed during study.

4.2.13 Participant 13

Participant 13 (P13) has 1 year of experience in the field of Games, Toys, Tents and Sports Goods - Games and Toys (Class 21, Subclass 01) according to Locarno Classification. She does not have any design experience in the field of defense industry. During the study she generated 2 concepts.

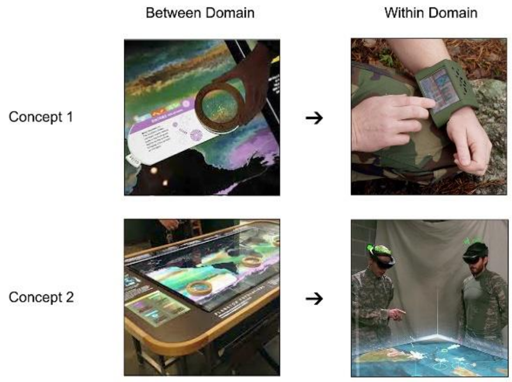

Figure 4.14 P13's Analogy Reflection Diagram

[1] At the first concept, participant inspired from her field of work. She was inspired from a product that she designed for educational purposes for children. She proposed a product that projects interface to any surface that it is placed in the field.

[2] At the second concept, participant inspired from her field of work. She was inspired from a product that she designed for educational purposes for children. She proposed a single textile surface which can be used as a virtual reality (VR) map on any location via VR glasses that soldiers would be equipped.

See Appendix C, Figure C.13 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.13 to see example sketch developed during study.

4.2.14 Participant 14

Participant 14 (P14) has 1 year of experience in the field of Packages and Containers for The Transport or Handling of Goods - Refuse and Trash Containers and Stands Therefor (Class 09, Subclass 09) according to Locarno Classification. He does not have any design experience in the field of defense industry. During the study he generated 5 concepts.

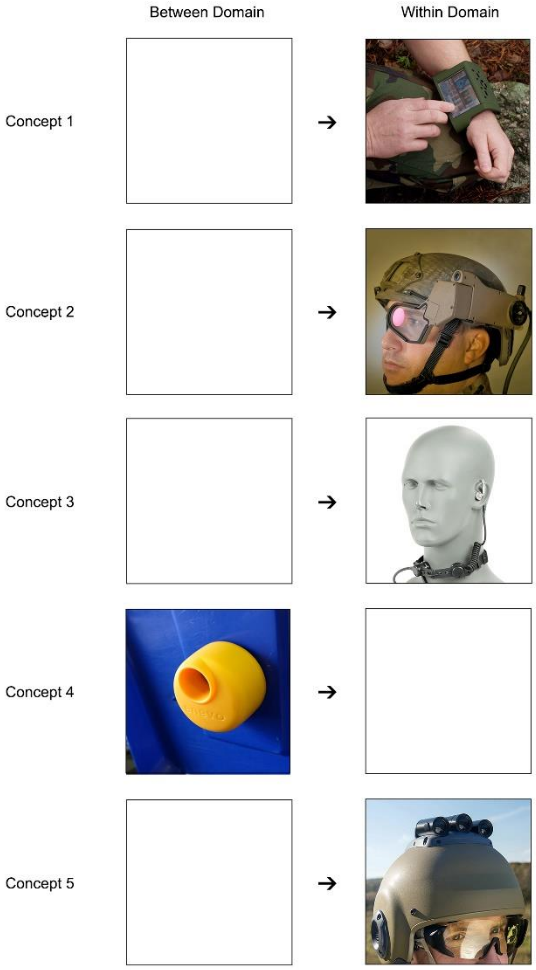

Figure 4.15 P14's Analogy Reflection Diagram

[1] At the first concept, participant uses no source image. He proposed an arm sleeve that contains a wearable display, health tracking sensors and exoskeleton.

[2] At the second concept, participant uses no source image. He proposed an interface which uses augmented reality (AR) technology to show a tactical map and possible evacuation paths to the user.

[3] At the third concept, participant uses no source image. He stated that sensors can be integrated to fabric in wearable technologies. He proposed a larynx microphone integrated to the fabric of the uniform.

[4] At the fourth concept, participant directly inspired from his field of work. He explained that in his early professional life, he designed an intelligent garbage container which maps the city according to its temperature with its sensors. He proposed using the same principle for future soldier concept. In his concept, he integrated sensors to uniforms which are mapping the geographic shapes and temperature of the field.

[5] At the fifth concept, participant uses no source image. He proposed a product which has several cameras on it. While user is in the cover, he can throw the product in vertical axis which allows him to get a panoramic shot of the field. This panoramic shot allows user to detect possible dangers without leaving his position.

See Appendix C, Figure C.14 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.14 to see example sketch developed during study.

4.2.15 Participant 15

Participant 15 (P15) has 1 year of experience in the field of Clocks and Watches and Other Measuring Instruments, Checking and Signaling Instruments - Instruments, Apparatus and Devices for Checking, Security or Testing (Class 10, Subclass 05) according to Locarno Classification. She does not have any design experience in the field of defense industry. During the study, she generated 3 concepts.

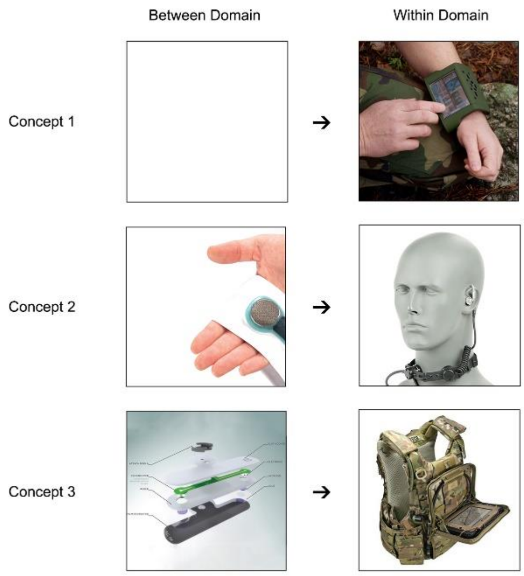

Figure 4.16 P15's Analogy Reflection Diagram

[1] At the first concept, participant uses no source image. She proposed a bracelet that projects interface to the user's wrist.

[2] At the second concept, participant directly inspired from her field of work. She stated that in medical products, wearable sensors integrated to fabric are commonly used. She proposed a larynx microphone integrated to the fabric of the uniform.

[3] At the third concept, participant inspired from her field of work. She was inspired from a product that she designed. She stated that flex cards are common in most consumer products. Inspiring from the function of being "flex", she proposed that integrating tablet PC's or other displays to flexible structures which would be mounted on a backpack.

See Appendix C, Figure C.15 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.15 to see example sketch developed during study.

4.2.16 Participant 16

Participant 16 (P16) has 2 years of experience in the field of Furnishing - Seats (Class 06, Subclass 01) according to Locarno Classification. She does not have any design experience in the field of defense industry. During the study, she generated 2 concepts.

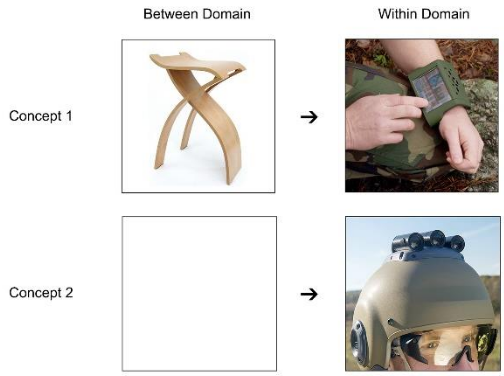

Figure 4.17 P16's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from her field of work. She was inspired from a form of a product. She proposed a glove which includes a flex screen, GPS module and health tracking sensors.

[2] At the second concept, participant uses no source image. She was inspired from a project she had seen. She proposed an integrated ballistic helmet which includes an in-ear earbud to detect the posture of user. She stated that this data may be used while evaluating health status of military personnel.

See Appendix C, Figure C.16 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.16 to see example sketch developed during study.

4.2.17 Participant 17

Participant 17 (P17) has 2 years of experience in the field of Medical and Laboratory Equipment - Apparatus and Equipment for Doctors, Hospitals and Laboratories (Class 24, Subclass 01) according to Locarno Classification. He does not have any design experience in the field of defense industry. During the study, he generated 5 concepts.

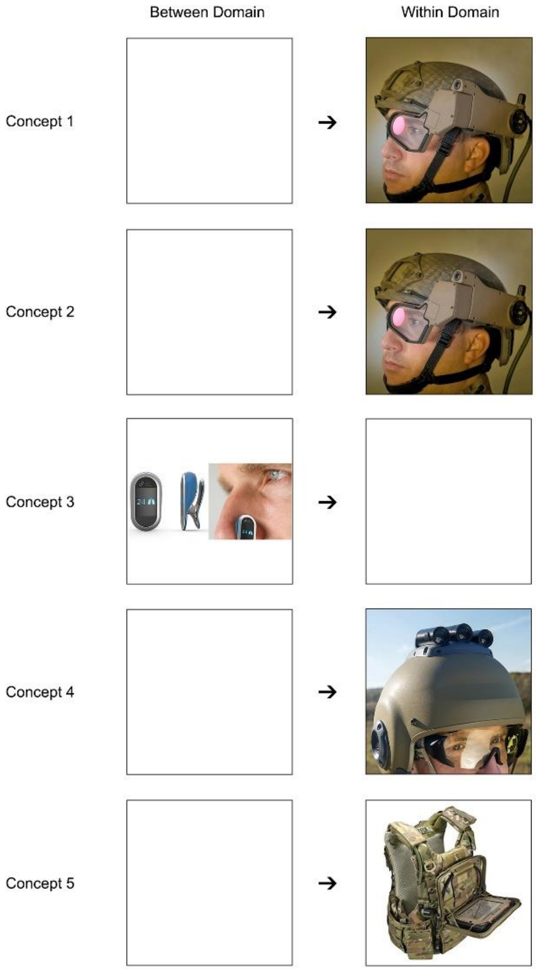

Figure 4.18 P17's Analogy Reflection Diagram

[1] At the first concept, participant uses no source image. Participant proposed an interface which is part of the HMD. Different from other interfaces, this concept considers the posture of the user. As user changes his posture, interface calibrates itself according to user.

[2] At the second concept, participant uses no source image. He proposed an interface which uses augmented reality (AR) technology to show tactical map and possible evacuation paths to user. He also stated that tags placed by other members of task force can be seen through AR.

[3] At the third concept, participant inspired from his field of work. He stated that pulse and breathing rate is a key point to understand the anxiety level of a person. He also stated technological infrastructure is convenient to measure both pulse and breathing rate reliably. He proposed a wearable product to detect anxiety level of soldiers and guide them to breathe properly to decrease anxiety level.

[4] At the fourth concept, participant uses no source image. He examined current static integration of cameras that placed on ballistic helmets from “Within Domain Analogy Sources”. He stated that with changing posture of user, cameras may miss the changing environmental factors. He proposed a rail that is mounted on the ballistic helmet which allows cameras to change its orientation according to military personnel’s posture.

[5] At the fifth concept, participant uses no source image. He combined his 2nd and 3rd concept. He proposed an interface specifically designed for medic units. Big data gathers all health condition of units deployed on field. This interface proposes the best route for medics, considering vital danger of personnel.

See Appendix C, Figure C.17 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.17 to see example sketch developed during study.

4.2.18 Participant 18

Participant 18 (P18) has 1 year of experience in the field of Household Goods - Cooking Appliances, Utensils and Containers (Class 07, Subclass 02) according to Locarno Classification. She does not have any design experience in the field of defense industry. During the study, she generated 2 concepts.

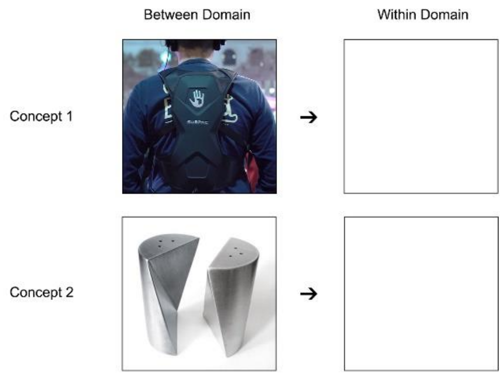

Figure 4.19 P18's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from her field of work. She was inspired from a project she examined while designing a product for a client. She proposed to integrate bass speakers to military backpacks to warn personnel with its vibration.

[2] At the second concept, participant inspired from the concept of integrity while developing the concept. She proposed a modular backpack which can be customized according to the needs of its user.

See Appendix C, Figure C.18 to see detailed “Between Domain Analogy Sources” created by participant. See Appendix D, Figure D.18 to see example sketch developed during study.

4.2.19 Participant 19

Participant 19 (P19) has 4 years of experience in the field of Lighting Apparatus - Public Lighting Fixtures (Class 26, Subclass 03) according to Locarno Classification. He does not have any design experience in the field of defense industry. During the study, he generated 2 concepts.

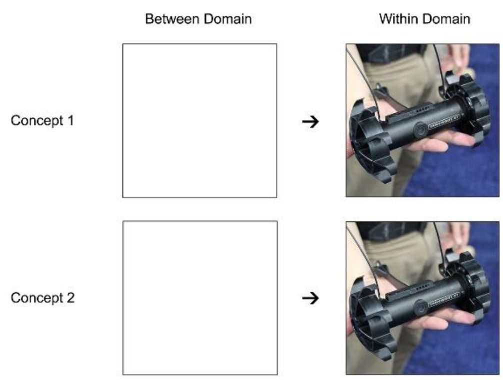

Figure 4.20 P19's Analogy Reflection Diagram

[1] At the first concept, participant directly inspired from his field of work. He was inspired from a past project about robotics that he has completed. He pointed that reconnaissance robots' cameras may be harmed while it was thrown. He proposed an inflatable system which triggers with an impact.

[2] At the second concept, participant inspired from his field of work. He was inspired from a past project about robotics that he has completed. He proposed a modular robot that may be configured during an operation according operation's needs.

See Appendix C, Figure C.19 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.19 to see example sketch developed during study.

4.2.20 Participant 20

Participant 20 (P20) has 6 years of experience in the field of Recording, Communication or Information Retrieval Equipment - Data Processing Equipment as well As Peripheral Apparatus and Devices (Class 14, Subclass 02) according to Locarno Classification. He has design experience in the field of defense industry. He contributed to a short-term project from defense industry. The brief of the project is designing a command and control console. During the study he generated 2 concepts.

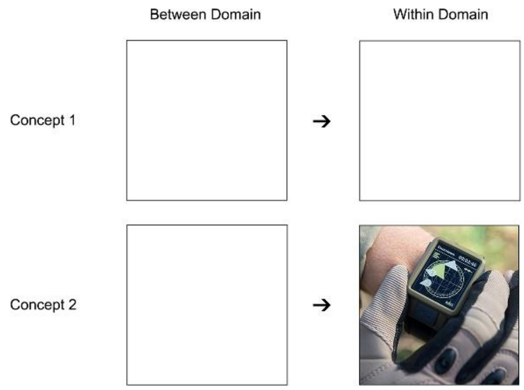

Figure 4.21 P20's Analogy Reflection Diagram

[1] At the first concept, participant neither used a source image nor a target image to transfer. Participant proposed a sensor integrated to the boot to map geographical properties of soil.

[2] At the second concept, participant directly inspired from his field of work. He was inspired from a smartwatch that he designed for elderly people which uses e-ink technology. He pointed that light discipline is an important issue and proposed an e-ink display which would not emitting light.

See Appendix C, Figure C.20 to see detailed "Between Domain Analogy Sources" created by participant. See Appendix D, Figure D.20 to see example sketch developed during study.

4.2.21 Types of Analogical Sources Used by Participants

In this study, four types of approach were observed while making analogies (see Figure 4.22). In "Approach 1", the participant uses one image from "Between Domain Analogy Sources" and transfers the concept to another one from "Within Domain Analogy Sources". In "Approach 2", participant uses one image from "Between Domain Analogy Source" and detects a target area to transfer which is not included in "Within Domain Analogy Sources". In "Approach 3", participant uses no image from "Between Domain Analogy Sources" but uses one image from "Within Domain Analogy Sources" to develop a concept. In "Approach 4", participant neither uses an image from "Between Domain Analogy Sources" nor an image from "Within Domain

Analogy Sources”. In this case participants stated that they cannot relate between image sets and relay on their past experiences to generate a concept.

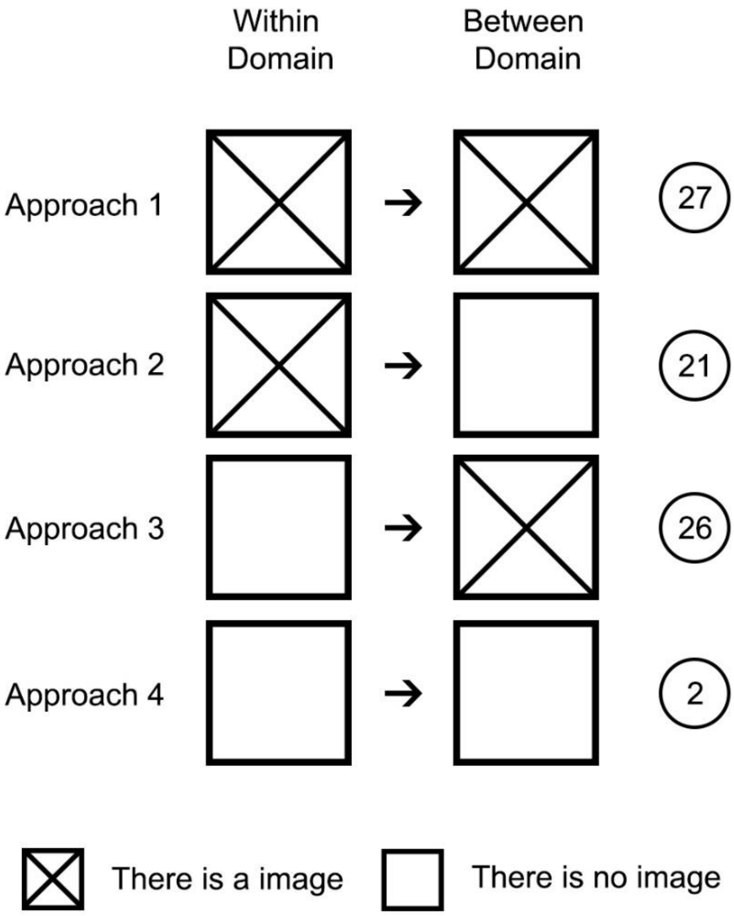

Figure 4.22 Type of Approaches Through Study

Through the study: Approach 1 is observed in 27 ideas, Approach 2 is observed in 21 ideas, Approach 3 is observed in 26 ideas and Approach 4 is observed in only 2 ideas (see Figure 4.22). As it can be seen in Table 10, Approach 2 and Approach 3 has better average scores comparing to other approaches. There is a certain similarity between Approach 2 and 3. In both approaches, participant is inspired from a single image and has detected the problem area to transfer without using an image.

Table 4.4 Average Score of Ideas According to Approach

Approach No.	Number of Apporaches	Average Score of Ideas	S.D
1	27	2.61	1.26
2	21	3.24	1.27
3	26	3.25	1.12
4	2	2.50	0.71

Participants stated that these approaches in which they used no image were occurred from several reasons:

- In Approach 2, participant had a concept in his/her “Between Domain Analogy Sources” but “Within Domain Analogy Sources” did not contain a target image to construct an analogy.
- In Approach 3, participant had an experience about a concept or a product from his/her industry but he/she did not have it in his/her “Between Domain Analogy Sources” image set.
- In Approach 4, participant cannot construct a connection between “Between Domain Analogy Sources” and “Within Domain Analogy Sources”.

4.3 Qualitative Analysis of the Study

In this section, qualitative analysis of the interviews is presented. After the idea generation session, an interview was done with participants.

Results shows that all participants had an experience about DbA tools, methods and techniques during their education. Some participants stated that they used Biomimicry, Word Tree and Patent Analysis during their academic projects as a part of design studio education. All participants pointed that in academic process, these DbA tools, methods and techniques were adopted for styling purposes only. However, although all of them had an experience in their academic life, only 8 participants indicated they are currently using DbA tools, methods and techniques during their professional life (see Table 4.5).

Most of them stated that these kind of creativity enhancement tools, methods and techniques are executed instinctively by product designers through their design process.

> P5: I did not consciously implicate DbA process in my professional projects. But after seeing this process of yours, I think in some way as designers, we are triggered by some visuals sources to create design solutions. But I can say that I have never done it systematically.[3]

Another interviewee pointed that variety of briefs are forcing designers to behave instinctively through design processes:

> P20: Actually, I cannot say DbA processes are methodologically involved in my design process. As a matter of fact, after we have received a new brief, we usually design our processes intuitively as designers. For every process, we are trying to design a process by learning almost everything we can learn from customer and market. And because this process has an inadequate timeline, such research is a bit insufficient and we have to move fast with our previous design experiences. In fact, we are forced to move faster through design process, so we are inclined to consider our previous experiences and often proceed with very intuitive solutions. [3]

P19 also supported the idea that creativity enhancement methods, tools and techniques are inhibited by nature of design:

> P19: So from project to project, process is really different. When you are working on a project, the expectations of the customer are also involved. When you are working for a customer, customer expectations, market expectations and

Table 4.5 Creative Enhancement Usage in Academic and Professional Process

	Usage in Academic Process	**Usage in Professional Process**
Participant 1	•	•
Participant 2	•	
Participant 3	•	
Participant 4	•	•
Participant 5	•	•
Participant 6	•	
Participant 7	•	
Participant 8	•	
Participant 9	•	
Participant 10	•	•
Participant 11	•	•
Participant 12	•	•
Participant 13	•	•
Participant 14	•	
Participant 15	•	
Participant 16	•	
Participant 17	•	•
Participant 18	•	
Participant 19	•	
Participant 20	•	

> constraints of product are leading you. There is usually no room left for you to move freely. Most customers do not want you to design a fantastic product but a product that provide the expectations of brief. Customer usually come up with several components and want you to create best configuration with that components. [3]

Even though most of the participants are prejudiced againts DbA methods, tools and techniques, DEKT-DbA change their perception in a positive way:

> P17: I think process of the study is efficient and fast. I especially like to point out the way that I like about this process. Study generates concrete concepts unlike other creativity methods, tools and techniques. [3]

Participants stated that the process of DEKT-DbA is highly compatible with the process of product design. Participants appreciate the fast pace of the study when they compare it with classical methods that were taught during their academic life. Despite the advantages of it, some participants pointed the disadvantages:

> P14: The image set you choose is very crucial for this study. Correlation between "Between Domain" and "Within Domain" is so important. So I think that better results can be obtained with a broader look rather than domain specific. For my specific case I could perform better if I create an image set with medical products. Since the process is coincidental, it may not be effective for all cases. [3]

Another important finding of the semi-structured interview is about frequency of the cross-domain innovation in professional process. Similar with the DbA methods, tools and techniques, also cross-domain innovation is conflicting with the professional

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[3] *Numbered statements are translated quotations from interviewees. Original Turkish versions are in APPENDIX H*

design process. Participants think that concept of cross-domain innovation is highly dependent with research and development (R&D) activity of a company. Several participant stated their companies are not investing in R&D activities so it is not possible to encounter with cross-domain innovation in their field of design.

4.4 Summary

This chapter presented analysis of both quantitative and qualitative data. Through the chapter all 76 concepts which are developed during the study are examined. Classification and scoring of these ideas are presented during chapter. At the end of this chapter findings of the semi-structured interview are displayed.

Findings pointed that, DEKT-DbA results in allows 4 types of design approaches. Approaches which are not defining both source and target have a better average scores comparing other approaches. Another important finding of this study is about the effect of domain knowledge on DbA process. Research reveals that, a product designer with no domain knowledge performs better (with an average score of 3.29/5) than a designer who has domain knowledge organizations, (with an average score of 2.52/5). The concept of Resistance to Change explains that designers with domain knowledge in certain area could construct operational blindness (Kemppainen et al., 2017).

Qualitative analysis pointed that only 8 of 20 participants are using DbA methods, tools and techniques in their personal life according to findings of semi-structured interview. Participants stated that using these type of methods, tools and techniques are conflict with the design process. For the most case, this occasion also inhibits the potential of cross-domain innovation for designers.

CHAPTER 5

CONCLUSION

In this chapter, conclusions of the study are presented. Primarily, general review of the study is demonstrated. After presenting the general review, outcomes of the study are briefly discussed and recommended procedure for DEKT-DbA is presented based on the outcomes of the study. Chapter concludes with the limitations of the study.

5.1 Review of the Study

Thesis starts with the introduction of problem statement and motivation of the study. As the researcher has been working on future soldier concepts and products, he was discerned that these type of integrated systems like soldier modernisation programmes (SMPs) is highly open for new ideas especially in the concept phase due to the variety of products in the system. In these systems integration of commercial off the shelf (COTS) products are very common (Valpolini, 2013). Starting from this point, this study aims to make a contribution to the concept generation phase of military products and systems that includes dual-use products, by integrating cross-industry innovation with the help of design-by analogy approaches (see Chapter 1).

Before defining the procedure of the study, literature of SMPs, military design process, cross-industry innovation and design by analogy has been reviewed. As distinct from traditional design process, concept generation phase has importance in extensive military systems. Through this concept generation phase, creativity enhancement methods, tools and techniques have a remarkable importance. The methods, tools and techniques should be used to create undetailed ideas and concepts which are free from judgment in terms of feasibility. In order to enrich the concept of SMPs with new ideas that are already employed in other domains, DbA procedure which is called DEKT-DbA is integrated to the concept generation process. Study aims to understand how cross-industry innovation can be supported through design by analogy within the context of military products. For the purposes of this research, empirical data was collected from 20 product designers (mean year of experience 2,78 years, SD=1,64) who work in various civil industries including automotive, furniture, health appliances, home appliances, civil transportation and wearable products. To define the brief of this study, two separate workshops were organized with the military experts. Experts emphasized the importance of situational awareness and informed the project team that dismounted soldier lacks situational awareness on the field which is a crucial need for contemporary military scenarios. During the study, participants conducted a concept generation session to develop concepts based on a brief that is structured to increase efficiency of situational awareness of dismounted soldier (See Chapter 2 & Chapter 3).

In the following chapter, results and analysis of the Domain Expert Knowledge Transfer through Design-by-Analogy (DEKT-DbA) study and semi-structured questionnaire that was executed after the DEKT-DbA study were presented. The analysis of the study contains two approaches which are qualitative and quantitative analysis. As Kemppainen, Hein and Manser (2017) stated analyzing qualitative data in the light of quantitative data increases the chance of accurate interpretation of results for complex real-world scenarios. Both methods are combined through the study (See Chapter 4).

In this chapter findings of this study are discussed to conclude thesis.

5.2 Conclusion of the Study

Changing technology and evolution of warfare demands more situational awareness (SA) and more connectivity between dismounted soldiers which leads countries to develop Soldier Modernisation Programmes (SMPs). As potential of SMPs are being discovered, more development projects are being announced around the world. Like many other countries which are aware of the importance of SA and future soldier concept, also TAF (Turkish Armed Forces) is interested in developing a SA for dismounted soldier and the concept of future soldier. Asal and Karakoc (2017) stated that equipment like radios, binoculars, cameras, global positioning systems (GPS), etc. will be gathered under a single system in near future. This statement is supported by research and development projects of Turkish defense industry companies like Aselsan. Aselsan released two versions of CENKER, which is a wearable command and control suite, in 2015 and 2017.

The concept of SMPs can be defined as product and system groups integrated on a dismounted soldier. There are many product and system groups that ensure the needs of dismounted soldier in both military and civil market. That wide spectrum of products create large number of possibilities to combine them as an integrated system. Developing such a complex military system with an unclear structure and fuzzy initial requirements, leads to an ill-defined (or wicked) design problem with an unknown number of solutions (Casakin, 2010). Considering that ill-defined structure, instead of using traditional design process, integrated design process that includes creativity enhancement methods, tools and techniques, including DbA, is introduced to military field (Tack & Gaughan, 2005, Tack, 2006). The term of DbA refers to transferring an information or a concept from a known situation to the problem area in the design process. Known situation is called as “source or base” while the problem area is called “target” (Casakin and Goldschmidt, 2000). The distance between the source and the target defines analogical distance. Source analogies can be found both in a similar field, which is called close-domain, and a distant field which is called as cross-domain (Fantoni et al., 2013).

During the DEKT-DbA study two types of image set is provided for participants: (1) within domain image set and (2) between domain image set. Within domain image set consists of products that were already deployed to the field for conceiving situational awareness for its user. Product set contains a helmet mounted display, a reconnaissance drone and robot, an e-textile vest, a larynx and bone-conduction microphone, a wearable display, sight systems and virtual reality tactical maps. Detailed explanation and usage scenario of every single product is provided under every image. Images set is selected by the researcher who has experience in soldier modernisation programmes. Between domain images set is unique for every participant. Before executing the study, participant was asked to select 12 images for between domain image set. He/she was asked to select at least 6 images directly related with their field of expertise. The rest of the images can be selected whether from participant's field of expertise or from other fields that participant uses as an inspirational source while in their professional works.

The main research question of the study is constructed as:

- How can cross-industry innovation be supported through design by analogy within the context of military products?

The main research question pushes the researcher to develop DEKT-DbA procedure to answer this question. During the DEKT-DbA study, participants generated 76 product concepts based on the brief about increasing situational awareness for military personnel deployed in the field. 76 product concepts were classified as 30 "C5ISR", 22 "Equipment and protection sub-systems", 10 "Sensor (detection) sub-systems", 2 "Power and energy sub-systems" and 12 "Autonomous and RC sub-systems". All 76 concepts are evaluated by 2 juries which have at least 5 years of product design experience in the field of the defense industry. Through the study the novelty of ideas was calculated as 0.79/1 for this study. After the scoring process by jury, Cronbach's Alpha was calculated as 0.94/1 which indicates that internal reliability of jury was "excellent" according to literature (Glen, 2014).

Sub-questions of the study:

- Soldier Modernisation Programmes (SMPs) have a rich product line which depends on many dual-used products and dual-used technologies. Considering equipment of SMPs also supported by dual-used products and cross-industry innovation, through employing DEKT-DbA, what can be the potential contribution of a designer out of defense industry to defense products and concepts?

- How does industrial affinity effect industrial designers in a creative process?
- How do industrial designers use design-by-analogy tools, methods and techniques to enhance creativity in their professional life?
- How does cross-industry innovation take place in industries that industrial designers work?

Major findings that respond to sub-questions are listed as:

1. This research has shown that product designers from different domains can potentially contribute to defense industry, while developing a concept at the early stages of a complex project. Through study, a product designer with no domain knowledge performs better (with an average score of 3.29/5) than a designer who has domain knowledge with certain experiences like contributing to a defense industry project or design competitions organized by both private and governmental defense industry organizations, (with an average score of 2.52/5).

2. Through the research 4 types of approaches have been seen. In “Approach 1”, participant used one image from “Between Domain Analogy Sources” and transferred the concept to another one from “Within Domain Analogy Sources”. In “Approach 2”, participant used one image from “Between Domain Analogy Source” and detected a target area to transfer which is not included in “Within Domain Analogy Sources”. In “Approach 3”, participant used no image from “Between Domain Analogy Sources” but used one image from “Within Domain Analogy Sources” to develop a concept. In “Approach 4”, participant neither uses an image from “Between Domain Analogy Sources” nor an image from “Within Domain Analogy Sources”. In this case

participants stated that they cannot relate between image sets and relay on their past experiences and knowledge to generate a concept. These four types summarize the path that designers use while in their product design experiences. Research has shown that fixed inspirations (as in Approach 1) are decreasing the quality of idea (with an average score of 2.61/5). It was observed that using a single image from any domain while developing a concept is increasing the quality of ideas (with an average score of 3.24/5 and 3.25/5). Lowest average score is observed while there is no inspiration source or target (with an average score of 2.50/5). From this analysis, it can be inferred that developing an innovative solution for cross-domain knowledge transfer can be supported with the help of DEKT-DbA procedure.

3. The semi-structured interview reveals that all of the participants had an experience about design-by analogy while studying industrial design. Participants stated that Biomimicry and Word Tree are the most common DbA tools, methods and techniques that is taught in industrial design education. Findings have shown that participants used DbA tools, methods and techniques with styling purposes instead of functional purposes in industrial design education. Participants stated that these methods had a complex structure to follow which inhibits the process of product design. They also stated that DbA and other creativity enhancement methods, tools and techniques has a complex structure to execute. Only 8 of 20 participants are using these kind of tools in their personal life according to findings of the semi-structured interview. Participants stated that using these type of methods, tools and techniques are conflicting with the design process. We can say that this situation also inhibits the potential of cross-domain innovation for designers. Combining quantitative and qualitative analysis reveals that designers who use DbA and other creativity enhancement methods, tools and techniques in their professional works performs above average considering the familiarity to these methods, tools and techniques.

To conclude, considering future soldier concepts are containing dual-used products, this thesis aims to explore the potential contribution of a designer out of defense industry to defense products and concepts. This study shows that DEKT-DbA tool has a potential especially at the early concept stages for defense industry projects. Ill-defined structure of complex systems of defense industry projects can allow the product designer from other domains to contribute to projects with their domain knowledge. It was observed that product designers who have no knowledge about defense industry tend to propose innovative concept ideas for defense industry projects. Despite the results of the study, because of inconsistent experiences in terms of output through undergraduate education, designers tend to believe these DbA and other creativity enhancement methods, tools and techniques are developed for academic purposes but not for professional process. Another concern of product designers is these DbA and other creativity enhancement methods, tools and techniques are time consuming and outcomes are mostly unpredictable. Participants of this study stated that structure of DEKT-DbA tool is compatible with product design process with its visually dominated structure.

5.3 Recommended Procedure for DEKT-DbA

Based on findings in Chapter 4, a recommended procedure for DEKT-DbA is defined in this section. The aim of this detailed explanation of DEKT-DbA procedure is to guide the researcher who is willing to execute this procedure.

First, it is important to fully understand in which cases DEKT-DbA can be used. DEKT-DbA aims to explore innovation potential of transferring knowledge from other domains while ideation process. DEKT-DbA is considered to be effective to solve ill-defined design problems. Ill-defined design problems can be determined by examining whether the set of problems are answered with a single answer. Ill-defined problems have no strict requirements and can have numberless solution sets.

After determining if procedure is suitable to apply on a single design problem, the stages that listed should be followed for executing ideal DEKT-DbA process:

1. Constructing the Brief
2. Preparation Phase
    2.1. Within Domain Sources
    2.2. Between Domain Sources
3. Concept Generation Phase
4. Evaluation

[1] *Constructing the Brief* is considered as a key stage for the procedure. The most important thing while constructing the brief is not to fixate participant with strict requirements. Brief should let participant to understand the design problem clearly. Considering that the participant has no domain knowledge, presenting examples is highly recommended while explaining the design problem. If the researcher designates that it is important to understand needs of the end user, interviews can be executed while constructing the brief.

Procedure continues with [2] the *Preparation Phase*. There are two image sets that needs to be prepared before the study: [2.1] Within Domain Sources and [2.2] Between Domain Sources. This study uses 12 images from each image source. Images should be arranged as two separate A3-size papers. Quantity of images may be enriched, and size of papers may change according to study.

Within domain image set should be prepared by the researcher and it consists of products or concepts that are related with the design problem. Before conducting study, 12 images should be selected by a researcher who has domain knowledge and knowledge about the state-of-the- art problems in this field. Within domain image set should aim to present current state of the art to participant. Detailed explanation and usage scenario of every single product should be provided under every image for explaining products in detail. If it is intended to develop a concept for a complex system, it is better to divide the entire system into subsystems. After subsystems are defined, equal number of images could be presented considering the number of subsystems.

Between domain image set is unique for every participant. Before executing study, participant should be asked to select 12 images for between domain image set. At least 6 images should be directly related with participant's field of expertise. The rest of the images can be selected whether from participant's field of expertise or other fields that participant uses as an inspirational source while designing a product. By letting participants to choose 6 inspirational sources at most, it is aimed to increase chance of attaining creative solutions. It would be appropriate to ask the participant to send the images by e-mail to the researcher before the study. After receiving between domain image set, researcher should arrange images digitally and print-out both pages.

After completing preparations, [3] the *Concept Generation Phase* begins. Mainly, the study is executed during that stage. Study should be conducted with one subject at a time in a quiet and comfortable room. Before the study no training programs are held. Procedure of this study is explained before starting the study. Throughout the session, interaction was avoided with participants except for questions asked by participants about within domain image set. In concept generation session participants were given A3-size papers to sketch their ideas in 30 minutes. In view of the fact that every product designer has a sketching and idea generation style, different kinds of drawing pens and pencils are provided. At sketching phase, participants were asked to sketch one idea per paper and pass on another paper for a different idea. The idea behind sketching one idea per paper is to ease evaluation procedure for jury.

After completing [3] Concept Generation Phase, [4] *Evaluation* should be performed to conclude the procedure. A jury consisting of at least two domain experts should score the concepts. A score from 1 to 5 is defined for this study. A score of 1 to 2 is considered that design requirements are not met while a score of 3 to 5 is considered the proposed design solution is more satisfying. After scoring, average score for every participant should be calculated. Concepts which are scored above average can be selected to develop feasible design solutions.

5.4 Limitations and Suggestions for Further Research

The study has several limitations, which may open up possibilities for further research. In this section, these limitations are discussed together with potential areas for future research.

Although, the study pointed out that designers from other domains may contribute to another domain by adopting the procedure of DEKT-DbA, it was only developed for defense industry. However, there is a possibility that this procedure can be adopted for and integrated to other domains of product design. Moreover, this study is conducted with 20 product designers from various civil domains. Study results show that developing an innovative cross-domain concept is not directly related with the domain, but it is highly related with personal traits and experience in the field of creative thinking. However, despite the findings of the study, it is important to consider that all 32 domains cannot be covered within a master thesis that Locarno Classification defines (Locarno Classification [LOC], 2013) to observe the effects of domain in this process. In future studies, an extensive research can be executed with designers from every domain that Locarno Classification defines. A research involving designers from every domain allows the researcher to evaluate effect of domain knowledge for every specific domain objectively excluding personal traits and experiences of designer. This type of study could statistically reveal how the distance of a non-defense domain effects the quality of a cross-domain innovation that developed for defense industry. The results to be obtained from this type of research could direct this extended study to a well excepted method which is focused on the field of industrial design. In order to develop the procedure further, it would be appropriate to experiment this tool through different product design cases with designers at different levels of experience.

Industrial design curriculum is an integrated curriculum including topics on technical, social/cultural and aesthetic issues (Bronet et. al, 2003). This integrated curriculum provides a broad perspective to product designers in terms of developing innovative concepts. Considering these facts, designers tend to think out of box which means they are familiar with idea generation processes. Study may be extended to professions which are not familiar with these idea development processes. Extending study to these professions may enrich this study in terms of transferring domain knowledge of these professions to idea generation process.

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APPENDIX A

PARTICIPATION CONSENT FORM (TURKISH)

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Endüstriyel Tasarım Bölümü Yüksek Lisans öğrencisi Utku Yücelmiş tarafından Yrd. Doç. Dr. Gülşen Töre Yargın danışmanlığındaki yüksek lisans kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı, savunma sanayinde analojik tasarımın kullanım potansiyelini incelemektir.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz, sizden beklenen, ankette yer alan bir dizi soruyu yanıtlamanız ve ardından yapılacak olan çalışmaya katılmanız beklenecektir. Tüm sürecin ortalama olarak 60 dakika sürmesi beklenmektedir. Anket sırasında ses kaydı, çalışması sırasında ise video kaydı alınacaktır.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Ankette, sizden kimlik veya kurum belirleyici hiçbir bilgi istenmemektedir. Cevaplarınız tamamıyla gizli tutulacak, sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardan elde edilecek bilgiler toplu halde değerlendirilecek ve bilimsel yayımlarda kullanılacaktır. Sağladığınız veriler gönüllü katılım formlarında toplanan kimlik bilgileri ile eşleştirilmeyecektir.

Katılımınızla ilgili bilmeniz gerekenler:

Anket, genel olarak kişisel rahatsızlık verecek sorular içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz cevaplama işini yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda anketi uygulayan kişiye, anketi tamamlamadığınızı söylemek yeterli olacaktır.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Anket sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Endüstriyel Tasarım Bölümü öğretim üyelerinden Yrd. Doç. Dr. Gülşen Töre Yargın (E-posta: tore@metu.edu.tr) ya da yüksek lisans öğrencisi Utku Yücelmiş (E-posta: utku.yucelmis@metu.edu.tr) ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad	Tarih	İmza
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APPENDIX B

INTERVIEW GUIDE (TURKISH)

Görüşme Soruları
1. Between Domain Visual Sources Seçim Önergesi Çalışmanın tamamlanabilmesi için çalışmanın küçük bir kısmının çalışmaya katılmadan önce yapılması gerekmektedir. Tasarım yaptığınız sektörde bulunan tasarım çözümleri ve ya sizin bu tasarım faaliyetlerini yürütürken kullandığınız görsel kaynaklar hakkında 12 imaj seçmeniz ve çalışma öncesinde araştırmacıya göndermeniz beklenmektedir. Çalışma sırasında katılımcıdan bir tasarım problemi çözmeye çalışması beklenecektir. Bu sebeple imajları bir tasarım problemini çözmeye odaklı seçmenizde fayda olacaktır. Seçeceğiniz imajları dilerseniz üzerinde çalıştığınız projelerden, dilerseniz internet üzerindeki imaj kütüphanelerinden seçebilirsiniz. Paylaştığınız görsellerin hiç biri siz izin vermediğiniz sürece üçüncü bir kişiyle paylaşılmayacaktır. 12 imajın minimum 6 tanesi direkt olarak çalıştığınız sektör ile bağlantılı olmak zorundadır, dilerseniz diğer imajları yine aynı sektördeki tasarım sürecinizde kullandığınız ve ilham almak için kullandığınız imaj setlerinden seçebilirsiniz. Seçtiğiniz imajların her biri için bir cümlelik açıklamalar yazarak araştırmacı ile paylaştığınızda ön çalışmayı tamamlamış olacaksınız.–
2. Ad & Soy ad?

3. Kısaca özgeçmişinizden bahsedebilir misiniz?

4. Bir endüstriyel tasarımcı olarak hangi sektörde çalışıyorsunuz? Daha önce bir yıldan fazla çalıştığınız deneyimlerinizi de listeden bulup işaretleyiniz

- ☐ Foodstuffs
- ☐ Articles of clothing and haberdashery
- ☐ Travel goods, cases, parasols and personal belongings, not elsewhere specified
- ☐ Brushware
- ☐ Textile piecegoods, artificial and natural sheet material
- ☐ Furnishing
- ☐ Household goods, not elsewhere specified
- ☐ Tools and hardware
- ☐ Packages and containers for the transport or handling of goods
- ☐ Clocks and watches and other measuring instruments, checking and signalling instruments
- ☐ Articles of adornment
- ☐ Means of transport or hoisting
- ☐ Equipment for production, distribution or transformation of electricity
- ☐ Recording, communication or information retrieval equipment
- ☐ Machines, not elsewhere specified
- ☐ Photographic, cinematographic and optical apparatus
- ☐ Musical instruments
- ☐ Printing and office machinery
- ☐ Stationery and office equipment, artists' and teaching materials
- ☐ Sales and advertising equipment, signs
- ☐ Games, toys, tents and sports goods
- ☐ Arms, pyrotechnic articles, articles for hunting, fishing and pest killing
- ☐ Fluid distribution equipment, sanitary, heating, ventilation and air-conditioning equipment, solid fuel
- ☐ Medical and laboratory equipment
- ☐ Building units and construction elements
- ☐ Lighting apparatus
- ☐ Tobacco and smokers' supplies
- ☐ Pharmaceutical and cosmetic products, toilet articles and apparatus
- ☐ Devices and equipment against fire hazards, for accident prevention and for rescue
- ☐ Articles for the care and handling of animals

- ☐ Machines and appliances for preparing food or drink, not elsewhere specified
- ☐ Graphic symbols and logos, surface patterns, ornamentation

5. Çalıştığınız sektörde kaç senedir faaliyet göstermektesiniz?

6. Daha önce savunma sanayi alanında tecrübeniz oldu mu? Olduysa yer aldığınız faaliyetleri açıklayabilir misiniz?

7. Çalışma aşamasına geçmeden önce, tez özelinde işlenen konuyu ve çalışmanın amacını size anlatmak istiyorum.

Dünyadaki askeri modernizasyon çalışmaları ürün odaklı incelendiğinde, birçok farklı sektörden, birçok farklı ürüne bağlı olarak gelişmekte olduğu gözlemlenmektedir. Konsept sistemlerde yer alan ürün ve teknolojilerin birçoğu ticari kökenli ürünlerin askeri alanlara entegre edilmesinin ile ortaya çıkmıştır. Bu şekilde hem sivil hem de askeri alanlarda kullanılan ürünler *"çift taraflı teknoloji"* (dual-use technology) olarak adlandırılmaktadır.

Bu çalışmanın temel amacı, askeri modernizasyon çalışmalarının ticari ürün ve çözümlerden de beslendiği göz önünde bulundurularak, görsel analoji metodunun sektörler arası inovasyon aracı olarak potansiyelini incelemektir. Analoji; bilinmeyen, bir olgunun, bilinen, benzer olgularla açıklanması olarak tanımlanmaktadır. Analoji ile tasarım kavramı (Design-by-Analogy) ise çözüm kümesini bulunduran bir kaynaktan, tasarım problemini barındıran hedefe doğru benzer olguların çekilmesi aksiyonudur. Hedef ve kaynak arasındaki çalışma alanlarının birbirine olan benzerliği fazlaysa yakın analoji, benzerlik az ise uzak analoji olarak sınıflandırılır.

Temel olarak kavramların üzerinden geçtiğimize göre size tasarım brifingini okumak istiyorum.

8. Çalışma Aşaması (Brief)

Geleceğin askeri çalışmalarında öne çıkan yetenek setlerinden biri de "durumsal farkındalıktır". Durumsal farkındalık yeteneği, sahadaki askerin saha hakkında anlık bilgi almasını sağlar. Anlık bilgi akışları şu şekilde şekillerde örneklendirilebilir:

- Düşman ve dost birlik pozisyonları,
- Anlık konum ve coğrafi kuzey,
- Personelin bulunduğu arazi bilgisi,
- Anlık meteorolojik bilgisi ve tahminleri,
- Personelin temel sağlık bilgileri,
- Personele iletilecek alarm durumları,
- Mühimmat durumu takibi,

gibi kritik bilgilerin sahadaki personele görsel ve ya işitsel olarak ulaştırılması ve ya gösterilmesi personelin etkinliğini arttırmaktadır. Sizlere verilen bu örneklerden en az bir problemi çözmek koşuluyla ürün çözümleri yaratmanız beklenmektedir. Tasarlanan çözüm ile bu bilgilerin sahadaki personele aktarılması sırasında, aktif muharebe durumunda bulunan personeli fiziksel ve zihinsel olarak meşgul edilmemesi önemli bir kriterdir.

Şimdi sizlere sektör özelinde ve sektör dışından toplamda 24 adet imajın bulunduğu A3 kağıtları veriyorum. Bu kağıtlarda yukarıda okuduğum brifing ile ilişkili olan sektörel çözümler ve sizin hazırladığınız sektör dışı görsel analojik kaynaklar bulunmaktadır. Bu doneleri kullanarak, size verilen 30 dakikalık süre içerisinde geliştirebildiğiniz kadar tasarım konsepti geliştirmeniz beklenmektedir. Tasarım alternatiflerini oluşturmadan önce tasarım problemini okumak ve üzerine düşünmek için dilediğiniz kadar süre kullanabilirsiniz, hazır olduğunuzu belirttiğinizde tasarım alternatifleri oluşturmak için 30 dakikalık sürenizi başlatacağım.

9. Tamamladığınız çalışma özelinde tasarım çözümleriniz üzerinden konuşalım. Konseptlerin üzerinden teker teker geçersek, çözümlerinizin analojik kaynaklar ile nasıl bağlantılı olduğundan bahsedebilir misiz?
10. Daha önce DbA yöntemlerinden herhangi birini eğitim ve ya profesyonel hayatınızda tasarım sürecine dahil ettiniz mi *10.1. [“Evet” cevabı veren kişilere sorulacak]* • Hangi DbA yöntemlerini kullandınız? • Kullandığınız yöntemi “Görsel Kaynaklar ile Analojik Tasarım” (Design Assisted by External Visual Representation) ile karşılaştırdığınızda diğer metodlara göre basit ve ya efektif olarak nitelendirebilir misiniz? Açıklayınız. *10.2. [“Hayır” cevabı veren kişilere sorulacak]* • Daha öncesinde size tanımlanan DbA kavramı özelinde, metodolojik olarak olmasa da benzer yöntemleri içgüdüsel olarak kullandığınızı düşünüyor musunuz?
11. Kendi çalıştığınız alanda sektörler arası inovasyon süreci ile karşılaştınız mı? Karşılaştıysanız kendi örneğiniz özelinde süreci anlatabilir misiniz? *11.1. [“Evet” cevabı veren kişilere sorulacak]* • Hangi sektörden hangi sektöre transfer gerçekleşti? • Transfer sırasında spesifik bir metodoloji kullanıldı mı yoksa deneysel olarak mı gerçekleşti?
12. Çalışmaya katıldığınız için teşekkür ederim.

APPENDIX C

EXAMPLE SKETCHES BY PARTICIPANTS

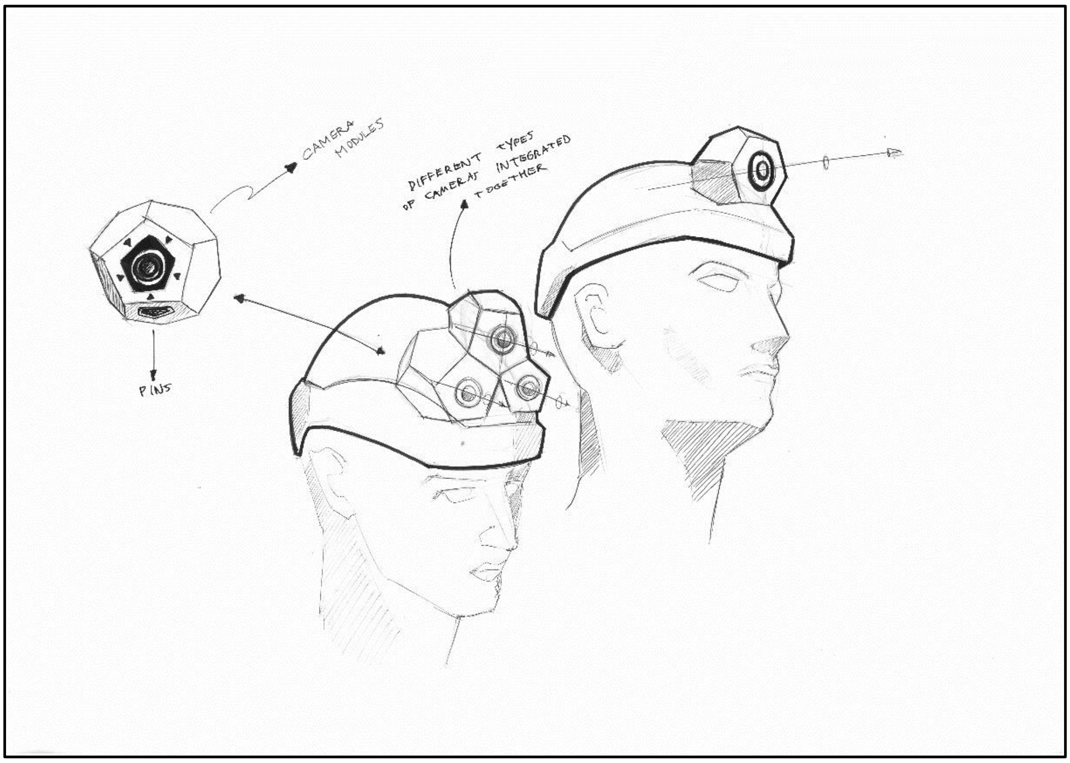


Figure C. 1 Example Concept from Participant 1

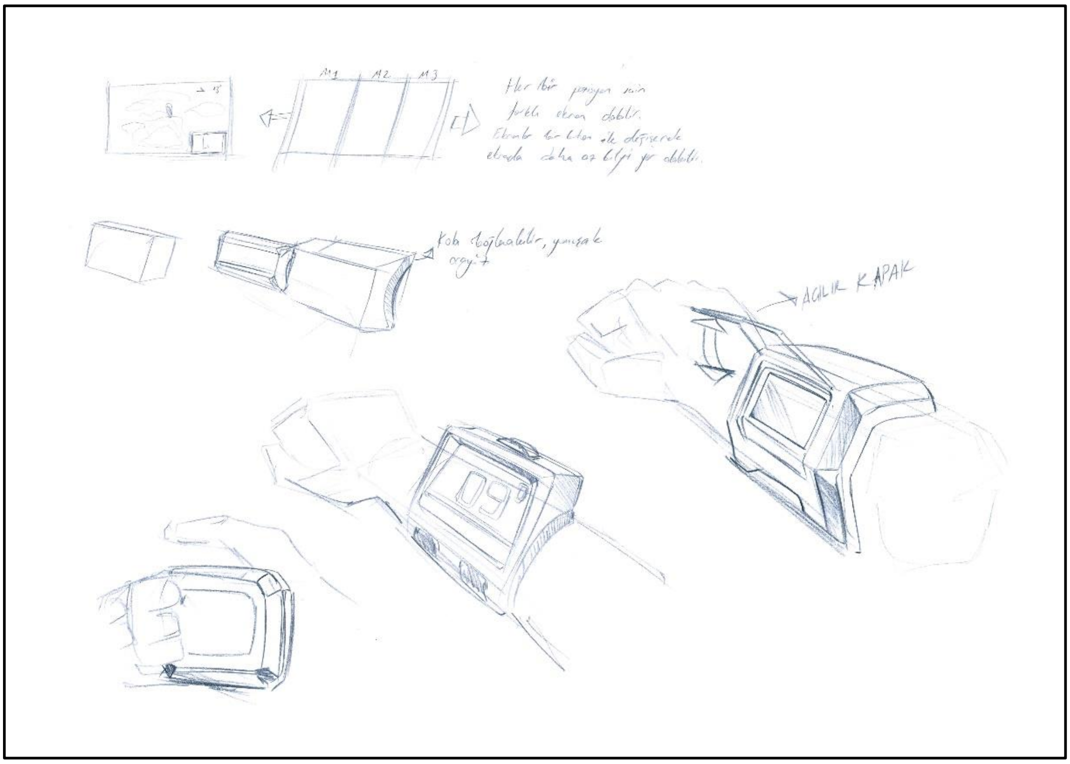


Figure C. 2 Example Concept from Participant 2

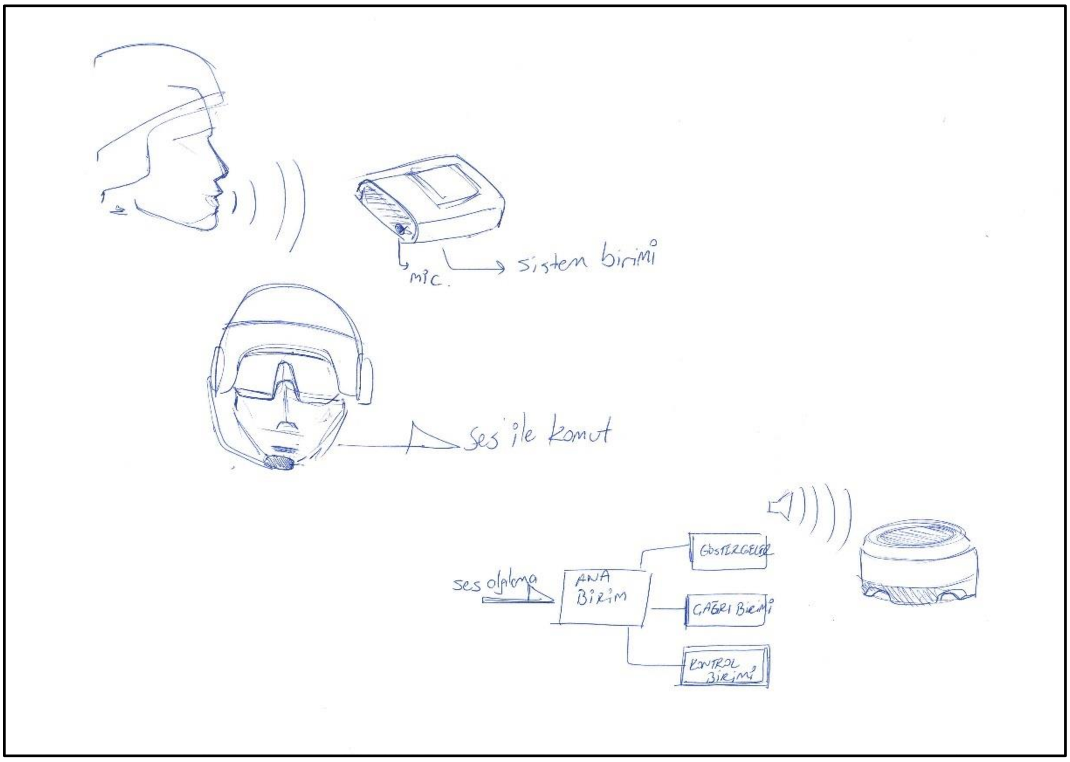


Figure C. 3 Example Concept from Participant 3

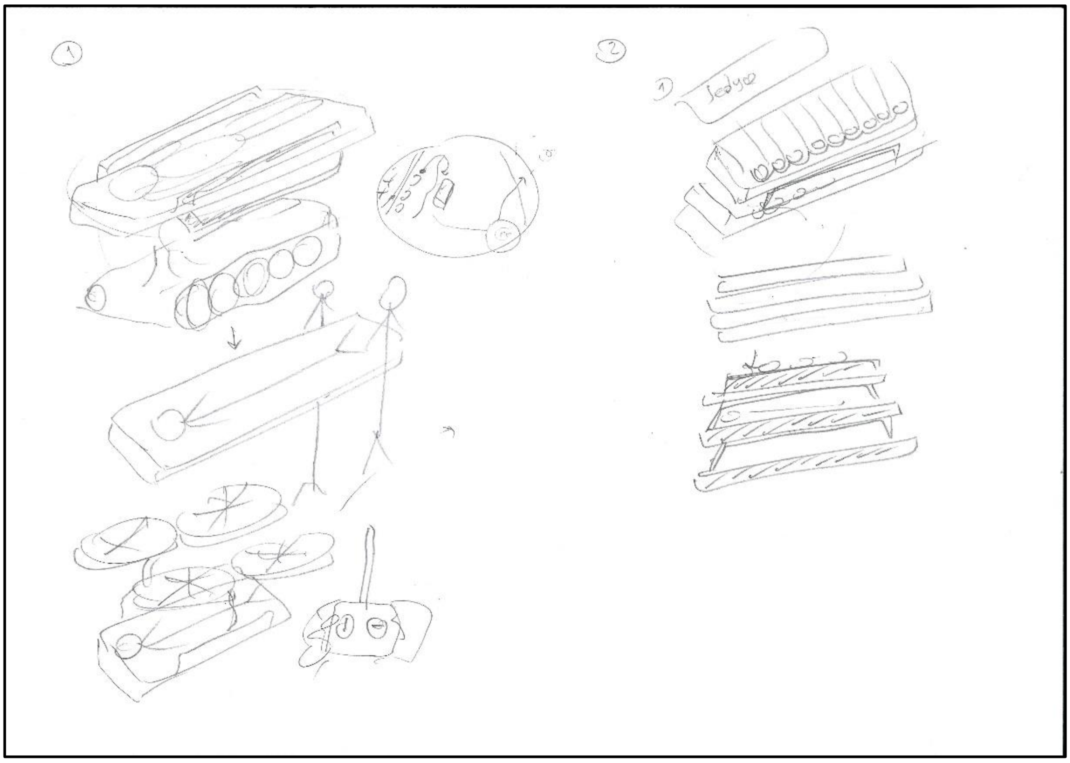


Figure C. 4 Example Concept from Participant 4

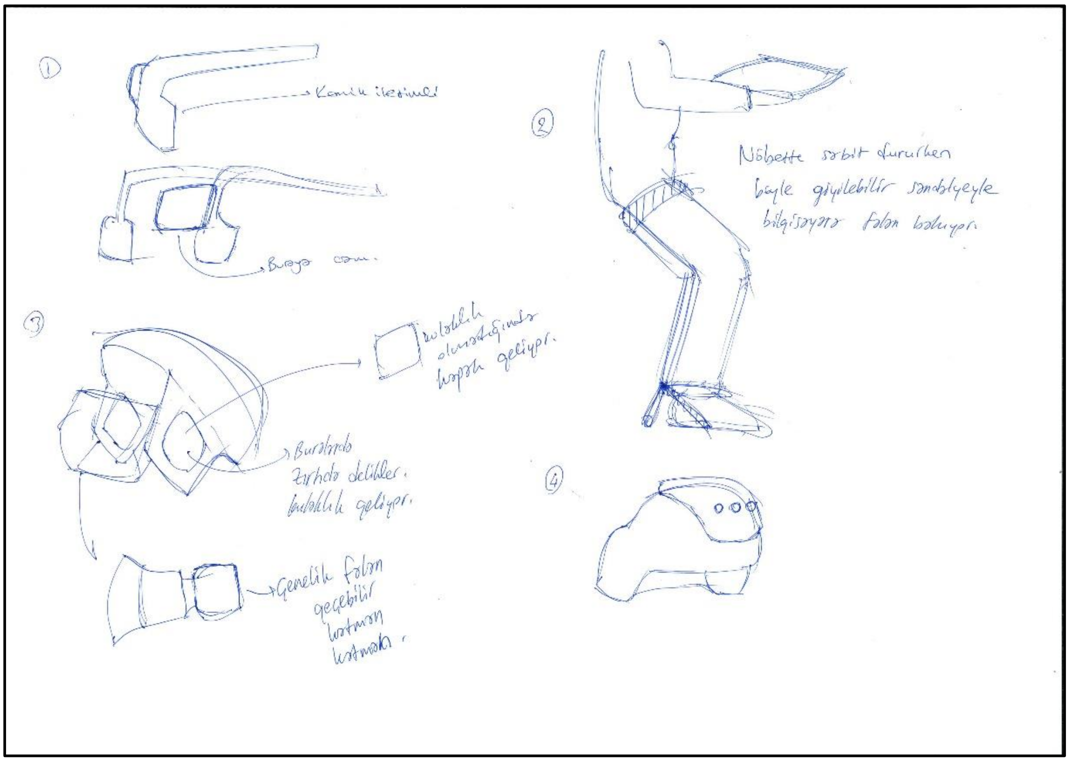


Figure C. 5 Example Concept from Participant 5

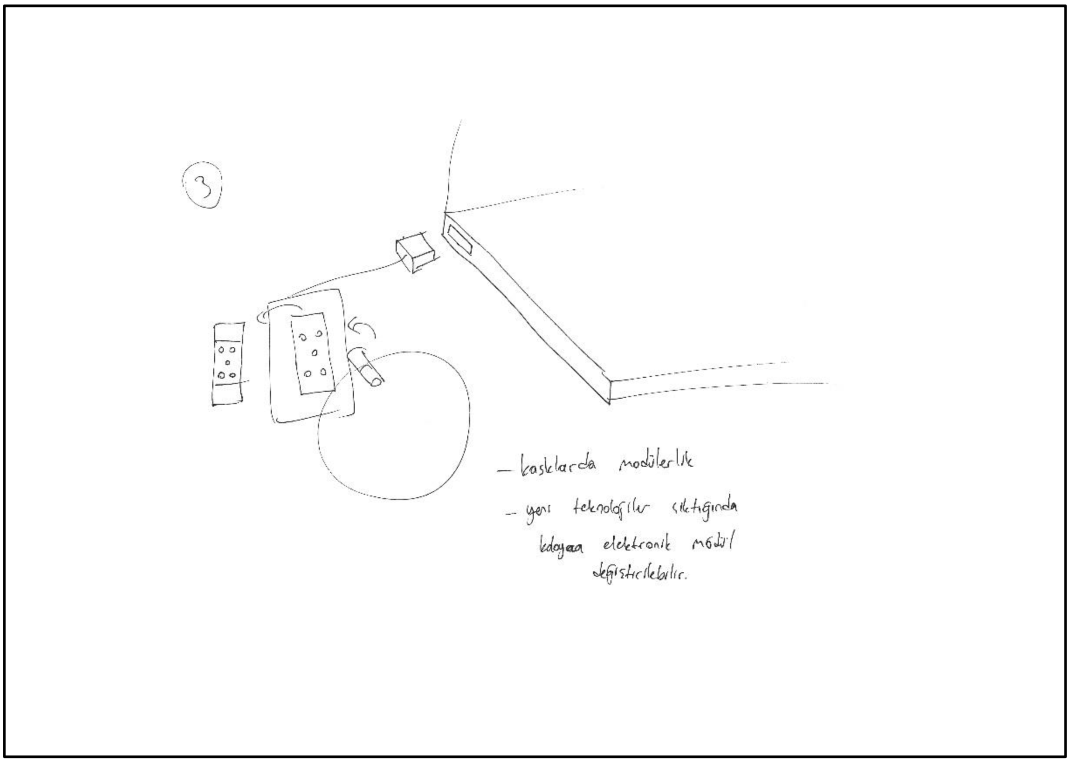


Figure C. 6 Example Concept from Participant 6

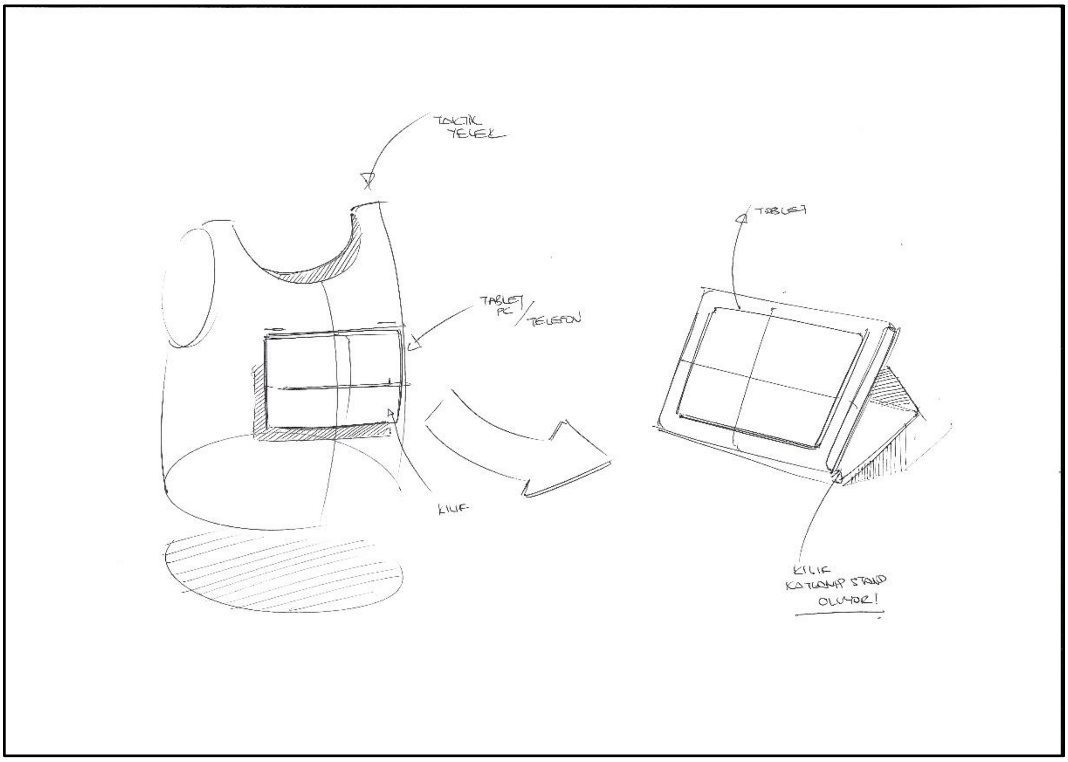


Figure C. 7 Example Concept from Participant 7

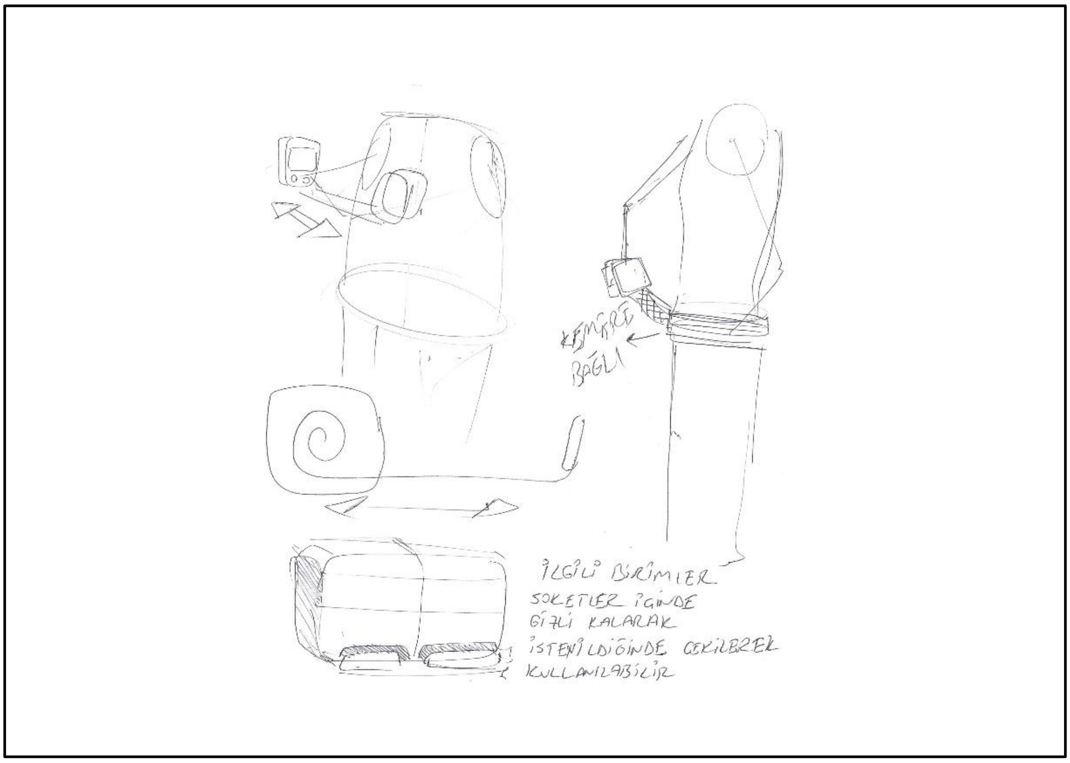


Figure C. 8 Example Concept from Participant 8

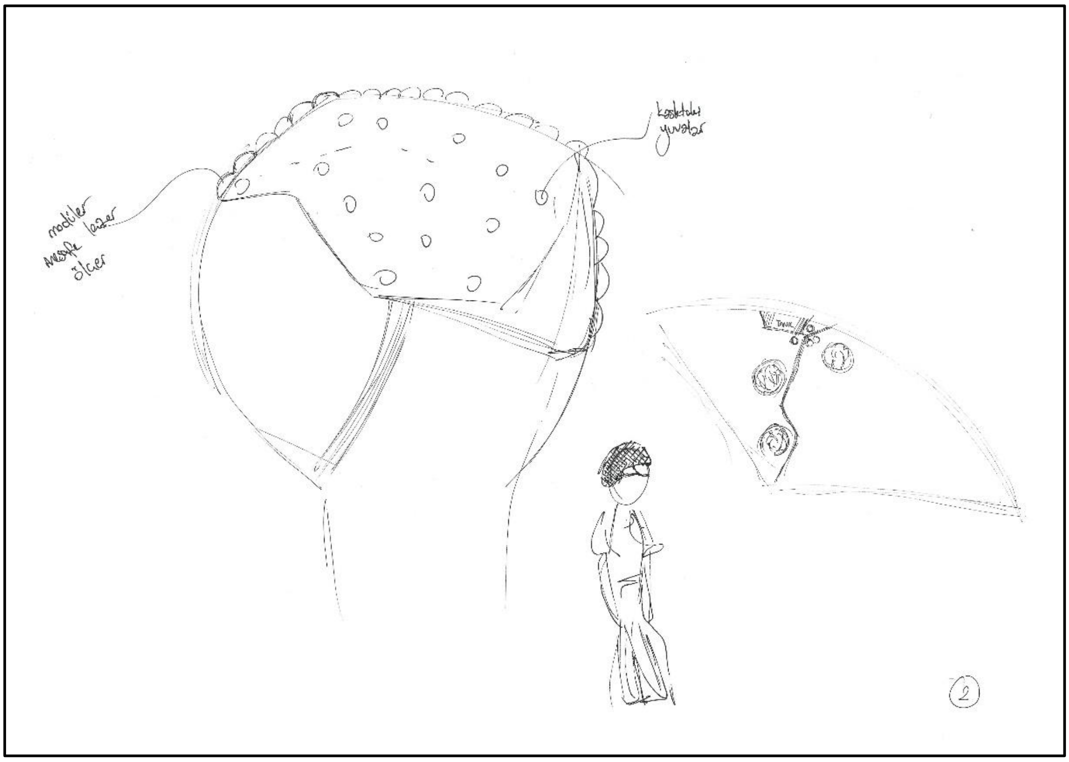


Figure C. 9 Example Concept from Participant 9

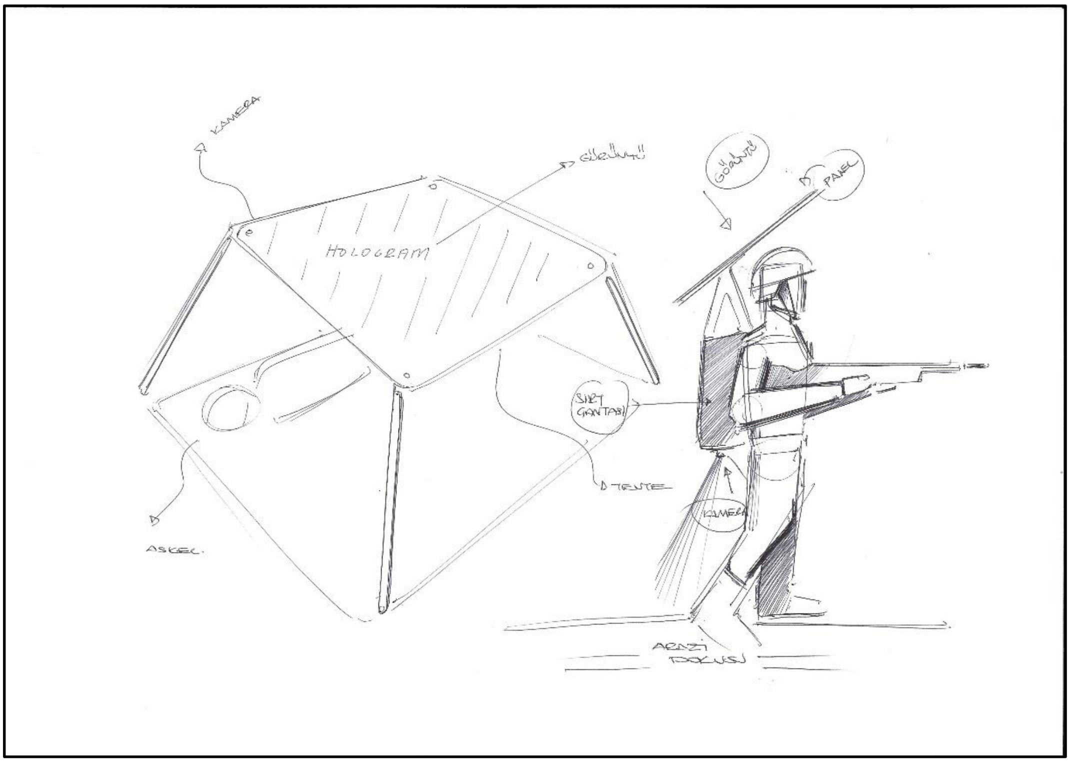


Figure C. 10 Example Concept from Participant 10

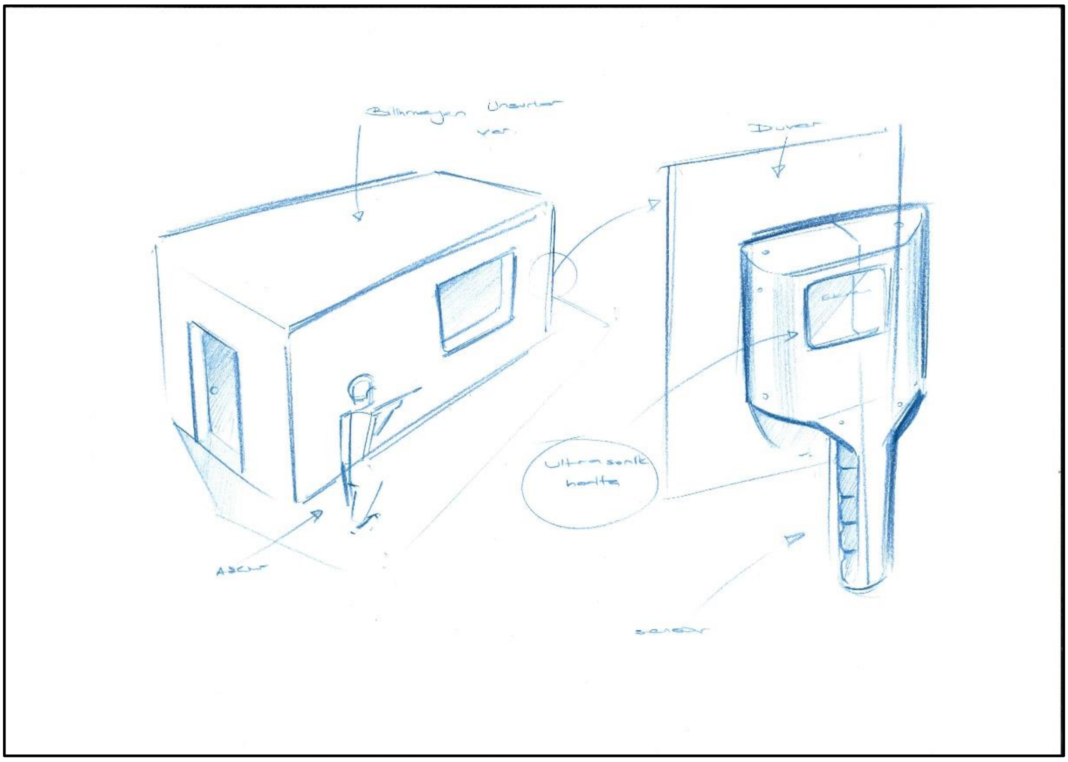


Figure C. 11 Example Concept from Participant 11

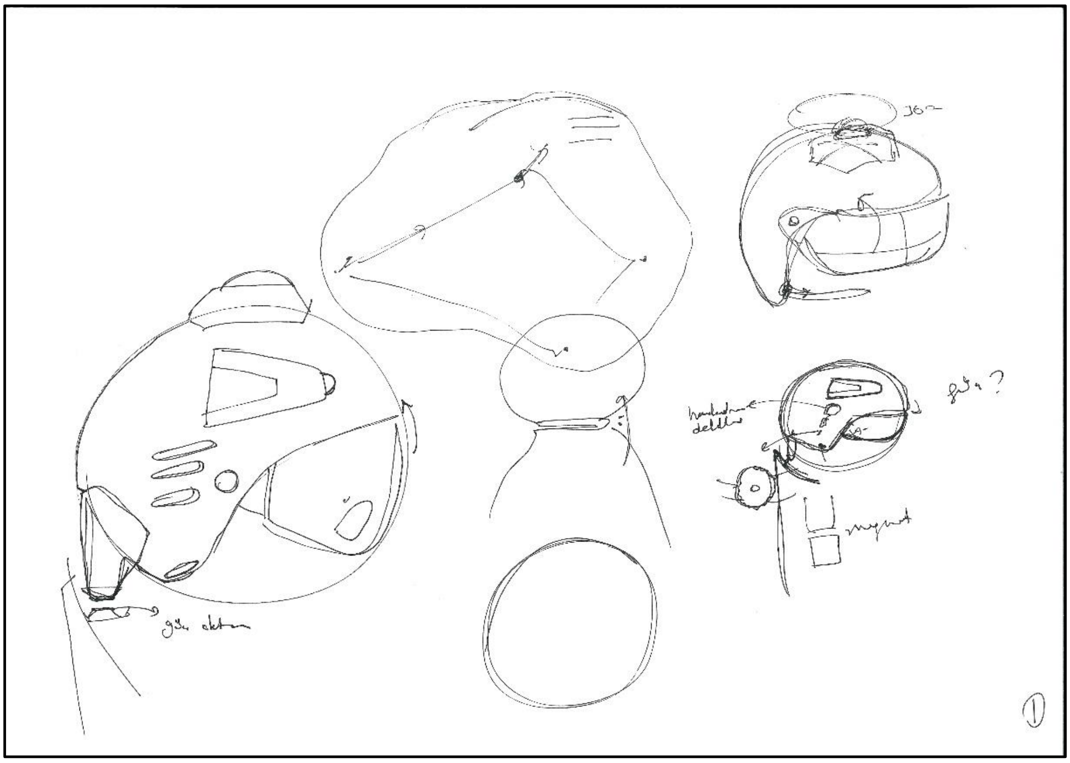
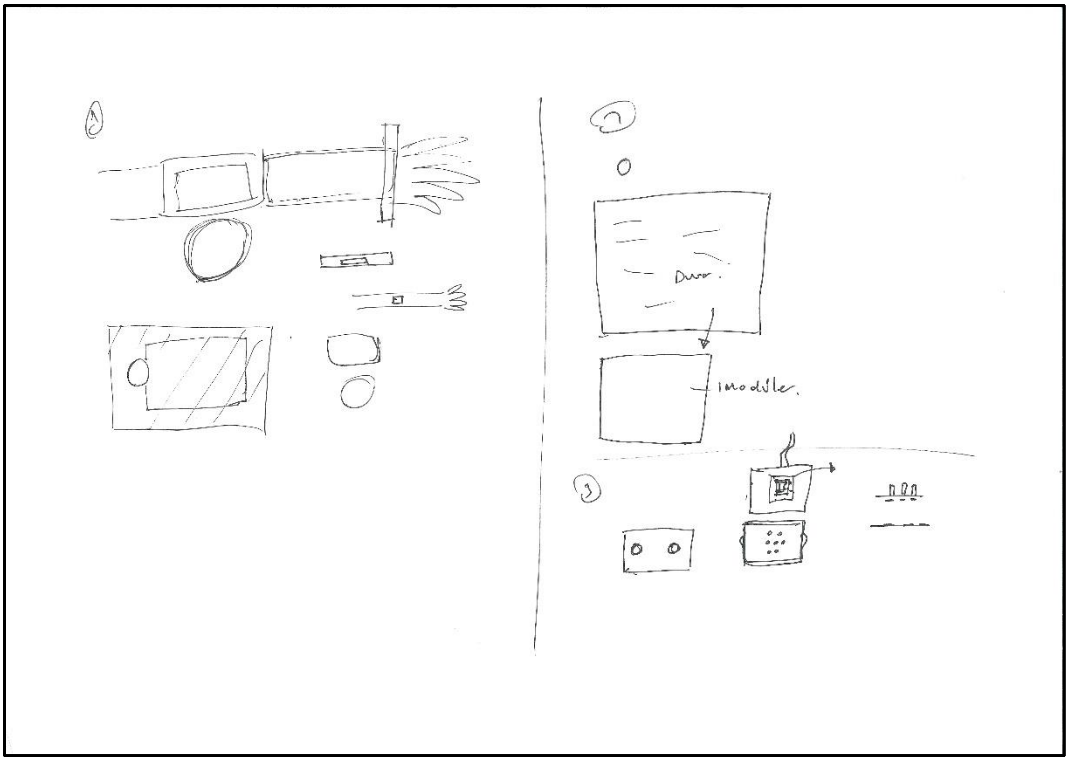


Figure C. 12 Example Concept from Participant 12



F**igure C. 13** Example Concept from Participant 13

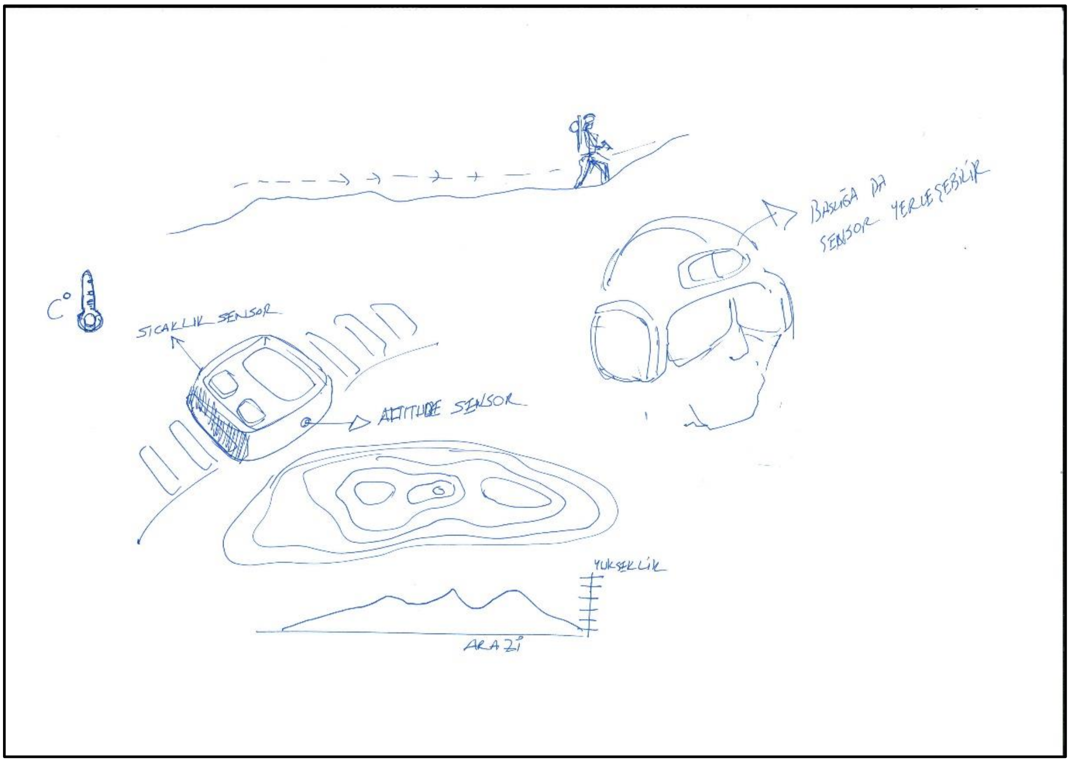


Figure C. 14 Example Concept from Participant 14

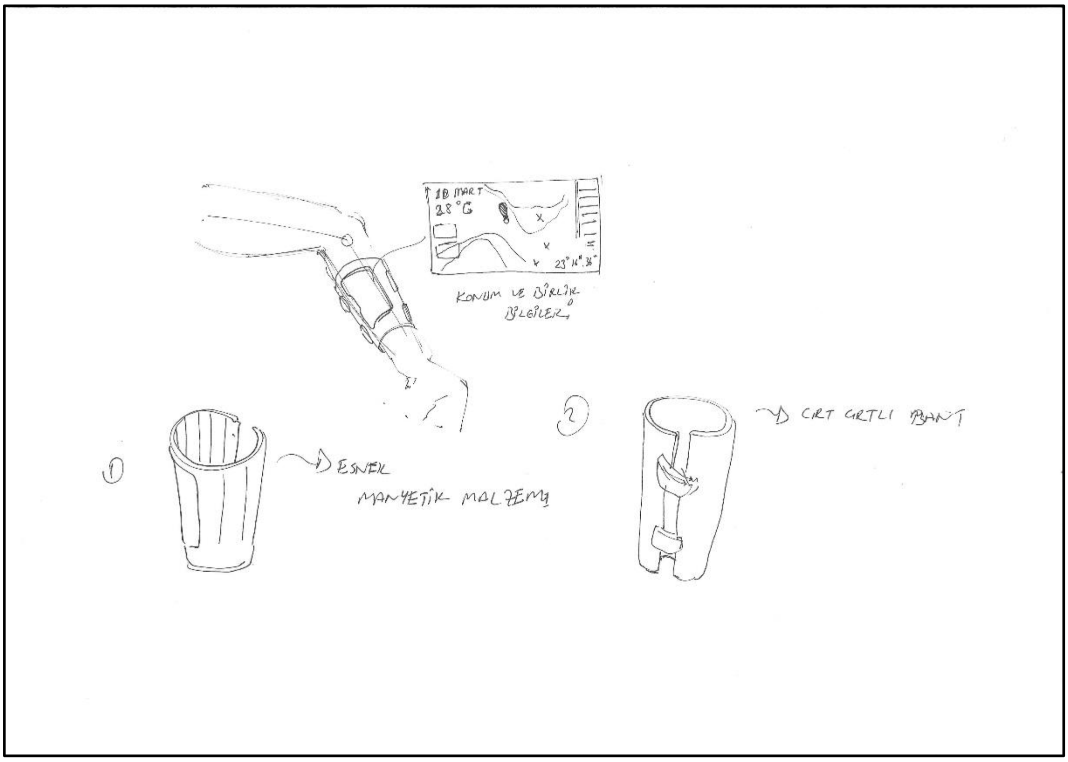


Figure C. 15 Example Concept from Participant 15

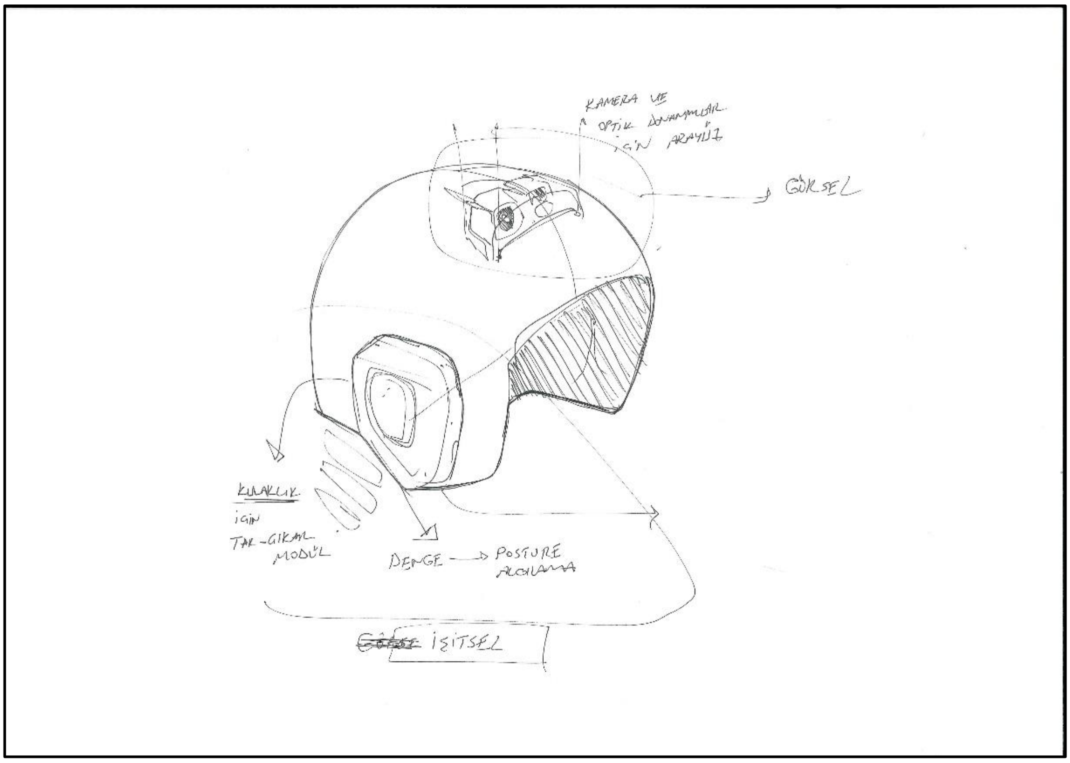


Figure C. 16 Example Concept from Participant 16

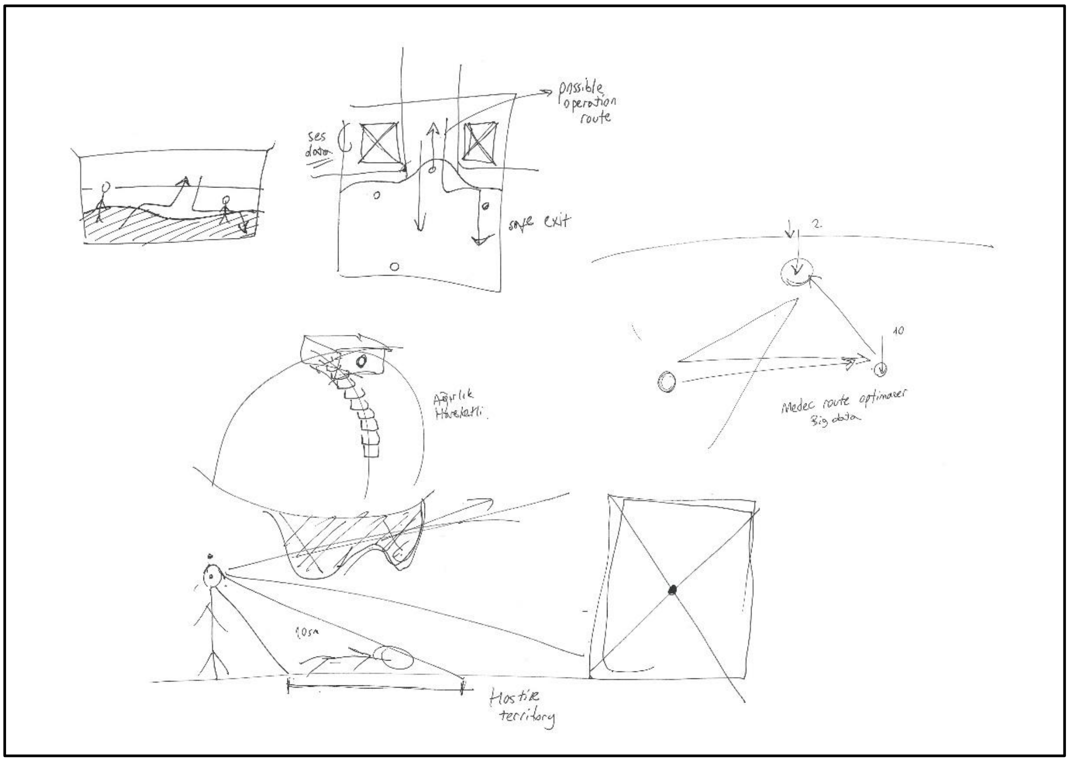


Figure C. 17 Example Concept from Participant 17

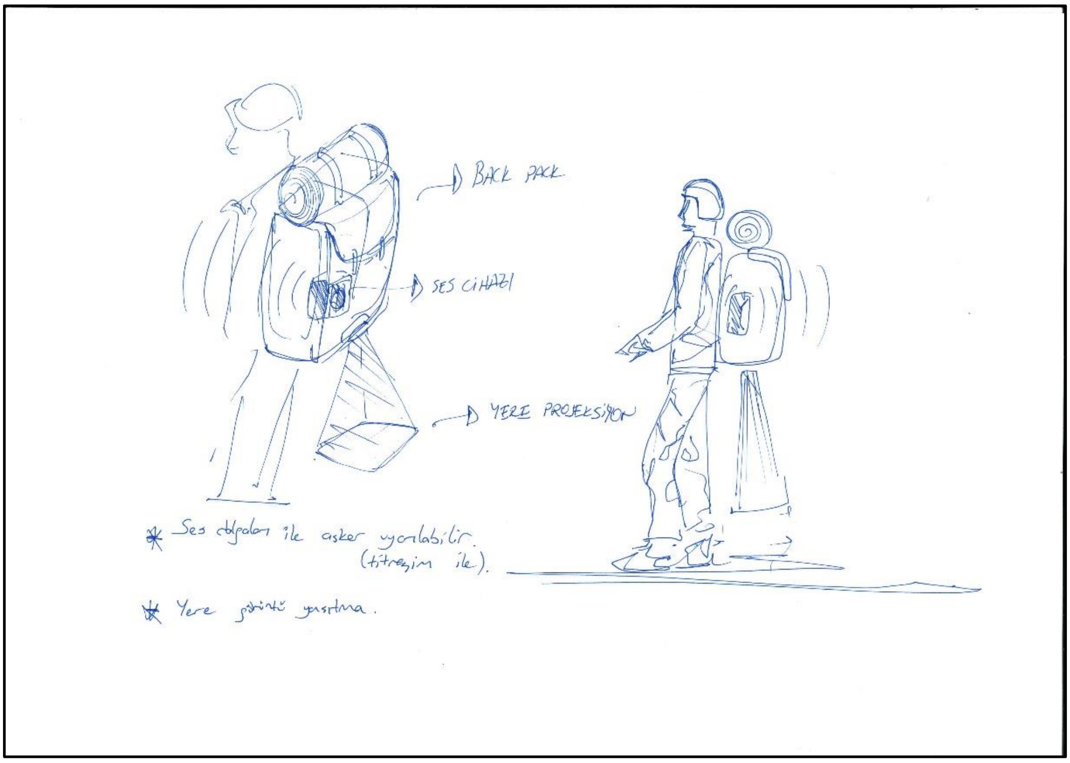


Figure C. 18 Example Concept from Participant 18

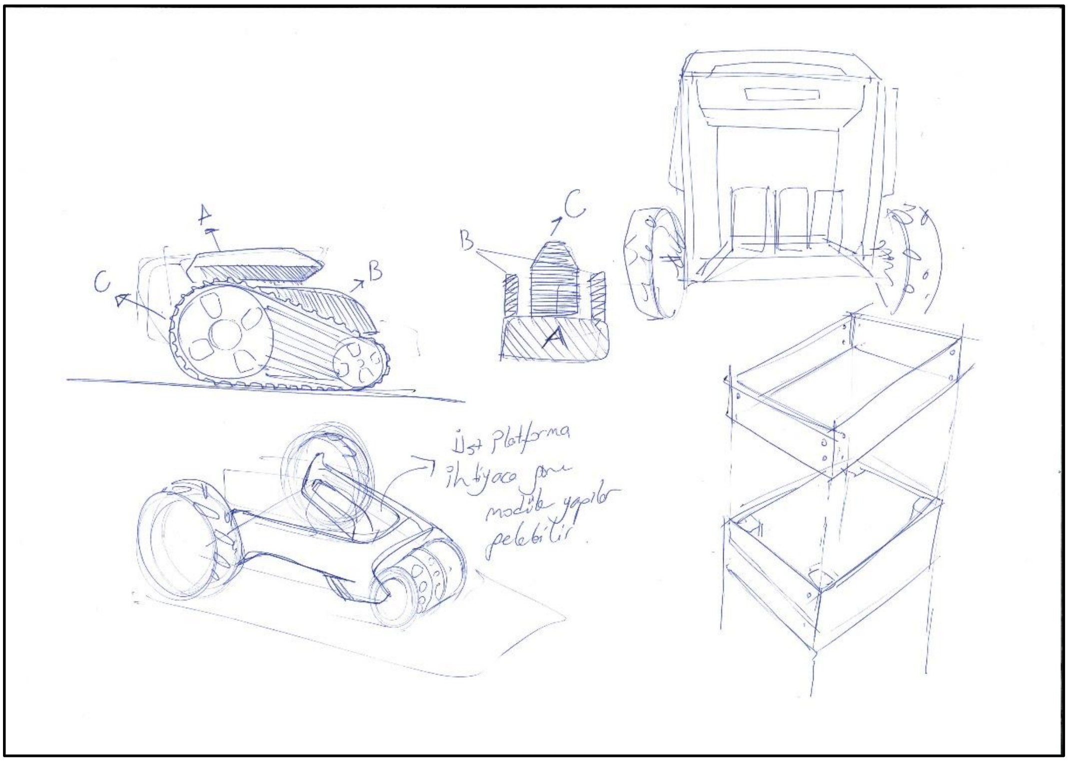


Figure C. 19 Example Concept from Participant 19

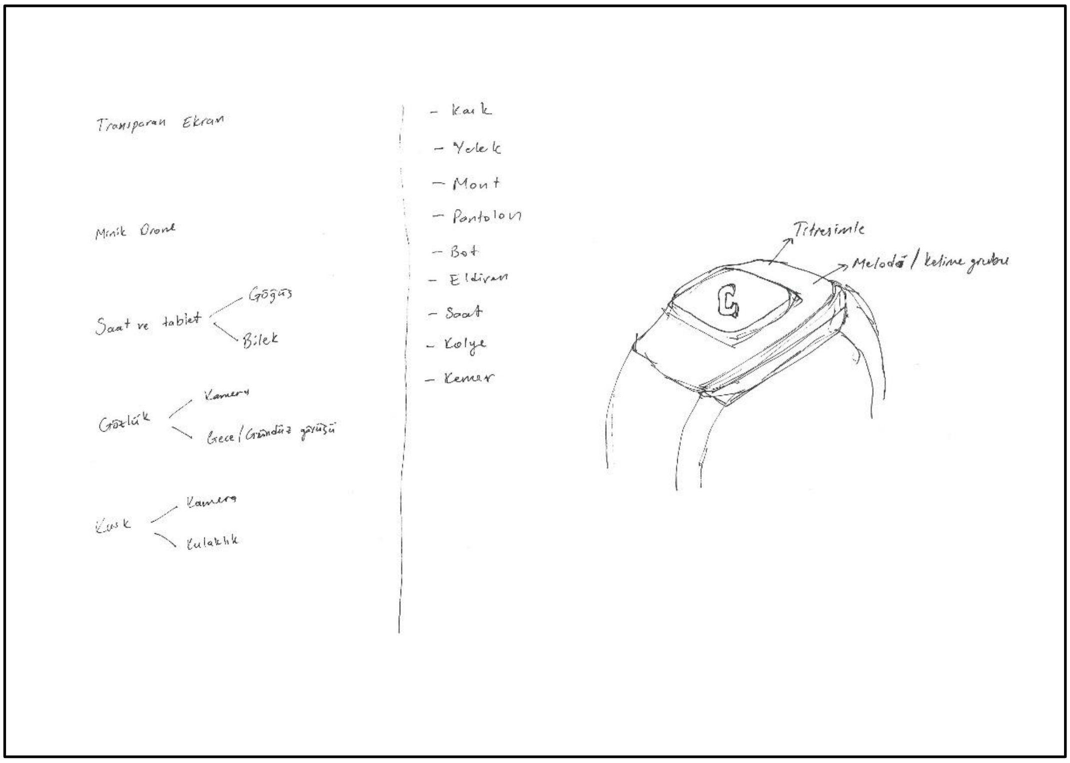


Figure C. 20 Example Concept from Participant 20

APPENDIX D

BETWEEN DOMAIN IMAGE SETS

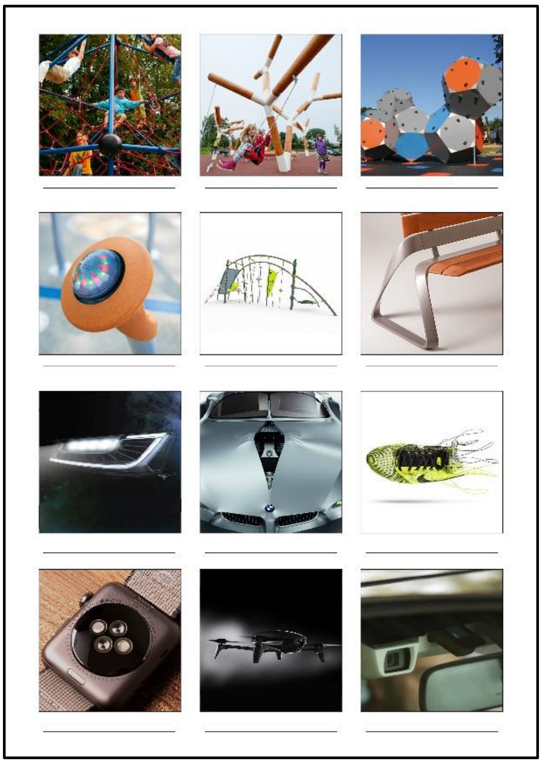


Figure D. 1 P1's Between Domain Image Set

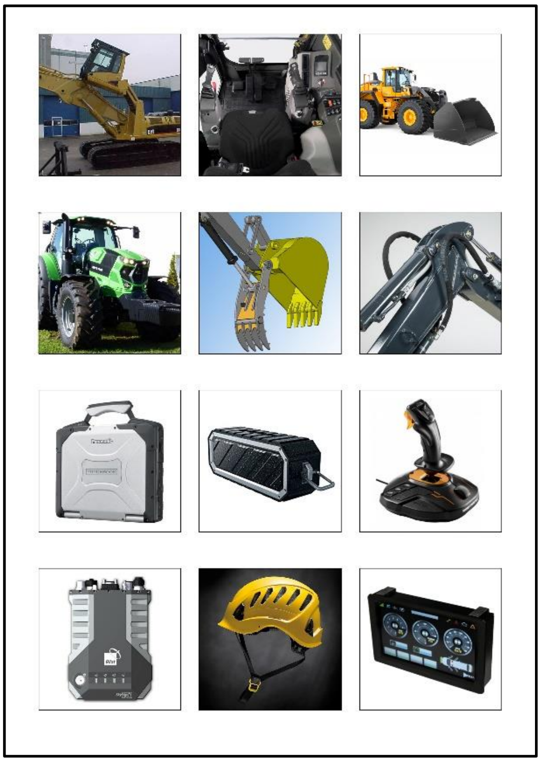


Figure D. 2 P2’s Between Domain Image Set

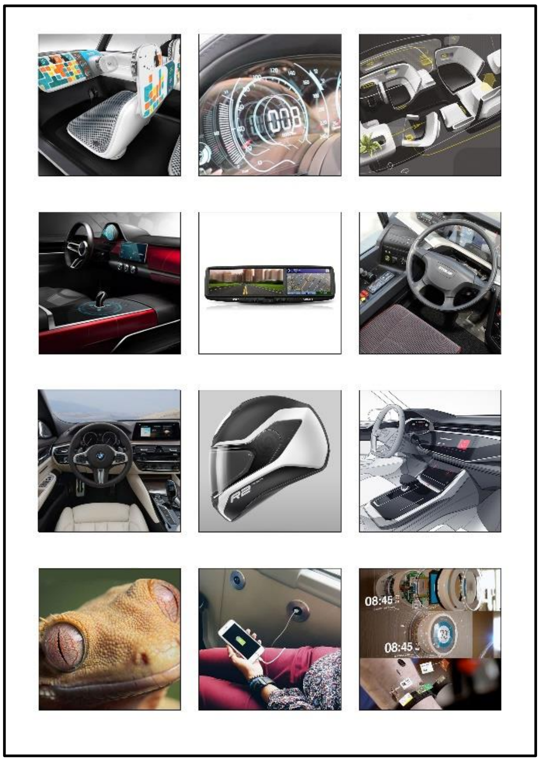


Figure D. 3 P3’s Between Domain Image Set

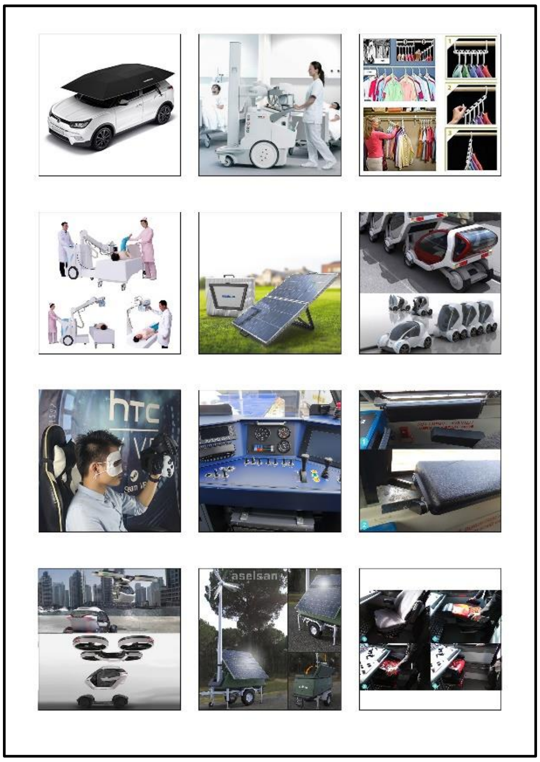


Figure D. 4 P4's Between Domain Image Set

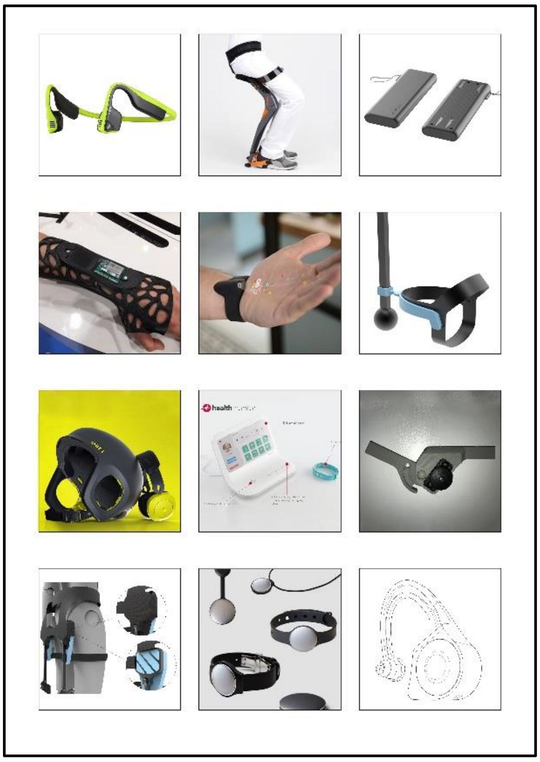


Figure D. 5 P5's Between Domain Image Set

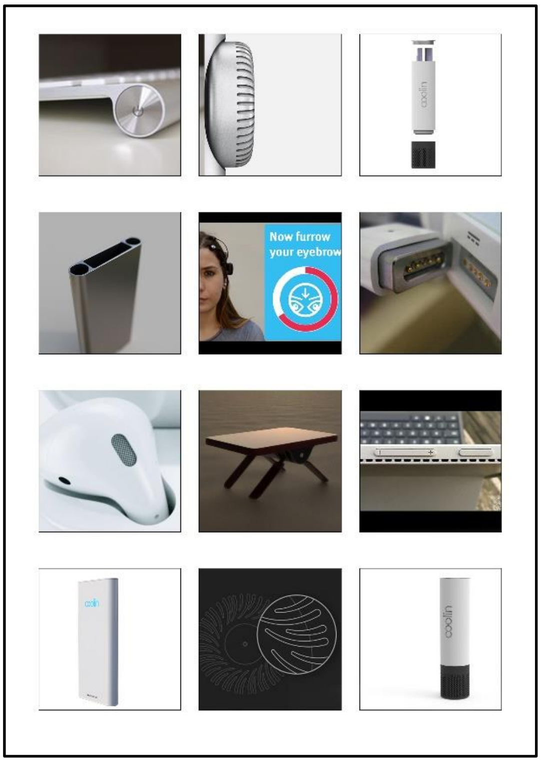


Figure D. 6 P6's Between Domain Image Set

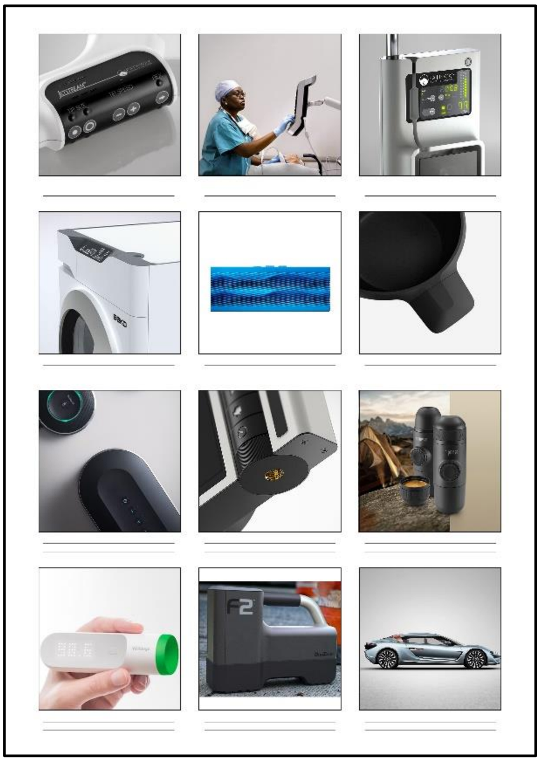


Figure D. 7 P1's Between Domain Image Set

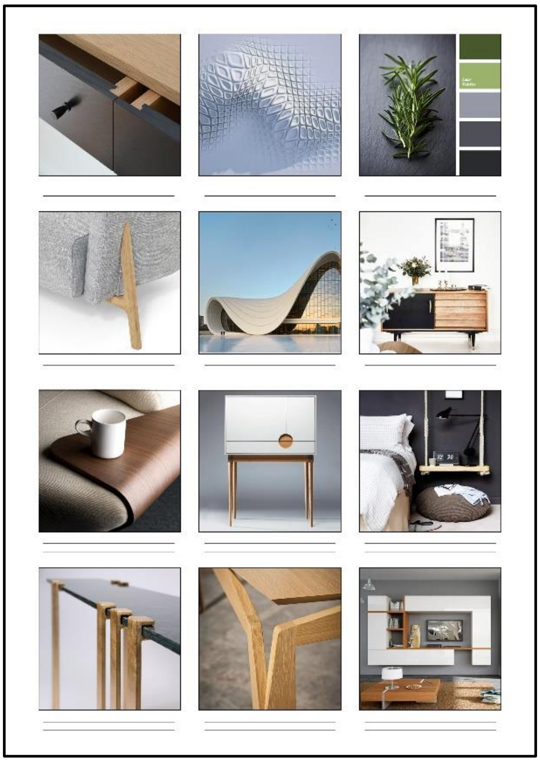


Figure D. 8 P8's Between Domain Image Set

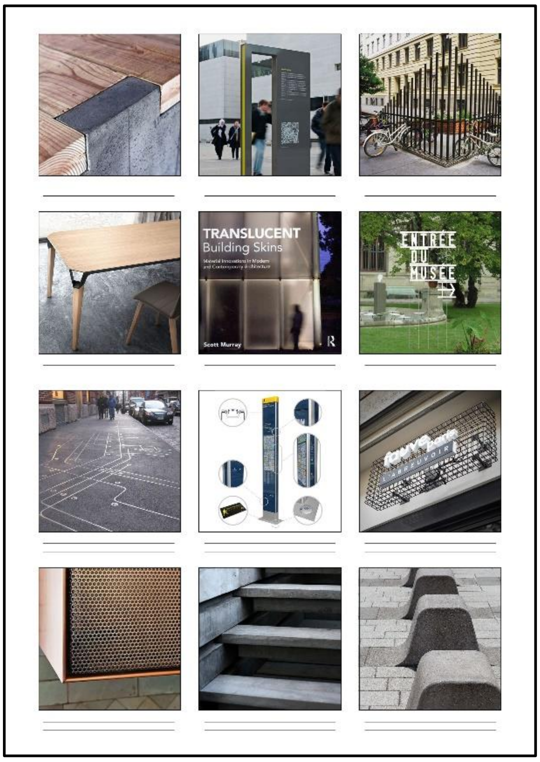


Figure D. 9 P9's Between Domain Image Set

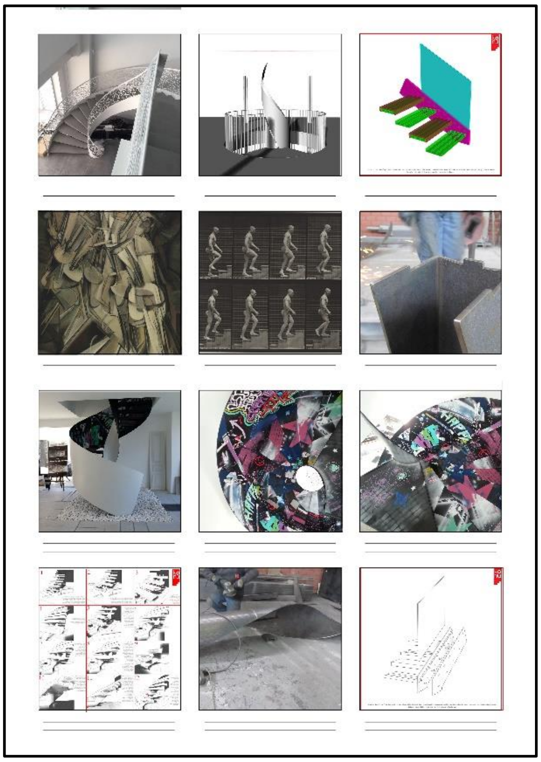


Figure D. 10 P10’s Between Domain Image Set

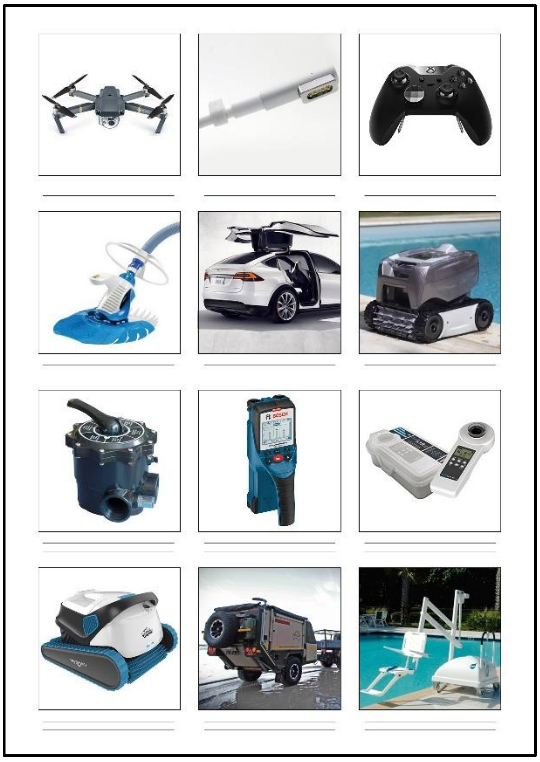


Figure D. 11 P11’s Between Domain Image Set

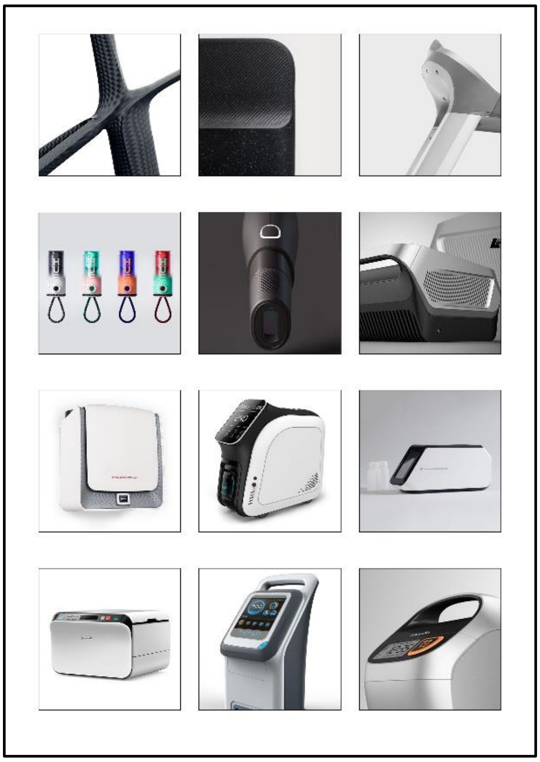


Figure D. 12 P12's Between Domain Image Set

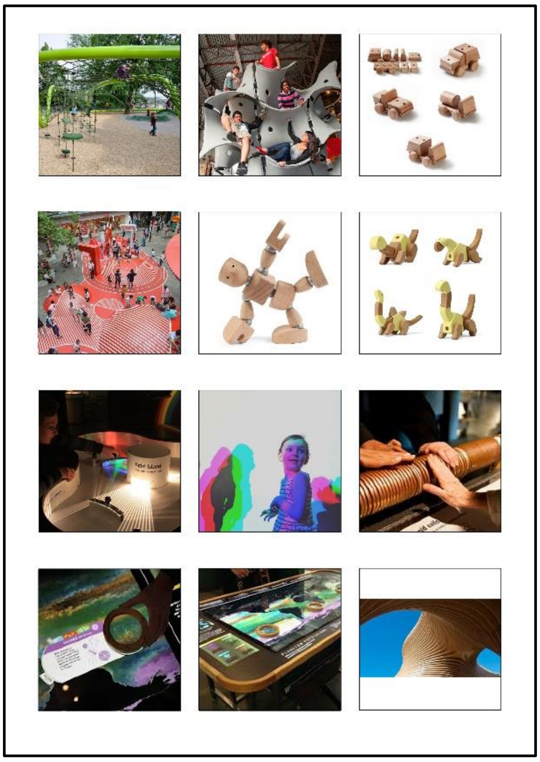


Figure D. 13 P13's Between Domain Image Set

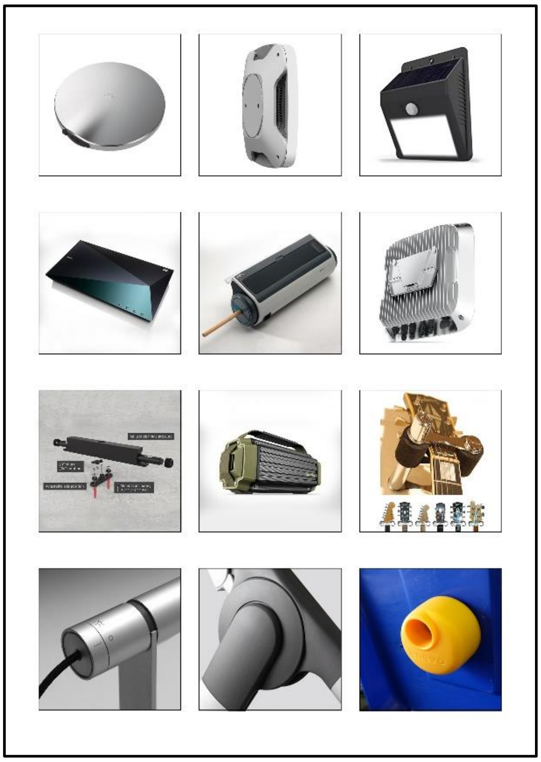


Figure D. 14 P14’s Between Domain Image Set

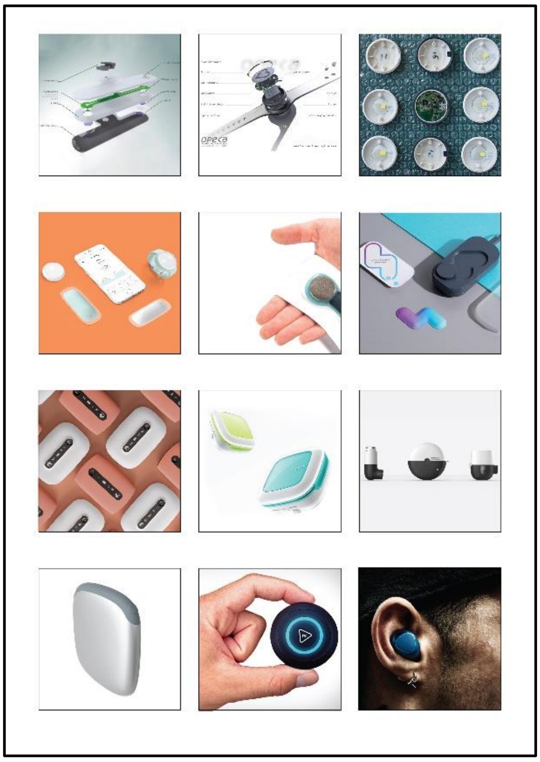


Figure D. 15 P15’s Between Domain Image Set

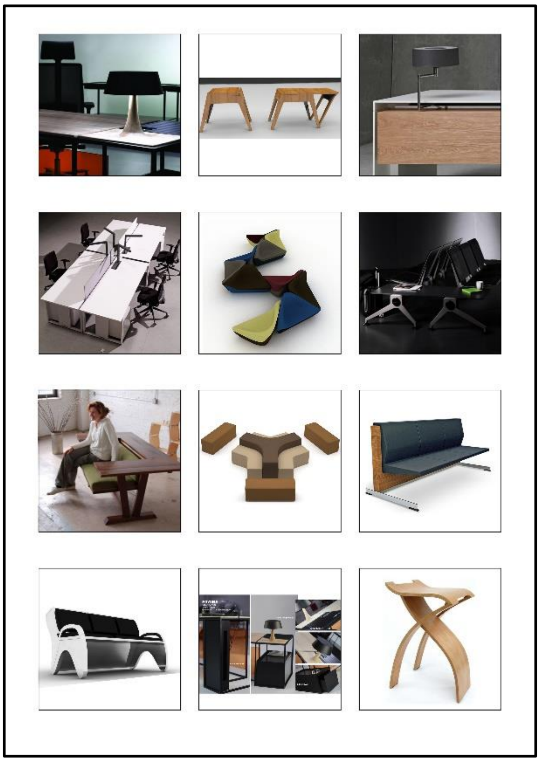


Figure D. 16 P16's Between Domain Image Set

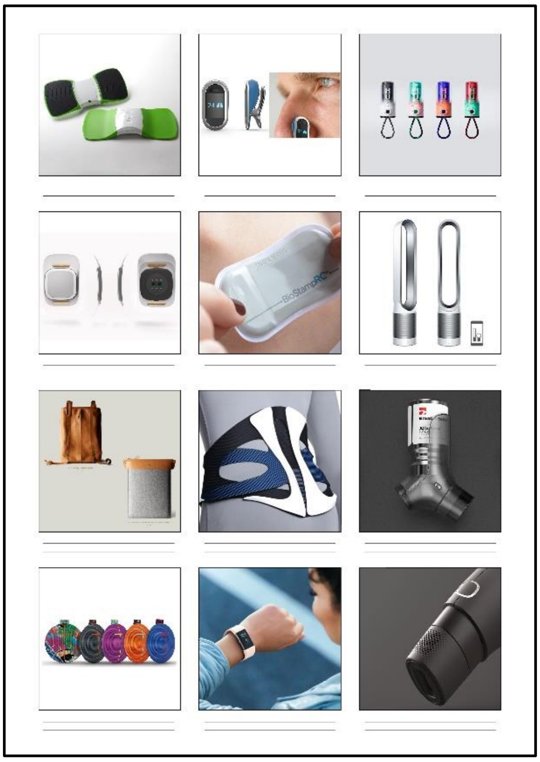


Figure D. 17 P17's Between Domain Image Set

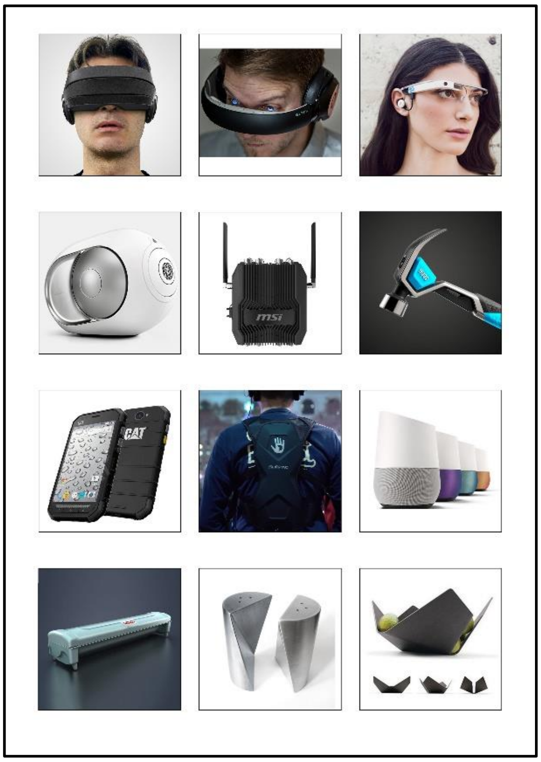


Figure D. 18 P1's Between Domain Image Set

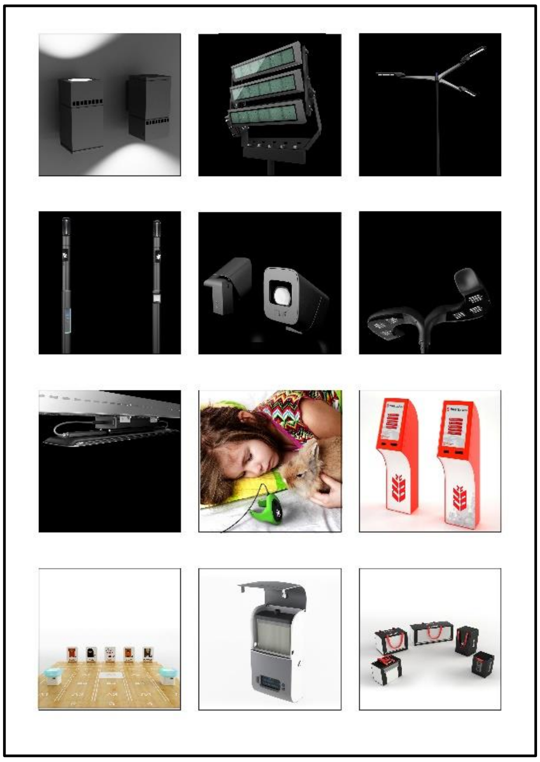


Figure D. 19 P1's Between Domain Image Set

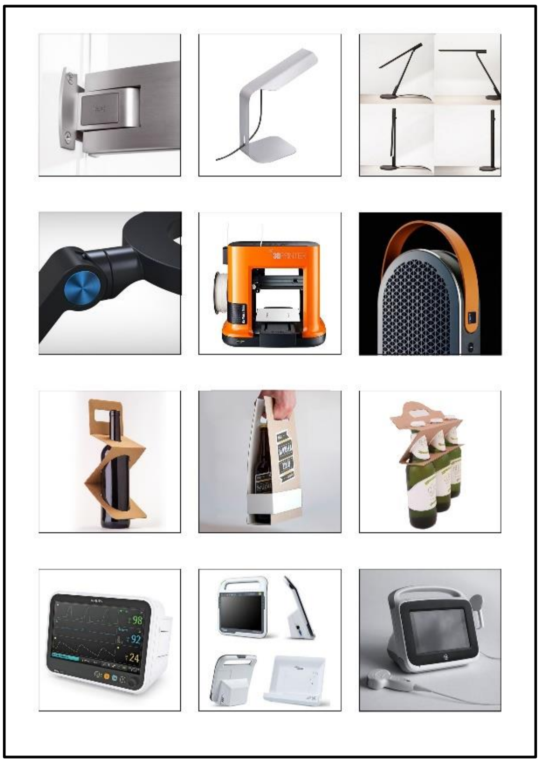


Figure D. 20 P's Between Domain Image Set

APPENDIX E

STATISTICAL CALCULATIONS OF STUDY

P 1	3,25	3,50		3,38
P 2	1,75	1,50		1,63
P 3	2,14	1,86		2,00
P 4	4,00	3,60		3,80
P 5	2,67	2,67		2,67
P 6	2,86	2,57		2,71
P 7	3,25	2,75		3,00
P 8	2,33	2,67		2,50
P 9	3,67	3,00		3,33
P 10	3,50	3,50		3,50
P 11	4,20	4,20		4,20
P 12	3,00	2,67		2,83
P 13	4,00	3,50		3,75
P 14	3,60	3,40		3,50
P 15	2,33	1,33		1,83
P 16	3,50	3,50		3,50
P 17	4,20	3,80		4,00
P 18	2,00	1,00		1,50
P 19	4,00	4,00		4,00
P 20	3,50	3,50		3,50
				3,06

Savunma Sanayinde Çalışanlar	2,52
Diğer Sektörler	3,29

NOVELTY	0,79

DURUM 1	2,61
DURUM 2	3,24
DURUM 3	3,18
DURUM 4	2,50

Figure E. 1 Scoring of Participants

APPENDIX F

CODING

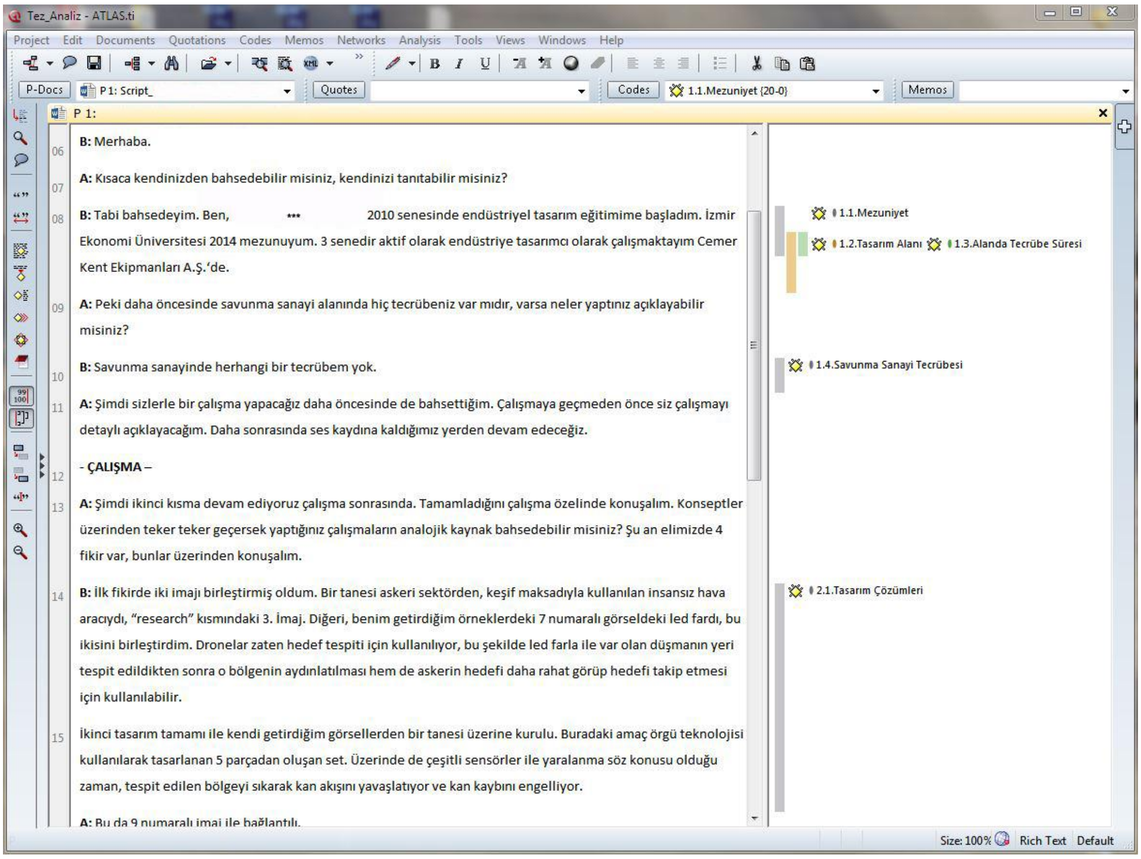
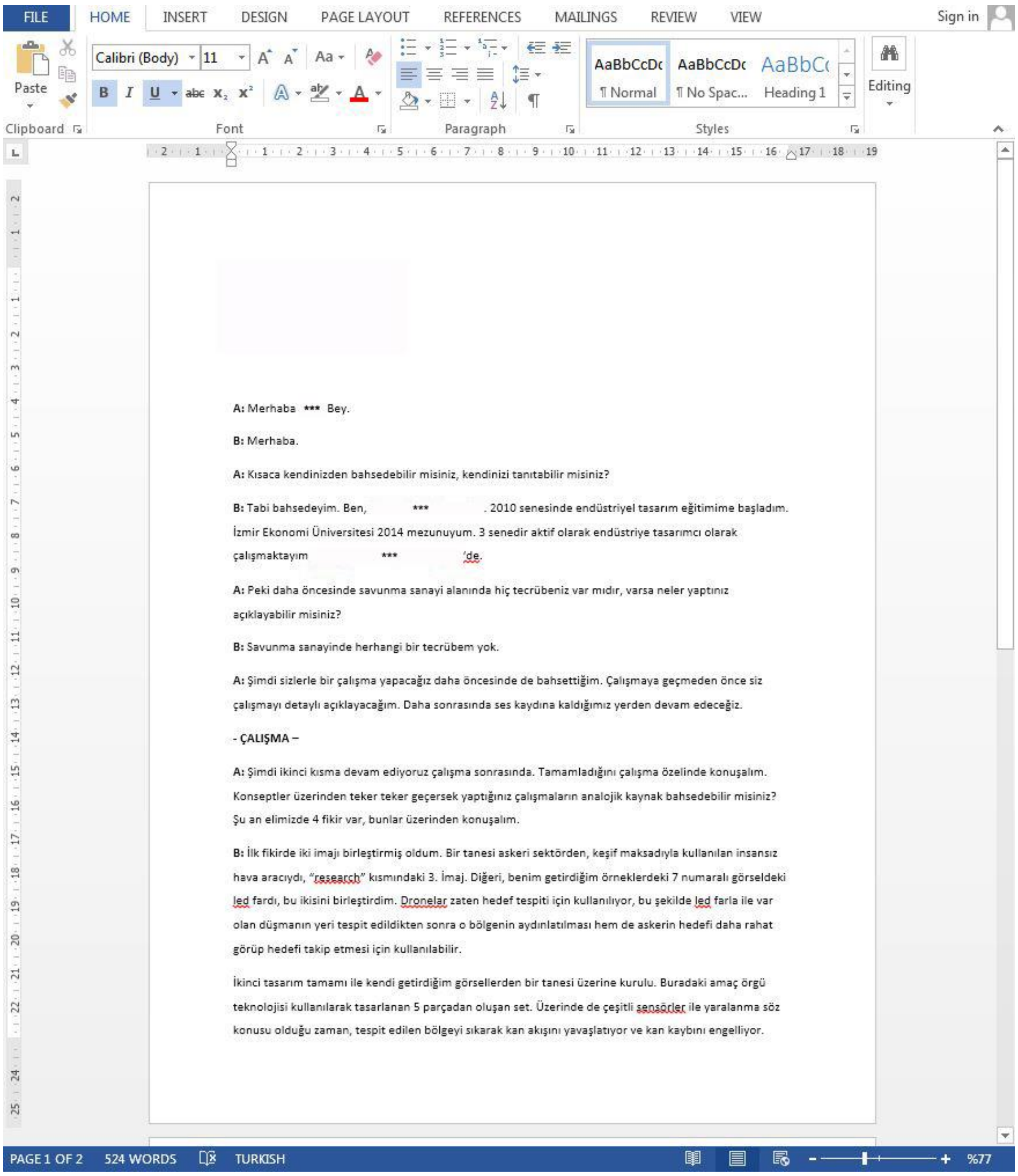


Figure F. 1 Coding In Atlas.ti

APPENDIX G

TRANSCRIPTION



A: Merhaba *** Bey.

B: Merhaba.

A: Kısaca kendinizden bahsedebilir misiniz, kendinizi tanıtabilir misiniz?

B: Tabi bahsedeyim. Ben, *** . 2010 senesinde endüstriyel tasarım eğitimime başladım. İzmir Ekonomi Üniversitesi 2014 mezunuyum. 3 senedir aktif olarak endüstriye tasarımcı olarak çalışmaktayım *** 'de.

A: Peki daha öncesinde savunma sanayi alanında hiç tecrübeniz var mıdır, varsa neler yaptınız açıklayabilir misiniz?

B: Savunma sanayinde herhangi bir tecrübem yok.

A: Şimdi sizlerle bir çalışma yapacağız daha öncesinde de bahsettiğim. Çalışmaya geçmeden önce siz çalışmayı detaylı açıklayacağım. Daha sonrasında ses kaydına kaldığımız yerden devam edeceğiz.

- ÇALIŞMA –

A: Şimdi ikinci kısma devam ediyoruz çalışma sonrasında. Tamamladığını çalışma özelinde konuşalım. Konseptler üzerinden teker teker geçersek yaptığınız çalışmaların analojik kaynak bahsedebilir misiniz? Şu an elimizde 4 fikir var, bunlar üzerinden konuşalım.

B: İlk fikirde iki imajı birleştirmiş oldum. Bir tanesi askeri sektörden, keşif maksadıyla kullanılan insansız hava aracıydı, "research" kısmındaki 3. İmaj. Diğeri, benim getirdiğim örneklerdeki 7 numaralı görseldeki led fardı, bu ikisini birleştirdim. Dronelar zaten hedef tespiti için kullanılıyor, bu şekilde led farla ile var olan düşmanın yeri tespit edildikten sonra o bölgenin aydınlatılması hem de askerin hedefi daha rahat görüp hedefi takip etmesi için kullanılabilir.

İkinci tasarım tamamı ile kendi getirdiğim görsellerden bir tanesi üzerine kurulu. Buradaki amaç örgü teknolojisi kullanılarak tasarlanan 5 parçadan oluşan set. Üzerinde de çeşitli sensörler ile yaralanma söz konusu olduğu zaman, tespit edilen bölgeyi sıkarak kan akışını yavaşlatıyor ve kan kaybını engelliyor.

Figure G. 1 Transcription of Interview

APPENDIX H

PARTICIPANT QUOTATIONS (TURKISH)

1) “Yani bilinçli olarak etmedim aslında hiç birini. Ama bu süreci gördükten sonra bir şekilde ettiğimi düşünüyorum yaptığımız çoğu şey aslında görsel ve çözümler ile tetikleniyor. Ama bu kadar sistematik olarak adaptasyonun olduğu bir çalışma yapmadım.” (P05)
2) “Aslında metodolojik yer aldıklarını söyleyemem. Aslına bakarsan biz süreçleri genelde sezgisel olarak her süreç için “brief”i aldıktan sonra baştan tasarlıyoruz. Karşı tarafın beklentileri pazar ve müşteri ile iliği şeyleri öğrenebildiğimiz neredeyse her şeyi öğrenip “brief” haline getirip, süreci tasarlamaya çalışıyoruz. Ve bu süreçte genelde yetersiz süre olduğu için bu araştırmalar biraz az kalıyor aynı zamanda da önceki tecrübelerimize dayanarak daha hızlı hareket etmek zorunda kalıyoruz. Aslında daha hızlı hareket etmek zorunda kaldığımız için önceki tecrübelerimize başvuruyoruz ve genellikle süreçler çok sezgisel çözümler ile ilerliyor.” (P20)
3) “Yani projeden projeye aslında çok değişiyor. Biraz da piyasaya çalıştığın zaman müşteri beklentileri de işin içerisine giriyor. Bir müşteriye çalıştığında, müşteri beklentileri, pazar beklentisi, ürün kısıtlarını yan yana koyduktan sonra aslında sana fazla hareket edecek bir alan kalmıyor çoğu zaman. Çoğu müşteri gelip de ben seni özgür bırakıyorum, sen uç kaç, fantastik bir ürün çıkaralım demiyor. Genelde müşteri kartımız bu, motorumuz bu, kartuşumuz bu, bunların üçünün bir araya geldiği bir ürün olacak şeklinde oluyor.” (P19)
4) “Çalışma süreci bence çok iyiydi ve çok hızlıydı. Çalışmanın sevdiğim yönü şu oldu özellikle onu belirtmek istiyorum. Somut çıktı üretmeye çok müsait olması sebebiyle ilgimi çekti. Diğer metotlara göre çok kesin sonuçlar çıkarıyor” (P17)
5) “Burada seçtiğin sektör çok kritik bir hal alıyor. Baktığın spesifik sektör ile yapmaya çalıştığın çalışmanın uyum sürecine bağlı olarak süreç sıkıntıya girebilir. O yüzden sektörel bazlı değil de daha geniş bakarak daha nitelikli bir şey çıkabilir diye düşünüyorum. En basitinden medikal sektör koysaymışım daha iyi olabilirmiş. Önceden kullanacağım diye görsel hazırlasam daha iyi olabilir en basitiyle burada görüntü benzerliğinden bir sürü şey çıkabiliyor. Rastlantısal olduğu için her noktada efektif olmayabilir, bazı şeyleri çıkaramayabilirsin.” (P14)

APPENDIX I

CATEGORIZING CONCEPTS

Drone birimlerine LED ışık takılıp takip ve tespit yapılması.	Autonomous sub-systems
Örgü vücut sleevelerine sensör entegre edilip sağlık bilgi takibi yapılması.	Sensor (Detection) sub-systems
Bileklikten yapılacak dost ve düşman tespitinin harita gibi kompleks yapılar yerine basit ve mekanik göstergeler ile kullanıcıya iletilmesi.	C5ISR sub-systems
Kameraların birbirine entegre edilerek istenilen kamera konfigürasyonlarının oluşturulması.	Sensor (Detection) sub-systems
Ekranda kullancıya gösterilecek bilgilerin farklı ekranlarda sunulması ve iş makinalarında kullanılan roller buton ile aralarında geçiş yapılması.	C5ISR sub-systems
Ekranın kol ve bilek bölgesine yerleştirilmesi.	C5ISR sub-systems
Ekran derine gömüldükten sonra üzerine tasarlanacak bir kapak yapısı ile hem korunmasını hem de ışık sızdırmazlığının sağlanması.	C5ISR sub-systems
3 Kırımlı katlanabilir HMD (Helmet Mounted Display) yapısı.	C5ISR sub-systems
Askerlerin üzerindeki cihazları şarj etmek için askerin donanımlarının üst bölgelerine güneş panelleri yerleştirilmesi.	Power and energy sub-systems
Otomotivdeki "trimler" bağlantı elemanı kullanılmadan montajlanır.	Equipment and protection sub-systems
Kaska entegre lazer sensörleri ile elde edilen datanın HMD'de gösterimi.	C5ISR sub-systems
Katmanlı gözlük yapısı ile manuel filtereler uygulanması (Gece görüşü, termal, vs.).	Sensor (Detection) sub-systems
Sesle kontrol sistemi.	C5ISR sub-systems
Yeleğe entegre "acil sil" hard buttonı.	Equipment and protection sub-systems
Otomotivdeki "Kluster" yapılarında kullanılan snapfit buton yapısının kaska birim entegre edilmesinde kullanılması.	Equipment and protection sub-systems
Quadrocopter ve ya paletli yapıya entegre olabilen sedye.	Autonomous sub-systems
Modüler paletli araç (İlk yardım, gözetleme, taşıma..)	Autonomous sub-systems
Askerin üstündeki modüler yapıya entegre güneş paneli. Modül, kamera ile yerdeki görüntüyü kamuflja olarak yansıtıyor.	Power and energy sub-systems
VR gözlük kılıfları gibi, tek kullanımlık kıyafet.	Equipment and protection sub-systems
Modüler yelek. Yeleğin ön, arka ve yan bölümleri cırt cırt ile değişebilir. Her modül mühimmat, sıhhiye ekipmanı, vs. gibi çeşitlendirilebilir.	Equipment and protection sub-systems
HMD'ye entegre kemik iletimli kulaklık.	Equipment and protection sub-systems
Sahadaki askerin taşınmayan cihazlarını kullanması için giyilebilir sandalye.	Equipment and protection sub-systems
Kaska entegre kulaklık. Aynı boşluğa çenelik, gözlük gibi ekipmanlar da takılabilir.	Equipment and protection sub-systems
Hem yelek hem de bileğe takılabilir arayüz bulunan giyilebilir bilgisayar.	C5ISR sub-systems
Teleskobik atılabilir robot. Böylece atıldığında daha korumalı olacaktır, yere çarpınca açılacak.	Autonomous sub-systems
"Voronoi" paterninin yelek arayüzü olarak kullanılması. Ekipman ve zırh bu yapı ile bağlanacak.	Equipment and protection sub-systems
Asimetrik fan tasarımı ile droneların sesinin azaltılması.	Autonomous sub-systems
Giyilebilir ekranlarda fazla menü bulunmakta, menüler sadeleştirilip bunların arasında geçiş sağlayacak buton tasarımı yapılabilir.	C5ISR sub-systems
Magnetik konektör detayı ile quick realease kask yapısının tasarlanması.	Equipment and protection sub-systems
"Beam forming micraphone" ile daha iyi ses akışının sağlanması.	C5ISR sub-systems
Atıldıktan sonra açılan atılabilir robot.	Autonomous sub-systems
Sensörler ile programlanabilir silah add-on'u.	Sensor (Detection) sub-systems
Sahada taşınamaz ekipmanların stationary kullanılması istendiğinde tripod ayakları ile sabit kalabilen katlanabilir tabla.	Equipment and protection sub-systems
Kol yüzeyine bileklik vasıtasıyla yansıtılan arayüz.	C5ISR sub-systems
Kamera için arayüz detayları barındıran, HMD, lazer mesafe ölçer ve kulaklığı kendi içinde barındıran balistik kask tasarımı.	Equipment and protection sub-systems
Yeleğe bağlı tablet arayüzünün yelekten sökülerek stand haline getirilmesi.	C5ISR sub-systems
Pozisyon göstermek için sadece led ışıkları kullanan yeleğe entegre gps modülü.	C5ISR sub-systems
VR ve HMD'lerin üstten de desteklenerek ergonomisinin arttırılması.	Equipment and protection sub-systems
Kask üzerine ray yapıları yapılarak bunların arayüz olarak kullanılması.	Equipment and protection sub-systems
Roller-clip ile yelek ve ya kemere cihazarın tutturulması.	Equipment and protection sub-systems
Lazer mesafe ölçerin genelin aksine bileklik olarak kurgulanması.	Sensor (Detection) sub-systems
Lazer mesafe ölçer ve proximity sensörlerinin kaska entegre olmasıyla 360 derece tarama ve farkındalık.	Sensor (Detection) sub-systems
Way-finding sistemleri ile Konsept 2'deki kaskı kullanarak askere yol çizilmesi.	C5ISR sub-systems
Statik imaj yerine dinamik kamuflaj. (Kameralar vasıtasıyla)	Equipment and protection sub-systems
Texturelü kıyafet ile gölge/ışık yaratarak kamuflaj sağlanması.	Equipment and protection sub-systems
Su analizi yapan matara ile askere farkındalık kazandırılması.	Sensor (Detection) sub-systems
Paletli emiş yeteneği olan havuz araçları konseptinin askeriyeye uygulanması. Bu şekilde yaralı personeli sahadan tahliye edebiliyoruz.	Autonomous sub-systems
Duvar arkası sensörü.	Sensor (Detection) sub-systems
Hidrolik lift ile (5 eksenli) araç üstü tamir çalışmalarının yapılabilmesi.	Autonomous sub-systems
Hoparlör taşıyan drone ile propaganda/bilgilendirme yapılması. Tek noktaya frekans odaklanması.	Autonomous sub-systems
Personelin kask ve kıyafeti arasında "astronot kaskı-kıyafeti" gibi bir ilişki kurarak enerji ve data aktarımı.	Equipment and protection sub-systems
Kol yüzeyine bileklik vasıtasıyla yansıtılan arayüz.	C5ISR sub-systems
İKA ve bomba imha robotlarının VR ile desteklenerek personelin girmediği bölgelerde personele bilgi aktarımı sağlaması.	Autonomous sub-systems
(Kola, duvara, vs.) Konulduğu her yere arayüz yansıtan ürün.	C5ISR sub-systems
Modüler yüzey. Üzerine VR uygulamalar ile interaktif haritalar yaratılabilir.	C5ISR sub-systems
Komple bir sleeve yapısına, giyilebilir bilgisayarı, sağlık sensörlerü ve exeskeleton entegrasyonu.	C5ISR sub-systems
HMD ekranından arttırılmış gerçeklik ile konum, hedef, vs. gösterimi	C5ISR sub-systems
Kafaya geçirilen sleeve yapısının içine entegre gırtlak mikrafonu ve kulaklık.	C5ISR sub-systems
Personelin gezdiği yerlerdeki yükseklik ve sıcaklık bilgisini kullanarak haritalandırma yapılması.	C5ISR sub-systems
Havaya atılan ürünün havada 360 derece görüntü almasıyla çevresel farkındalık kazanımı.	C5ISR sub-systems
Kol yüzeyine bileklik vasıtasıyla yansıtılan arayüz.	C5ISR sub-systems
Gırtlak mikrofon için textil sleeve.	C5ISR sub-systems
Çanta üzerinden strüktür kullanılarak ekranın öne alınması.	Equipment and protection sub-systems
Eldivene entegre sağlık sensörü, gps ve flex ekran.	C5ISR sub-systems
Kaska entegre kulaklık sayesinde postürün algılanması.	Sensor (Detection) sub-systems
Kişinin postürüne göre HMD ekranındaki görüntünün displacement yapması.	C5ISR sub-systems
HMD ekranında arttırlmış gerçeklik ile cephe ve rota gösterimi. Çıkış rotalarının oluşturulması.	C5ISR sub-systems
Personelin nabız, nefes değerlerine bakarak stres seviyelerinin ölçülmesi. Stres seviyesine göre doğru nefes almalarını sağlamak.	Sensor (Detection) sub-systems
Kafa postüründen bağımsız kameranın çevresel faktörlere odaklanması. Kask üzerinde ray yapısı yardımı ile kamera yönlendirilecek.	C5ISR sub-systems
Sıhhiye birimlerine rota ve derecelendirme oluşturularak efektifliklerinin arttırılması.	C5ISR sub-systems
Çantaya yerleştirilen bass ile ekibin tehditlere karşı uyarılması.	Equipment and protection sub-systems
Modüler çanta yapısı.	Equipment and protection sub-systems
Dış kabuğu darbe ile açılan throwbot.	Autonomous sub-systems
Farklı komponentler ile farklı gerekler için kullanılabilen robot.	Autonomous sub-systems
Bot ile zemin analizi ve haritalandırılmasının yapılması.	Equipment and protection sub-systems
E-ink ekran kullanan arayüz. Işık disiplini sağlar.	C5ISR sub-systems