# EFFECT OF GOAL ORIENTATION AND DIFFERENT HUMAN-COMPUTER INTERACTION MODALITIES ON USERS' ENGAGEMENT

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**EFFECT OF GOAL ORIENTATION AND DIFFERENT HUMAN-COMPUTER INTERACTION MODALITIES ON USERS' ENGAGEMENT**

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# ABSTRACT

EFFECT OF GOAL ORIENTATION AND DIFFERENT HUMAN-COMPUTER INTERACTION MODALITIES ON USERS' ENGAGEMENT

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The purpose of this study is to investigate the effects of goal orientation and alternative human computer interaction modalities on user engagement. Performance-oriented and learning- oriented individuals exhibit motivational differences. Learning-oriented individuals focus on progress and mastery, whereas performance-oriented individuals focus on ability. Twenty-five participants participated in the study. They were asked to accomplish the same task with three alternative modalities of interaction, namely mouse, eye tracker and Microsoft Kinect V2. The participants also filled in a goal orientation questionnaire and user engagement questionnaire. The findings revealed that different modalities resulted in different task completion times. The completion time was then used as a factor for the analysis of the efficiency of the interaction. Further analyses showed significant interactions among the goal orientation of the participants, their engagement scores and the interaction modalities.

Keywords: Goal-Orientation, task engagement, human-computer interaction modalities, Eye Tracker, Microsoft Kinect V2.

# ÖZ

## HEDEF YÖENLİMİ VE FARKLI İNSAN BİLGİSAYAR İLETİŞİM YÖNTEMLERİNİN KULLANICILARIN GÖREV BAĞLILIKLARINA OLAN ETKİSİ

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Bu çalışmanın amacı, kişilerin hedef yönelimlerinin ve farklı seçeneklerdeki insan-bilgisayar etkileşim yöntemlerinin, kişilerin görev bağlılıklarına olan etkisini incelemektir. Performans- yönelimli ve öğrenme-yönelimli kişiler motivasyonel farklılıklar göstermektedirler. Öğrenme yönelimli kişiler ilerleme ve öğrenmeye odaklanırken, performans yönelimli kişiler becerinin kendisine odaklanırlar. Yirmi beş katılımcı, mouse, Microsoft Kinect V2 ve göz takip cihazı olmak üzere, üç farklı insan-bilgisayar etkileşim yöntemini, aynı görevde kullanarak çalışmaya katılmıştır. Ayrıca her katılımcı hedef yönelimini ve görev bağlılığını ölçen iki ölçeği cevaplamıştır. Bulgular farklı insan bilgisayar etkileşim yöntemlerinin görev tamamlama sürelerini değiştirdiğini göstermektedir. Bu zamansal fark, yapılan analizlerde insan ve bilgisayar etkileşiminin verimini gösteren bir faktör olarak kullanıldığında; sonuçlar kişilerin hedef yönelimlerinin, görev bağlılıklarının ve insan bilgisayar etkileşim yöntemlerinin bir etkileşim içerisinde olduğunu göstermektedir.

Anahtar kelimeler: Hedef yönelimi, göreve bağlanma, insan-bilgisayar etkileşim yöntemleri, eye tracker, Microsoft Kinect V2.

*TO MY DEAR WIFE AND BROTHER*

*FOR THEIR TRUST AND CONTINUED SUPPORT*

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| Abbreviation | Meaning |
|---|---|
| LO | Learning Oriented |
| PO | Performance Oriented |
| UEs | User Engagement Scale |
| V2 | Version 2 |
| HCI | Human Computer Interaction |
| AS | Application State |
| MN | Modality Name |
| TN | Trial Number |
| TAT | Target Appearance Time |
| COS | Cursor Out of Start Point |
| CET | Cursor Enter the Target |
| TH | Target Hit |
| MOC | Movement time of Cursor |
| TLT | Target life Time |
| CP | Cursor Position |
| TP | Target Position |
| TS | Target Size |

# CHAPTER 1

# INTRODUCTION

In this chapter, objectives and the scope of this thesis are presented. A brief outline and related studies are introduced to prepare a basis for the broader literature.

## 1.1 The Objectives and Scope of the Study

Interface between human and computer is considered as a border between physical world and virtual environment. This border is designed for reducing the complexity of the virtual environment. There are numbers of different types of interfaces such as command line interface, natural language, query dialog, point and click (Dix, Finlay, Abowd & Beale, 2005). These interfaces differ in their complexity and any of them needs at least one interaction modality. For instance, a command line interface needs a keyboard and usage of keyboard relatively easy that any literate person can intuitively understand the usage of the keyboard. However, efficiency of the interaction is highly related to users' keyboard experiences. In the given example above, usage complexity of the modality is another concern for efficiency of interaction between human and computer. Therefore, interdisciplinary studies attach importance to develop intuitively understandable input-output devices (Wachsmuth & Flöchlich, 1998).

In the relation of human and computer, humans are active processors that interact with the virtual environment via three subsystems: perceptual sensory, motor system and cognitive system (Card, Moran & Newell 1983). Comprehension of these three subsystems is particularly important for creating better interaction modalities. Typical computer systems consist of at least two different inputs and one output device namely, screen, mouse and keyboard. Using multimodal interactions in a single application is common approach to increase efficiency of the interaction between human and computer (Dix et al., 2005). Moreover, there are number of sophisticated devices (Agathya, Brilliant, Akbar & Supadmini, 2015; Freman & Balakrishnan, 2016; Fallon, Kuindersma, Karumanchi, Antone, Schneider, Dai & Koolen, 2015) that are designed for maintaining better interaction between human and computer. Collecting and providing richer information are the main characteristics of these sophisticated devices.

There are mainly two different classes of interaction modalities between human and computer. Verbal modalities support language base interaction, whereas non-verbal modalities consider the physical properties of the user. For instance, keyboard and speech recognizer are well-known text entry devices that language provides a base for the interaction between human and computer. These devices can be listed under verbal interaction modalities. On the other hand, non-verbal modalities collect users' physical information such as, limbs position, visual appearance, heartbeat, body temperature and so on. However, using more than one perceptual channel or collecting as many as information about the user is not guaranteed an efficient interaction. Since the modality of interaction is an input or an output device, the interface between human and computer should be convenient with the modality of interaction. For instance, using a keyboard is not a proper input device for point and click interface. Point and click interface is probably the most frequently used interface style. Basically, user can point a word or a location or a button on the screen and can click it (Dix et al., 2005). Using a keyboard for a point and click interface will be inconvenient for some task, even it is impossible use for a task such as pointing a specific screen location.

Interacting with virtual environment via verbal or non-verbal interaction modalities probably has its own pros and cons. However, investigating these interaction modalities' limitation and understanding their reciprocal relation with users are key steps for developing novel interaction methods and devices.

There may be number of different effective factors related to interaction between human and computer. Nevertheless, probably another key step for designing efficient interaction modalities is to understand users' experiences. As mentioned earlier, human is the active part of the interaction. Therefore, users' characteristics and their personal preferences should be considered (IJsselsteijn, De Kort, Poels, Jurgelionis & Bellotti, 2007; Benford, Giannachi, Koleva & Rodden, 2009; Bernhaupt, Ijsselsteijn, Mueller, Tscheligi & Wixon, 2008). Since experience of the user is a determinative factor, probably the task engagement is a useful predictor for understanding of how users perceive the efficiency of the modality of interaction.

As objectives of the study, an application is developed for supporting different interaction devices namely eye tracker, mouse and Kinect V2. A logging mechanism is created to observe time period of kinematic behavior of participants. An adopted goal orientation scale applied to the participants. And finally, a user engagement scale adopted and translated to Turkish and applied to the participants.

## 1.2 Purpose of the Study

The aim of the study is to investigate effect of interaction effect of users' characteristics and three different interaction modalities on users' task engagement. In detail, mouse, eye tracker and Kinect V2 are used to investigate how these different interaction modalities differ users' experiences. In order to understand users' experiences, their task engagements are measured after each modality and compared to understand how these different types of modality effect their engagement to the task. Additionally, goal orientation of the users' also considered as an effective factor. Therefore, the relation between goal orientation and engagement of users' are investigated. Lastly, movement time for point task has been analyzed for different type of modalities. And these timing scores are compared to understand whether they have different time pattern or not.

To sum up, task completion time score of the participants are going to present the modality efficiency. Recall that some of modalities are far better for certain interfaces. For instance mouse is a perfect device to manipulate point and click interface whereas keyboard is even far from being useful. Therefore, there are different time trend with respect to modalities. So that since goal orientation is an effective factor for the motivation, people who have performance-oriented goal orientation, are engaged more if the modality provide relatively easier task completion time. On the other hand, people who have learning-oriented goal orientation are engaged more if the modality provides an interaction that they can improve their skill.

In the Chapter 2, mentioned concepts and theories and modalities and their relevant literature are presented. And finally, in the Chapter 3, detailed explanation of theoretical integration is explained.

## 1.3 Thesis Outline

This thesis composed of five chapters. The second chapter presents relevant literature. The third chapter includes theoretical framework of the thesis and presents the research questions and motivation of the thesis. At the fourth chapter developed application, procedure of the conducted experiment, used questionnaires and the description of the relevant logs have been reported. In chapter five, findings of the study are presented. And finally, discussion of the outcome, possible future works and limitations of the study are presented.

CHAPTER 2

## LITRATURE REVIEW OF RELATED RESEARCH

In this chapter, related research and theories are presented to prepare a theoretical framework of the present study. In the first section, modalities are presented and some of modalities related to the study are given in detail. In the second section, human part of the interaction between human and computer and related factors are presented. In the summary section, a brief explanation of the integration of presented modalities and human related factors are explained.

### 2.1 Modality in Human-Computer Interaction

In every computerized task, users must use a device for interacting with the virtual world. These devices between human and computer have profound effect on efficiency of the interaction (Dix, et al., 2004). Therefore, developing new devices and increasing the efficiency of the interaction between human and computer is a hot topic in multidisciplinary areas. As mentioned in Chapter 1, collecting and processing verbal or non-verbal information of users are possible ways to maintain an interaction between human and computer. Although the primary communication medium is language for human, without non-verbal communication it is not completed. Non-verbal communication conveys the unspoken message (Matsumoto, Frank, & Hwang, 2012) via body language (Fast, 1988). In the given definition above, words “body language” and “communication” may misdirect the reader. It is important to note that, non-verbal interaction does not only need to convey semantic meaning but also can consist different properties of users such as spatial, emotional, physical information. On the other hand, verbal modalities are only language dependent and all possible inputs coded via verbal interaction modalities such as keyboard, speech recognizer etc.

#### *2.1.1 Verbal Modalities*

Language is one of the symbol systems that humans use to transfer message while they communicate. These symbols transferred with signals, which are semantically meaningful. Since displacement property of language provides a way to transfer the message in space and time, this property distinguishes language from other communication modalities (Krauss, 2002). Therefore, using language dependent mediums for representing stored or real-time information on computer is the best and most useful modality while users communicate with computers. As general approach, verbal modalities converge on text entry method. In this method all types of incoming signals provided by modality, are converted to textual information. For instance, in Figure 1 a speech recognition system diagram and the conversion of the incoming input can be seen. Therefore, text entry method is the most fundamental element of the verbal modalities. Some of well-known text entry devices are keyboard, speech recognizer and handwriting modalities that are probably the most representative devices of verbal modalities.

*Keyboard*

The very common component of computer is a keyboard, which is used for communication via textual data. Users communicate with computer by a key pressing that causes a character code to signal to the computer.

*Handwriting*

Handwriting is a usual activity for literate people. Rather than using keyboard, using handwriting seems more natural as a text entry method. Basically, handwriting of the users are taken as an input and converted into textual entry (Dix, et al., 2005). This method is used for large document analysis, which consists handwriting. The first step of the handwriting system is to analyze document as a digital image and segmentation of this image into smaller pieces. Then the next step is identification of the segmented data as textual entry. If the modality is pen-based then the system needs an additional component such as camera, scanner, which is used for analyzing the trajectory of the handwriting. (Fink & Plötz, 2102)

*Speech Recognition*

Speech recognition is a general model, which is used for recognizing the speech signal. The system decodes the speech into a smaller segment such as words that are consistent by the syntactic, semantic and pragmatics of the recognized language. Although there are number of studies that are trying to develop a successful speech recognition system, (Chorowski, Bahdanau, Serdyuk, Cho & Bengio, 2015; Sak, Senior, Rao, & Beaufays, 2015) but these systems are still far from the desired level of speech recognition. Indeed speech recognizer works well but the desired level corresponds to perfect speech recognition where the capacity of the system should lead people to use speech recognizer rather than a keybord.

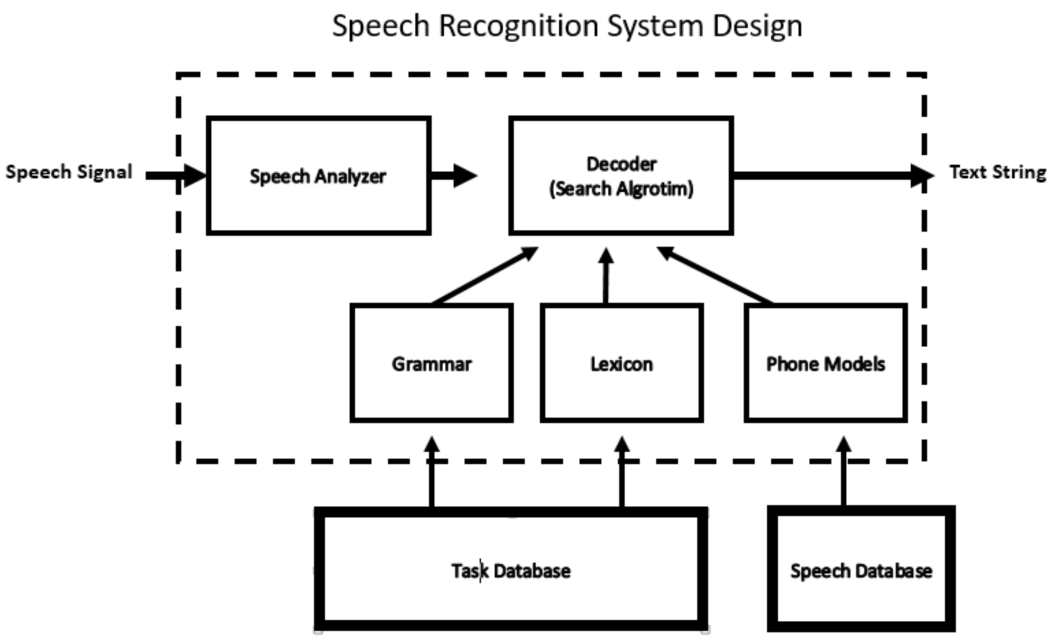



Figure 1. Speech Recognizer Diagram (Adopted form, Ehsani & Knodt, 1998)

### *2.1.2 Non-Verbal Modalities*

In the last decade, the tendency of the human computer interaction approaches changed its direction towards multi modal interaction in a single application such as collecting and providing text, graphic, auditory and gestures which provide a more natural interaction (De Queiroz, Fechine, Barbosa & Ferreira 2009). Except text, which is a verbal modality, auditory and graphic information can be used as a verbal or non-verbal modality. For instance, a sound may represent a word or it may represent a noise in interaction between human and computer. Additionally, graphic information can consist textual information or any other visual information that is not related to language. Furthermore, as mentioned in Chapter 1, there are a number of different information that can be defined as non-verbal information such as facial expression, hearth rate, body temperature and so on. Nevertheless, gesture is a non-verbal modality, which is actually processed a set of spatial positions of the body parts of the user. Gestures are claimed as essential in human-computer interaction (Biswas & Basu, 2011). In the scope of present study, as non-verbal communication modality, gestures are used to manipulate virtual environment.

Gestures are non-verbal communicative behaviors that convey information in communication. They are spontaneous, unintentional behavior, which accompany the speech of a person. (McNeill, 2008) In HCI, non-verbal information can be separated into three subcomponents: touch, facial expressions and postures. In the social context, collection of subgroups may extend with the touch, sounds, silence, smell and taste (Calero, 2005). On the other hand, posture related gestures could be classified into five different types: gesticulation, emblems, speech-linked, pantomime and signs. Gesticulations are relatable motions that take place with the speech. Emblems are conventionalized specific posture of arm, hand, finger or any other part of body such as the sign of OK. Speech-like gestures occur as a part of speech such as saying, “the bird was flying“, and simultaneously showing a hand movement as it’s flying. Pantomime is a sequence of gestures that are not a part of speech; rather they are a gesture show that occurs without speech. Signs are different than any other gestures that are lexical words and these gestures have their own linguistic structure, which makes these gestures a language. (McNeill, 2008) Nevertheless, this study particularly focuses on gestures that can be used as an information source for a modality of interaction. Particularly an emblem namely *pointing* is used within the study. Therefore, understanding of pointing gesture is important within the study.

#### *Pointing*

Kita (2003) mentioned about the pointing gestures as communicative movement that illustrates a vector from a body. This is a certain direction that can indicate a direction, location or a specific object. It is a building block of human communication. In particular, pointing is a unique behavior that separates humans from other species. Pointing is a primordial in human ontogenesis. It is used as sophisticated communicative device. (Kita, 2003) For instance, an infants’ first spoken word is generally supported with a pointing gesture (Goldin-Meadow & Butcher, 2003). Therefore, pointing is a natural behavior that humans are competent to use. Since pointing is a gesture that humans are competent to use, designing a device, which maps this particular behavior into virtual environment, probably provides the most efficient interaction between human and computer. However, as mentioned in Chapter 1, the modality of interaction and the interface between human and computer must be convenient. For example, a DOS screen cannot manipulate with the pointing modality. Current computer systems have an ability to point and manipulate any location on screen. Literally, this ability is named as point and click interface. And by the help of a pointing modality, point and click interface can be manipulated as pointing and selecting any location on the screen (Dix, et al., 2005). There are several devices that are used for transferring the pointing behavior into the virtual environment such as touch pad, track ball and so on. In the following section you can find some of these devices that are particularly related to present study.

*Mouse*

The mouse is the most frequently used input device in human-computer interaction. It provides a way of interaction that user can accomplish several tasks such as pointing, dragging, dropping and selecting. Mouse was developed by SRI and used in a modality comparison research in 1967. The first generation was developed as mechanical device that consists two potentiometers and a differential analyzer (English, Engelbart & Berman 1967).

After several years, a ball took the place of these potentiometers; and finally, current generation mouse uses a light rather than a ball and a light detector chip for converting the analog movement to digital signals. It is a small box that transfers the positional changes of the user's hand to a pointer on the screen (Dix, et al., 2005). Note that the posture of the hand, while users manipulating the virtual environment with mouse, is similar as the pointing gesture of a hand in real world. The first mouse can be seen in Figure 2.

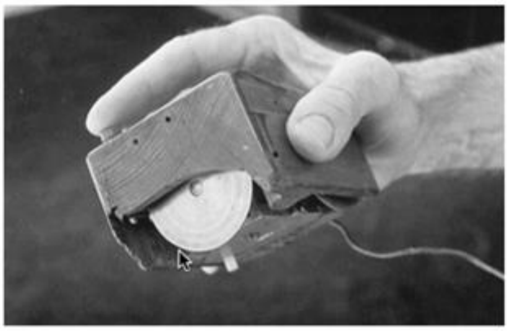


Figure 2. The First Mouse

*Gaze*

Visual exploration is a continuous event that may be the most informative sensory input of the cognition. Therefore, inevitably visual system becomes the most dominative perceptual components of cognition. It is obvious that eye movements almost do not require any effort to attend any point in the environment. And for sure, it is impossible to see any random movements with respect to eyes. In the literature, both normal and abnormal eye movements are studied by number of researchers for many years (Sibert & Jacob, 2000). There are mainly five categories for measuring the eye movements.  These categories are Electro-OculoGraphy, scleral contact lenses, Photo-OculoGraphy, Video OculoGraphy and video based pupil corneal reflection integration. Currently, using corneal reflection method is a popular technique. This technique simply calculates the position of eye by using the pupil center and corneal reflection. These two reference points and their relative position remain constant if the movement sourced by head; however, their relative positions change if the movements are sourced by eyes. Center of the pupil and corneal reflection namely Purkinje, are generally created using infrared light source that is located at a stable position relative to eye. Due to the source of the infrared is stable, the Purkinje is stable and the pupil can rotate because of the eye movement their relative position can be calculated.

Using an eye tracker, as a pointing device is relatively novel technique that basically provides a way to manipulate screen location by looking at it (Stellmach & Dachselt, 2012). It is a useful and very fast pointing device; Researchers are interested in the usage of eye trackers as advanced user interface (Zhai, Morimoto & Ihde 1999; Hutchinson, White, Martin, Reichert & Frey, 1989; Tecce, Gips, Olivieri, Pok & Consiglio, 1998; Hansen, Andersen & Roed 1995; Kaufman, Bandopadhay & Shaviv, 1993; Jacob & Karn, 2002). However, it is not proper to use for drawing task that eye does not smoothly move in a line. Using gaze is particularly important for disabled people who cannot move their hands and for a particular task in which using hands is not possible behavior.

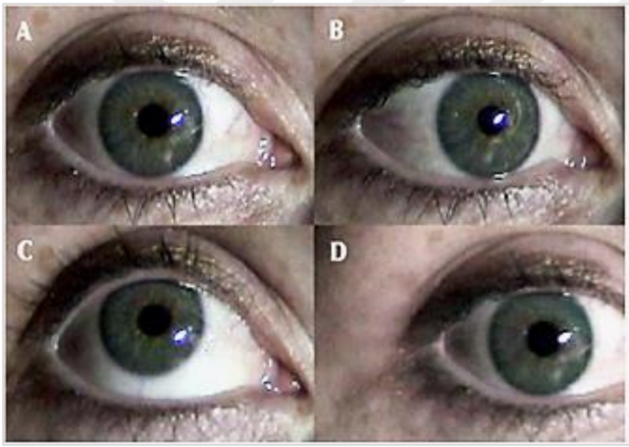



Figure 3. Pupil and Purkinje (Richardson & Spivey, 2004)

*Kinect*

As another modality, Kinect V2 used in the study. Kinect is a sensor that is developed by Microsoft that provides information about tracked user's body limbs position in three-dimensional coordinate system. Simply, Kinect emits an infrared point clouds and tracking these points cloud by an infrared camera. And processing received image of the infrared clouds' shape and brightness then decides about the depth information. In this study, Kinect V2 was used to collect different joints' coordinates of tracked body. Nevertheless, not all of body's joints have been used for the analysis. Only the right hand tip has been used to manipulate the cursor of the application. Considering as a pointing device Kinect needs more effort than eye trackers and mouse that the participants need to move their several limbs to point any location in the virtual environment.

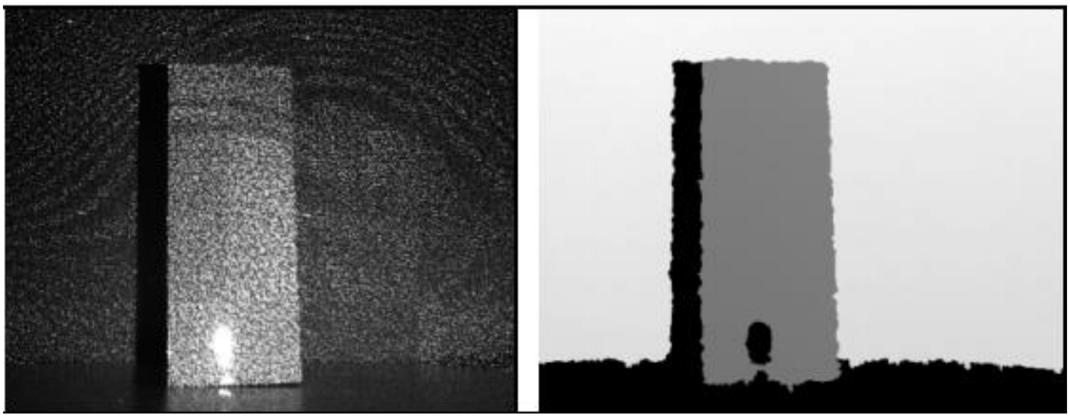


Figure 4. An example of Kinect V2 Points Cloud and the Resulting Depth Image (Khoshelham, 2011).

## 2.2 Human in Human Computer Interaction

Since the modalities are the main topic of the Human-Computer Interaction (HCI) research field, inevitably rather than Cognitive Science literature thesis covers number of HCI studies. However, human part of the topic belongs to Cognitive Science and following quotation from Dix et al. (1993) may summarize the issue.

> "The ideal designer of an interactive system would have expertise in a range of topics: psychology and cognitive science to give her knowledge of the user's perceptual, cognitive and problem-solving skills; ergonomics for the user's physical capabilities; sociology to help her understand the wider context of the interaction; computer science and engineering to be able to build the necessary technology; business to be able to market it; graphic design to produce an effective interface presentation; technical writing to produce the manuals; and so it goes on." (Dix et al., 2005)

The conjunction of HCI and Cognitive Science is human that HCI need cognitive science for understanding the user. Broadly, the user perceives, uses, decides, and manipulates information that all are related to domain of cognitive science (Boring, 2002). Comprehension of the user gives a chance to predict and explain the interaction between user and computer. Therefore, the rest of the Chapter consists human related factors that are possibly effective in efficiency of interaction between human and computer.

### *2.2.1 Task Difficulty and Motivation*

Motivation literature provides a base for understanding engagement behavior of the users. The definition of the users' engagement was given by Q'Brein (2010) that users' engagement is some of particular motivational behaviors. Therefore, providing a broad content of the motivation literature would be proper to begin behavioral part of the study.

"Why" is a popular question about human behavior that we frequently try to answer. For instance, "why does a person behave in a particular way?" from the Cognitive Science perspective, we try to understand the decision of a person who concentrated on a continuous process. The answer of a "why" can be given within the field of motivation (Deci, 1975). In order to improve effort of a person, there are five main motivators that intrinsically satisfy the person to improve his or her performance (Hackman & Oldham, 1976). According to Herzberg's hygiene theory (1966), these motivators enhance the satisfaction and motivation of the person if the motivators consisted by the work. These five motivators are recognition, achievement, responsibility, advancement and personal growth. The review of Fulmer and Frijters (2009) will be useful to see the long run of the measurement of motivation.

Brehm and Self reported (1998) that motivational intensity increases with increasing difficulty of instrumental behavior. It is also reported in the same study that motivational arousal drops when task requirement overrun the individual skills and abilities. There exist several papers claiming about the factors, which have effect on the relationship between difficulty of the task and the motivation. (Shunk, 1983; Capa, Audiffren, 2008; Nicholls, 1984) There is a glaring cut off point between a task difficulty and the motivation of the user. From the learners' perspective, it was reported that learners get bored if challenge of the task is too simple or too hard (Wang, 2007). Therefore, task must be designed under consideration of this cut off point (Brehem & Self, 1998).

There are several other factors related to motivation. One of the frequently studied factor is, a person's goal orientation, which is highly influential on motivation. Dweck studied goal orientation in 1986. However, the early goal orientation studies were applied to children. Although subjects of the studies were children, there are number of studies that findings on children can be extended to adults (Colquitt & Simmering, 1998).

According to findings of the goal orientation studies, there are mainly two types of orientation: performance and learning orientation. These two different types of oriented individuals show differences with respect to their motivational behaviour (Steele-Johnson, Beauregard, Hoover & Schmidt, 2000). Related studies indicate that performance oriented children focus on their ability level, whereas learning oriented children focus on their mastery and progress about the task. For instance, if a person has a learning oriented personality then the person will have a tendency to show mastery oriented behavioral pattern. (Dweck & Leggett, 1988). In Table 1, you can see the behavioral pattern of different goal orientations. In this context, behavior of any person falls into one of three different patterns that can be seen in Table 1.

Table 1. Behavioural pattern of different goal orientation (Dweck & Leggett, 1988)

| **Theory of Intelligence** | **Goal Orientation** | **Perceived Present Ability** | **Behavioral Pattern** |
|---|---|---|---|
| Entity<br>Fixed Intelligence | Performance (Goal is to gain positive judgments/ avoiding negative judgments of competence) | High | Mastery Oriented<br>(Seek challenge; high persistence) |
| | | Low | Helpless<br>(Avoid challenge; low persistence) |

| | | | |
|---|---|---|---|
| Incremental<br>Intelligence is malleable | Learning<br>(Goal is to increase competence) | High or Low | Mastery Oriented<br>(Seek challenge that fosters learning; high persistence) |

*2.2.2 How to Measure User Engagement*

User engagement is a popular concept in especially user-centered web application. It represents the efficiency of the interaction (Attfield, Kazai, Lalmas & Piwowarski, 2011). User Engagement Scale (UEs) was developed by O'Brien (2010) to understand the online shopping experiences of users. In detail it is developed for understanding the implications of the hedonic and utilitarian motivation on user engagement. After numbers of severe shooting experiences in America's schools, attention emerged to the violent video games. The shooters were students and most of them were playing violent video games. As a result it was proposed that there are number of reasons to concern about being subject of violent video games (Anderson, 2000). As consequences of mentioned unfortunate situations, game related impacts and factors are taken under the spotlight. User Engagement Questionnaire is a tool that measures the engagement of participants after exposition of a video game (Wiebe, Lamb & Sharek, 2014). It was derived from the O'Brein's User Engagement Scale. The derived scale (see Appendix B) has 28 different items that measure six different sub scales, these are:

- Focused attention,
- Felt involvement,
- Aesthetic,
- Novelty,
- Endurability,
- Perceived usability.

These six subscales represent four different factors:

- Focused attention,
- Felt involvement,
- Aesthetic,
- Satisfaction.

The subscales novelty, endurability and perceived usability covered by the satisfaction factor. Reliability analysis of both original and derived form of UEs has found that Cronbach's alpha values are between .88 and .89 for reliability. And validity analysis of derived user engagement scale has found general strength.

Note that, original User Engagement Scale (Wiebe et al., 2014) translated into Turkish and adopted for interaction modality. The original scale of Wiebe and his friends was designed the scale to measure online game engagement of users. However, website related questions derived for the modality of interaction. Than another master student whose background is English Literature, examined the adaptation. Additionally, adaptation also examined by the supervisor of the study. In A and Appendix B you can see both original and adopted scales.

*2.2.3 How to Measure Goal Orientation*

Especially in educational environments, goal orientation accepted as strong predictor for performance (Dweck, 1991). Mainly three types of orientation can be classified as performance oriented or learning oriented or performance avoidance (Dweck, 1986). In short, performance oriented person evaluates his or her performance among others and avoid from any task if failure is an option and also if person thinks if he or she perceived that he or she has this ability than the person show mastery oriented behavior (Steele-Johnson et. all, 2000). Contrary to performance orientation, learning oriented person sees any competence as a possible improvement event (Dweck, 1986). Since goal orientation is directly related to performance of a person, understanding the goal orientation of employees in a work environment provides a way to understand employees' behaviors and interests (Vanderwalle, 1997). The goal orientation scale of Vanderwalle was developed for specifically work environment to assess goal orientation of the employees. Vanderwalle reported that the reliability scores of the instrument prove that it is a consistent and stable instrument. The Cronbach's alpha is ranged from .85 to .89. Moreover, validity of the scale is very consistent for the hypothesized relationship that is found as a discriminative tool for assessing goal orientation of a person (1997). Vanderwalle's questionnaire has been used in the study of Tayfur (2006) that the internal consistency of the Turkish adaptation has been found as .85, .75, .71 for learning goal, performance prove, and performance avoidance respectively. Translation of the scale done by a graduate student and Tayfur independently, and a psychology student also evaluate these two translated versions. However, Vanderwalle's instrument had been used in Tayfur's study with 5-point Likert type scale (1= Strongly Disagree, 2 = Disagree, 3= Neither Agree nor Disagree, 4= Agree, 5= Strongly Agree). See Appendix C for adopted goal orientation scale.

## 2.3 Summary

As mentioned at the beginning of this chapter, interaction modality is a key concept in HCI. Efficiency of interaction devices differ the quality of the interaction between human and computer. As a main perspective, researchers in HCI try to develop more intuitive devices, which reduce the need of users' skill. For example, using a mouse in 3D virtual environment is highly problematic whereas using a haptic device is a better option to map users hand movements into virtual environment.

In this Chapter an eye tracker presented as an alternative pointing device. The eye tracker may be the most proper example for indicating why the main tendency in HCI tries to make interaction more intuitive. Simply, using an eye tracker on computer does not require any effort and skill to accomplish pointing task that people accomplish the task as how they use their eyes in their daily life. Since the mouse is the most frequently used interaction modality in current computer system, probably the mouse is the most proper device to compare novel devices for especially point and click task. Microsoft Kinect V2 is relatively novel device that currently popular as non-verbal interaction modality.

Understanding users' behavior and analyzing their interaction are also two main questions to increase efficiency of the interaction between human and computer. Inevitably, since interaction between human and computer is a subjective experience, self-report measurement tools are designed to evaluate users' experience. The User Engagement Scale provides a quantitative scale for understanding task engagement of the user. In the context of human-computer interaction, human is the central point of the relation. Note that human is an active agent in this reciprocal relation. Since the dynamic part of the interaction is human, understanding its characteristics is a vital issue. Goal Orientation Scale is a measurement tool that supports categorical information about the people's goal orientation. Understanding users' engagement under consideration of goal orientation types may alternate the understanding of efficiency about modality of interaction.

In the end, integration of user engagement scores, goal types and modalities' efficiency can be an informative experiment to understand how interaction modalities have an effect on people's engagement. Furthermore, it may provide a way to understand, does person's goal orientation type has an effect on his or her engagement with respect to different interaction modalities?

# CHAPTER 3

# RESEARCH QUESTIONS AND PREDICTIONS

In this chapter, research questions of the thesis are attempted to be justified with a consistent theoretical framework. In order to reduce the complexity of this chapter, research questions are presented in two different parts. The following section consists four research questions. The first and the second questions are related to technical measurements and interaction modalities. And the third and fourth section presents human related research questions, which are appraisal of participants.

As mentioned at the previous chapters, there is a relationship between motivation and task difficulty. If a task is too easy then people show lower motivational behavior towards the task. On the other hand, if a task needs higher capacity than a person's skill then the motivation also drops (Brehem & Self, 1998). One of the motivation related factors is the goal orientation where different orientations lead people to behave differently. For example, since learning oriented people consider every competence as a source of mastery, hard tasks may not drop their motivation; however, difference between the required skills and having skill should be not enormous. Contrary to learning oriented person, performance oriented person may not show motivational drop for the easy task. As mentioned earlier, this type of goal orientation only concerns their skills (Steele-Johnson et al., 2000).

User engagement questionnaire (O'Brien, 2010) was designed for understanding hedonistic and utilitarian motivation of user engagement in online shopping. In this study a derived form of the User Engagement Scale was used which is specially adopted for understanding of engagement of video-game players (Wiebe et al., 2014). In this sense, measuring the user engagement while they interact with the application of this study and identifying their goal orientation is an important integration.

In short, modalities, goal orientation and task difficulty defined as independent variable of the study. Moreover, user engagement and time scores of the participants defined as dependent variables.

As an independent variable task difficulty has five different levels, which are different distances between start and the target location on the screen. Beside, goal orientation has two different types, which are learning and performance oriented. Furthermore, three different modalities were used as three levels independent variables.

First of all, it is expected to observe the main effect of the modalities of interaction that different modalities should differ the efficiency of the interaction between the user and the task.

*Research Question 1: How do different modalities of interaction result in different task accomplishment times?*

The answer of "how" related to first research question is probably sourced by the different kinematic requirements of the experimented interaction modalities. Therefore, it is proper to ask the second research question about these kinematic requirements.

*Research Question 2: How different interaction modalities exhibit different time-distance relationship.*

As mentioned in earlier chapters, there is a relationship between motivation and the task difficulty. And engagement defined as a motivational behavior. In this study, although efficiency is a wider concept, the completion time of the task, assumed as a determinative factor for the efficiency of the interaction. It means, that the more efficient interaction result with the faster task completion. This assumption at least provides a comparable different modality metrics for the study. And, probably it is expected to observe this efficiency difference on users' engagements. Therefore, participants' engagement scores are expected to be different with respect to modalities of interaction.

*Research Question 3: How user engagement results in task efficiency differences among different modalities.*

Since the goal orientation of a person is an effective factor for the person's motivational behavior, probably their engagement scores altered by the persons' goal orientation type. Additionally, recall that the modalities have different kinematic requirements and it result with different task accomplishment time with respect to modalities. Since time scores of the participants is an indicative for level of difficulty, performance oriented person's engagement scores are expected to find relatively higher for faster modality than the slow modality. Additionally, learning oriented person's engagement scores are expected to be relatively higher for slow modality than the fast modality.

*Research Question 4: How efficiency of the interaction modality differs the engagement scores of the participants with respect to their goal orientation.*

In the Method, Data and Analysis chapter, all mentioned variables are presented in detail. Moreover, you can find the answer of how these variables operationally defined and collected from the participants.

# CHAPTER 4

# EXPERIMENTAL STUDY: METHOD, DATA & ANALYSIS

In this chapter, designed application, experimental flow, devices, recorded logs and special conditions are presented.

## 4.1 Participants

25 subjects participated to conducted experiment from Middle East Technical University and Atılım University. 3 of the participants were employees of the Informatics Institute and the rest of them were students. All of the subjects had no glasses or contact lenses. Their ages ranged from 20 to 42 and 5 of them were male and 20 of them were female. Except one, the participants were right handed. Nevertheless, all participants used their right hand.

## 4.2 Materials

A standard desktop computer was used for presenting the environment of the experiment. Screen resolution of the computer was 1600 x 1200. Left-upper corner of the screen represents the first pixel of the resolution which can be represent as x =0, y=0 in terms of screen coordinates. And, the last pixel on the screen can be represented as x=1200, y = 1600 which corresponds to right-bottom corner of the screen. Three different modality devices were used. The first device was EyeTribe eye tracker used for collecting gaze locations of participants. A4Tech a desktop mouse was the second modality device. And the last device was Microsoft Kinect One that provides 3 dimensional locations of the participants' body parts. In the experiment, an application was developed using object oriented programming language C#. The developed application stands for moving the cursor with different types of modality. For the Kinect, only the right hand tip's joint was used for manipulating the cursor location. Note that 3D right hand tip's coordinate transformed into 2D screen coordinate with the coordinate mapper supported by Microsoft Kinect's SDK. For eye tracker, right eye's raw screen coordinate was used. And for the mouse, screen coordinate received from the System.Forms.Inputs library of C# resources. A chin rest was used for collecting eye movements' data. In Figure 4 set up of the experiment can be seen.

### 4.3 Procedure

Before the experiment, each subject filled the informed consent form, demographic information form and goal orientation scales. Except these three forms, experiment has three phases and each phase has its own practice session. In each phase users were exposed to 10 practice and 50 trial tasks with a particular modality. Moreover, given 50 trials were given in 5 different locations that each location has been presented 10 times. Modalities were given in all possible orders across the participants. After each phase participants filled the user engagement questionnaire. As a result, since all participants exposed to all modalities, design of the experiment can be summarized as 3 x 5 repeated measure design. You can see the experimental environment and setup in the Figure 7.

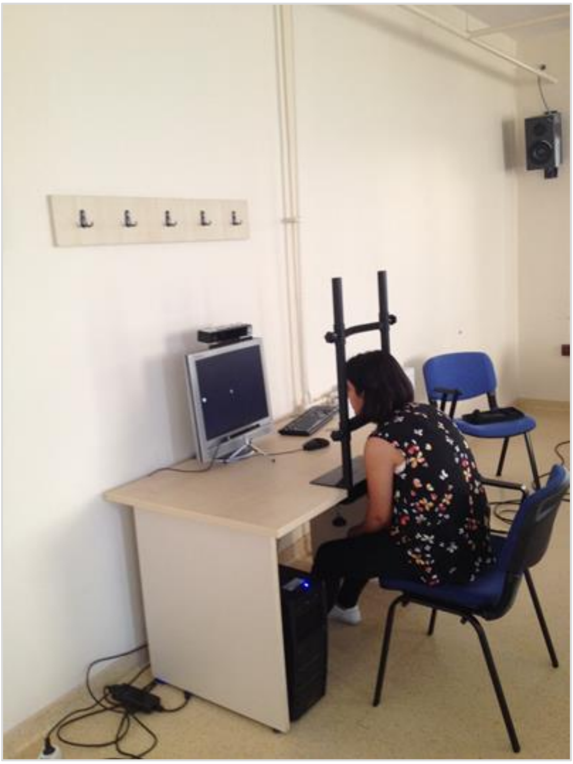


Figure 5. Experimental Setup

*4.3.1 Tasks*

The task is, simply moving the mouse cursor between two stimuli; these stimuli can be named as starting point and target point. At the beginning of the each phase participants exposed to a practice session. In the practice session 10 tasks have to be accomplished by the participants. In order to avoid the familiarization, location of targets assigned randomly. After the practice session, subjects were exposed to 50 trials to accomplish each phase.

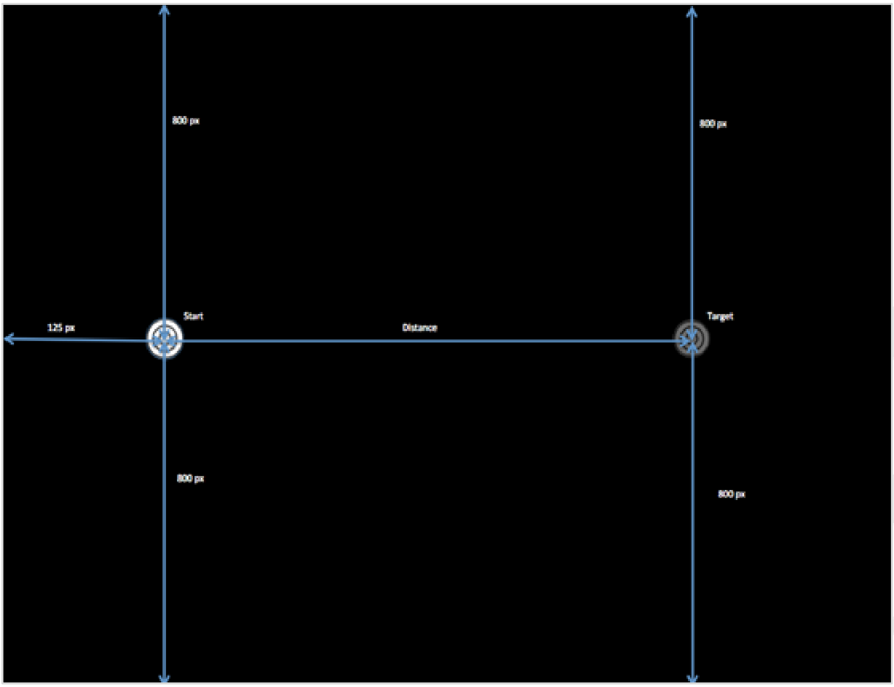



Figure 6. Task Interface and Locational Metrics of Start (left) and Target (right) Stimulant

*4.3.2 Stimuli*

Starting point is a white 50 pixels diameter bulls eye that positioned at the left middle of the screen which correspond to x=125, y=600 screen coordinates and its position is stationary for the entire experiment. The target is a gray bulls eye, which has 50 pixels diameter. And for the 50 trials, targets are appeared at 5 different randomly chosen horizontal coordinates that correspond to one of these x={500, 700, 900, 1100, 1300} coordinates. And vertical coordinates of the targets were y=600 and this coordinate was identical for all the targets. Note that all given metrics correspond to the center of the stimuli. In Figure 5 you can see the orientation of the stimuli and their appearances.

*4.3.3 Experimental Flow*

In detail, for each trial, participants have to locate the cursor on the starting point to trigger the target to appear. Then they need to locate the cursor on target to make it disappear. The former event named as triggering event and the latter called as hit event from now and then. There is no chance for trigger event for the new target before the triggered one is hit by the participants. Therefore, each trial has its own timing and they are in consecutive order. When the participants locate the cursor at the starting position, there are five different possible locations that target can be appeared.

*4.3.4 Procedural Restrictions*

In order to establish proper interaction and avoid unrelated behaviours of participants, some procedural adjustments were inevitable. In this section, detailed explanations of these adjustments are given.

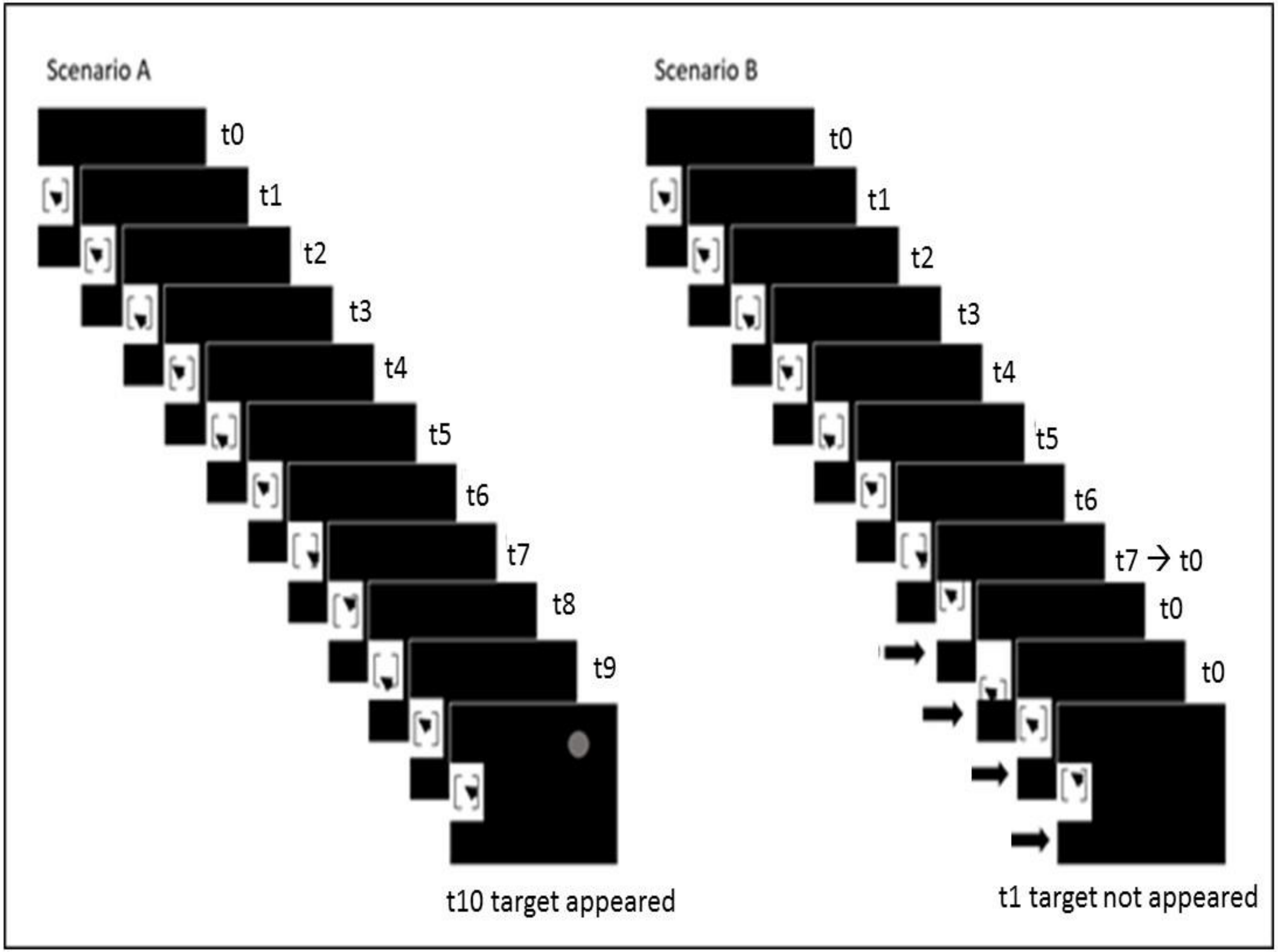
*Avoiding promiscuous movement*

Since the click event is problematic for eye tracker and Kinect, it was not used within the application. There are possibilities to create different types of click events for Kinect and eye tracker. Since processing time of these possible click events would be different, separation of this processing time from the movement time was not an option. However, without a click event, record of the task's log is also problematic such as, participants may accomplish the task unintentionally. For instance, participants' movements may be done for being close to the target but this movement may pass above the target unintentionally. In this scenario, this unintentional movement results with a wrong log. Therefore, instead of the click event, a conditional algorithm defined for simulating the click event.

*Click Simulation*

In each trial, for each triggering event the cursor must be in a 0.5 visual angle for 10 consecutive frames. Same conditional procedure applied for also the hit event where participants have to locate the cursor on the target in the range of a 0.5 visual angle for 10 consecutive frames.

Note that, for triggering event there may be no promiscuous movement but this procedure provides a chance to ignore preparation time of the subjects. In Figure 6 the mentioned conditions above given in time sequence that each t time represented as a screen frame.

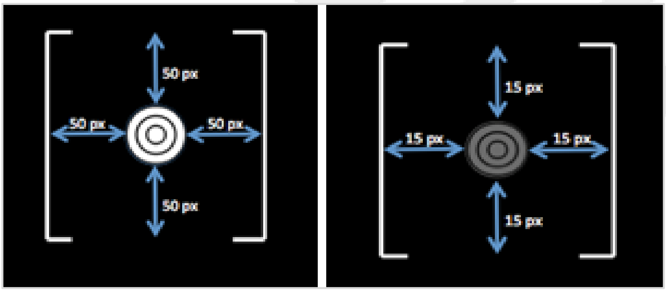

Scenario A
t0
t1
t2
t3
t4
t5
t6
t7
t8
t9
t10 target appeared
Scenario B
t0
t1
t2
t3
t4
t5
t6
t7 → t0
t0
t0
t1 target not appeared

In the Figure 9, scenario A is the successful triggering flow whereas scenario B is failed. In scenario A, you can see that the cursor remains in the border for 10 consecutive frames and note that at the frame t10 the target is appeared successfully. On the other hand, since consecutive 10 frames continuously searched for the triggering event, algorithm sets new boundary for each position if the cursor is out of the boundary. In scenario B, you can also see this failed triggering event, at t7 cursor failed to stay in the boundary, which is defined at next frame as t0. And at after the eighth frame, because of the violation of the previously defined boundary, new boundary and new frame's number is defined by the algorithm continuously.

*Stimuli boundaries*

In order to construct an equal distance between the target and the start locations, two different boundaries were defined for the start and the target stimuli. These boundaries are invisible and they have different values for the start and the target stimuli. The start stimuli's boundaries were located 50 pixels left, right, top and bottom of the start location. Moreover, the target stimuli's boundaries were located at 15 pixels left, right, top and bottom of the target stimuli. The time log recorded considering these boundaries, which provides consistent and equal distance for each trial across participants. In Figure 10, boundaries and stimuli are presented.

Figure 8. Illustration of Start (left) and Target (right) Stimuli And Metrics




*Eye movement assumption*

In terms of kinematic control, eyes are superior to other organs that their motions are precise and fine. Therefore, it can be assumed that there is no way to observe any promiscuous motion of eyes. Additionally, accuracy problem is problematic especially for the low cost eye trackers like the Eye Tribe eye tracker.. Therefore, in the light of these problems related to eye trackers, some special adjustments were necessary for the eye trackers modality but these adjustments were innocuous for the clearance of the data. There are two conditions different than Kinect and Mouse. These conditions are frame numbers and range of the cursor location, which is related to avoidance of promiscuous movement. The frame number reduced to 5 where for Kinect and Mouse this number was 10. And also the range increased to 25 pixels where for Kinect and mouse the range was 5 pixels. Due to the accuracy problem of eye tracker, triggering event and hit event was not possible with a small range such as 5 pixels. Recall that for mouse and the Kinect cursor must be in a 5 pixels range for 10 consecutive frames. There was no possibility for the eye trackers to locate cursor in the range of 5 pixels for 10 consecutive frames. However, when the target appears and when the subject moves their eye towards target it is obvious that eyes are on the target. Note that, since the time log was calculated and recorded with respect to two boundaries located around the start and target stimuli, these conditional differences are not harmful for the eye tracker data.

*4.3.5 Measures and Logging*

In the present study, logging mechanism of the developed application contains the following logs given in Table 2.

Table 2. Table of Logging Values

| Log Name | Type of Value | Description of Log | Log Abbreviation |
|---|---|---|---|
| Application State | String | It shows the state of the application. State can be two possible values that application can be in a practice or in an experiment state. | AS |
| Modality Name | String | This log stands for identification of the modality name. | MN |
| Trial Number | Integer | This log represents the number of stimuli. | TN |
| Target Appearance Time | Long | It shows system time when the target appeared. | TAT |
| Cursor Out of Start Point | Long | This log takes the record of system time point, when triggering event occurs and cursor out of the starting point boundary. | COS |
| Cursor Enter the Target | Long | This log takes the record of system time point, when the cursor passes through the boundary of target. | CET |
| Target Hit | Long | This log records the system time when the target hit by the participant. | TH |
| Movement time of Cursor | Long | This log is actually calculated by the subtraction of Cursor Out of Start and Cursor Enter the Target logs. | MOC |
| Target life Time | Long | This is the total lifetime of each target that the log represents the time period between the targets appeared and hit by the participants. | TLT |
| Cursor Position | Integer | This log indicates the screen coordinates of the cursor when the target hit by the participants. | CP |
| Target Position | Integer | This log shows the screen location of each hit target. | TP |
| Target Size | Integer | This log indicates the target size for the target that hit by participants | TS |

In the Table 2, all variables related to the developed application are given with their descriptions and abbreviations.

Movement time of the cursor (MOC) is the main output of the application. This log is used for evaluating the movement in time between the start and target stimuli. All other logs are taken for easier classification of the data.

### 4.4 Goal Orientation Assignment Procedure

Before reporting the findings of the study, it is important to explain assignment procedure of the goal orientation across participants. Recall that Goal Orientation Scale can differentiate three different goal orientation types that learning oriented, performance oriented and performance avoidance. For these three different goal orientation types there are three different groups of questions in the scale.

The first five questions are related to learning orientation. The next four questions are related to performance orientation and the last four questions are related to performance avoidance. Since the study considers learning and performance orientation, last four questions were not taken into account. Nevertheless, except two participants, the rest of the participants rate the learning orientation questions with higher scores than performance orientation questions. Therefore, in order to separate the sample into two different goal orientation types, the differences between learning oriented scores and performance-oriented scores are calculated for each participants. And simply, a median split is conducted to understand two different sides of the sample. In Table 3 you can see the sum of learning orientation, performance orientation scores and calculated scores and assignment of the participants.

# CHAPTER 5

# RESULTS

In this chapter, the findings of the study are reported. All analyses are conducted with open source statistic tool namely JASP 0.7.5.6 (JASP Team, 2016). In the following tables and results engagement scores of the subjects are given in 3 different variables namely, GAZE, KINECT and MOUSE. Goal orientation of the participants given as two types, LO for learning oriented, PO for performance oriented. The DISTANCE is another variable of the study that has five different levels. 500, 700, 900, 1100, and 1300 are the locations of the target stimulant; however, since the starting location is stable, they are five different distances that participants need to move the cursor horizontally. Moreover, in the following sections Post Hoc comparisons reported as pairs for the distances. For instance, a comparison between the location x=500 and x =700 given as pair (500,700). Finally, time scores are given in milliseconds.

This chapter has three sections. The first section consists analyses of goal orientation types of the participants. The second section includes the analysis of the *Research Question* 1 and *Research Question* 2. And the last section provides analyses of the *Research Question* 3 and *Research Question* 4.

## 5.1 Statistics for Goal Orientation Assignment

In the Table 3, and you can see the learning orientation, performance orientation and the calculated scores of the participants.

Table 3. Goal Orientation Scores, Calculated Scores and Assignments

| SUBJECT NO | LO | PO | CALCULATED SCORE | GOALORT |
|---|---|---|---|---|
| 1 | 20 | 13 | 7 | LO |

| | | | | |
|---|---|---|---|---|
| 2 | 21 | 16 | 5 | LO |
| 3 | 17 | 9 | 8 | LO |
| 4 | 19 | 13 | 6 | LO |
| 5 | 20 | 15 | 5 | LO |
| 6 | 19 | 20 | -1 | PO |
| 7 | 17 | 16 | 1 | PO |
| 8 | 19 | 19 | 0 | PO |
| 9 | 20 | 14 | 6 | LO |
| 10 | 17 | 11 | 6 | LO |
| 11 | 20 | 15 | 5 | LO |
| 12 | 19 | 15 | 4 | LO |
| 13 | 21 | 11 | 10 | LO |
| 14 | 18 | 15 | 3 | PO |
| 15 | 16 | 16 | 0 | PO |
| 16 | 21 | 18 | 3 | PO |
| 17 | 21 | 17 | 4 | LO |
| 18 | 16 | 18 | -2 | PO |
| 19 | 20 | 17 | 3 | PO |
| 20 | 17 | 17 | 0 | PO |
| 21 | 19 | 17 | 2 | PO |
| 22 | 20 | 20 | 0 | PO |
| 23 | 20 | 12 | 8 | LO |
| 24 | 19 | 18 | 1 | PO |
| 25 | 18 | 17 | 1 | PO |

In the Table 4, descriptive statistics of the calculated orientation scores are given.

Table 4. Descriptive Statistics for Calculated Scores

| **Descriptive Statistics** | |
|---|---|
| | **CALCULATED SCORE** |
| **Valid** | 25 |
| **Missing** | 0 |
| **Median** | 3.000 |
| **Std. Deviation** | 3.175 |
| **Minimum** | -2.000 |
| **Maximum** | 10.00 |

And also frequency table of calculated scores can be seen in the Table 5. Note that number of the learning oriented individuals and performance oriented individuals are almost same number.

Table 5. Frequency Table for Calculated Scores.

| Frequencies for CALCULATED SCORE | | | | |
|---|---|---|---|---|
| | **Frequency** | **Percent** | **Valid Percent** | **Cumulative Percent** |
| -2 | 1 | 4.0 | 4.0 | 4.0 |
| -1 | 1 | 4.0 | 4.0 | 8.0 |
| 0 | 4 | 16.0 | 16.0 | 24.0 |
| 1 | 3 | 12.0 | 12.0 | 36.0 |
| 2 | 1 | 4.0 | 4.0 | 40.0 |
| 3 | 3 | 12.0 | 12.0 | 52.0 |
| 4 | 2 | 8.0 | 8.0 | 60.0 |
| 5 | 3 | 12.0 | 12.0 | 72.0 |
| 6 | 3 | 12.0 | 12.0 | 84.0 |
| 7 | 1 | 4.0 | 4.0 | 88.0 |
| 8 | 2 | 8.0 | 8.0 | 96.0 |
| 10 | 1 | 4.0 | 4.0 | 100.0 |
| Total | 25 | 100.0 | 100.0 | |

Lastly, contingency table is given (see Table 6) for the distribution of the goal orientation. You can see that 12 of the participants are assigned as learning oriented (LO) and 13 of them assigned as performance oriented (PO).

Table 6. Contingency Table of the Participants Goal Orientation

| Contingency Tables | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **SBJNO** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **GOAL_ TYPE** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **Total** |
| LO | | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 12 |
| PO | | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 13 |
| Total | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 25 |

### 5.2 Analysis of *Research Question* 1 and *Research Question* 2

In Table 7, you can find the descriptive statistics of movement time of the different interaction modalities GAZE *( M = 95.47, SD = 43.13 )*, KINECT ( M = 1653, SD = 710.4 ), MOUSE *( M = 340.2, SD = 74.67 )*.

Table 7: Descriptives for Task Accomplishment Time for Different Devices

| Descriptive Statistics | | | |
|---|---|---|---|
| | **GAZE** | **KINECT** | **MOUSE** |
| **Valid** | 125 | 125 | 125 |
| **Missing** | 0 | 0 | 0 |
| **Mean** | 95.47 | 1653 | 340.2 |
| **Std. Deviation** | 43.13 | 710.4 | 74.67 |
| **Minimum** | 21.10 | 761.3 | 181.8 |
| **Maximum** | 235.2 | 3963 | 523.8 |

### *5.2.1 Analysis of Research Question 1*

In order to understand whether modality of interaction has an effect on task completion time, three different modalities' scores are assigned as repeated measure factors. According to repeated measure ANOVA analysis, the movement time is statistically significant *(F (2,8) = 1390.60, p < .001)*. Additionally, interaction of the distance and movement time is found as statistically significant *(F (2,8) = 45.10, p < .001)*. In table 8 related results are presented.

Table 8. Repeated Measure ANOVA Result for Movement Time and Distance

| Within Subjects Effects | | | | | |
|---|---|---|---|---|---|
| | **Sum of** | **df** | **Mean Square** | **F** | **p** |
| Movement Time of Modalities | 1.753e +8 [a] | 2 [a] | 8.766e +7 [a] | 1390.60 [a] | < .001 [a] |
| Residual | 1.513e +7 | 240 | 63037 | | |

*Note.* Type III Sum of Squares

[a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated (p < .05).

In Table 9, post hoc comparison using Tukey HSD indicated that gaze movement time (GAZE-MT) is statistically different than Kinect movement time (KINECT_MT) *(p < .001)*, and also gaze is different than mouse movement time (MOUSE_MT) *(p < .001)*. Additionally, Kinect movement time (KINECT_MT) is also statistically different than mouse movement time (MOUSE_MT) *(p < .001)*. These results show that the Research Question 1 is satisfied that different modality results with different task accomplishment times.

Table 9. Post Hoc Comparison for Different Interaction Modality

| Post Hoc Comparisons - Movement Time | | | | | |
|---|---|---|---|---|---|
| | | **Mean Difference** | **SE** | **t** | **$p_{tukey}$** |
| GAZE_MT | KINECT_MT | -1557.3 | 31.76 | -49.035 | < .001 |
| | MOUSE_MT | -244.7 | 31.76 | -7.706 | < .001 |
| KINECT_MT | MOUSE_MT | 1312.5 | 31.76 | 41.328 | < .001 |

In Figure 9, you can see the movement time trend of different modalities.

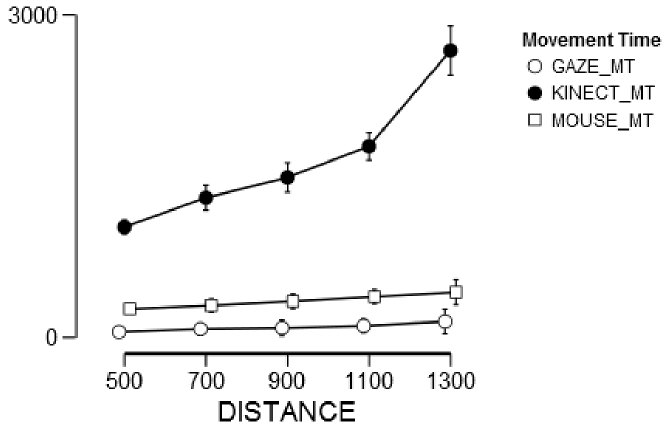



Figure 9. Descriptive Plot of Movement Time for Different Modalities

*5.2.2 Analysis of Research Question 2*

In order to understand whether any modality implies different time accomplishment time with respect to distance, repeated measure ANOVA was used for each modality accomplishment time.

*Kinect Time-Distance*

The first modality is Kinect you can see from the Table 10 that Kinect movement times are significantly different with respect to distance ($F(4,992)=92.756$, $p<.001$).

Table 10. Repeated Measure ANOVA Table for Movement Time of the Kinect with respect to Distance

| Within Subjects Effects | | | | | |
|---|---|---|---|---|---|
| | Sum of Squares | df | Mean Square | F | p |
| KINECT TIME | 4.411e +8 [a] | 4 [a] | 1.103e +8 [a] | 92.756 [a] | < .001 [a] |
| KINECT TIME * GOAL Type | 8.212e +6 [a] | 4 [a] | 2.053e +6 [a] | 1.727 [a] | 0.142 [a] |
| Residual | 1.179e +9 | 992 | 1.189e +6 | | |
| | | | | | |
| *Note.* Type III Sum of Squares | | | | | |
| [a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated (p < .05). | | | | | |

According Post Hoc comparison, almost all of the distance score significantly different than each other. In the Table 11 you can see the relavant Post Hoc comparison Tukey-HSD test result. Additionally, in the Figure 10, time difference can be seen that horizontal axis represents the distances and the vertical axis presents the time scores’ mean of the participants.

Table 11. Post Hoc Comparison for Gaze Movement time for different distance

| Post Hoc Comparisons - KINECT TIME | | | | | |
|---|---|---|---|---|---|
| | | **Mean Difference** | **SE** | **t** | **p tukey** |
| K500 | K700 | -369.8 | 97.60 | -3.789 | 0.002 |
| | K900 | -489.2 | 97.60 | -5.012 | < .001 |
| | K1100 | -799.8 | 97.60 | -8.195 | < .001 |
| | K1300 | -1756.1 | 97.60 | -17.992 | < .001 |
| K700 | K900 | -119.3 | 97.60 | -1.223 | 0.738 |
| | K1100 | -430.0 | 97.60 | -4.406 | < .001 |
| | K1300 | -1386.2 | 97.60 | -14.203 | < .001 |
| K900 | K1100 | -310.7 | 97.60 | -3.183 | 0.013 |
| | K1300 | -1266.9 | 97.60 | -12.980 | < .001 |
| K1100 | K1300 | -956.2 | 97.60 | -9.797 | < .001 |

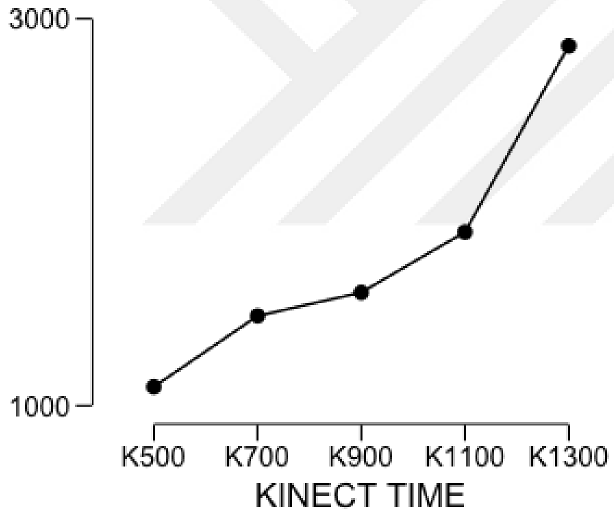



Figure 10. Kinect Movement Time Trend with respect to Distance

*Gaze Time-Distance*

According to repeated measure ANOVA analysis given in the Table 12, movement time of the Gaze modality is significantly different with respect to distance (F(4,992)=25.460, *p<.001).*

Table 12. Repeated Measure ANOVA Table for Movement Time of Gaze

| Within Subjects Effects | | | | | |
|---|---|---|---|---|---|
| | **Sum of** | **df** | **Mean** | **F** | **p** |
| Gaze Time | 1.114e +6 | 4 | 278396 | 25.460 | < .001 |
| Gaze Time * GOAL Type | 45565 | 4 | 11391 | 1.042 | 0.384 |
| Residual | 1.085e +7 | 992 | 10935 | | |
| *Note.* Type III Sum of Squares | | | | | |

Post Hoc comparison using Tukey HSD, indicated that except the pair (G900,G1100) all other pairs are significantly different. And also you can see the time and distance relation from the Figure 11.

Table 13. Post Hoc Comparison of Movement Time of Kinect

| Post Hoc Comparisons - Gaze Time | | | | | |
|---|---|---|---|---|---|
| | | **Mean Difference** | **SE** | **t** | **p tukey** |
| G500 | G700 | -25.785 | 9.360 | -2.755 | 0.047 |
| | G900 | -29.897 | 9.360 | -3.194 | 0.013 |
| | G1100 | -51.540 | 9.360 | -5.506 | < .001 |
| | G1300 | -89.261 | 9.360 | -9.536 | < .001 |
| G700 | G900 | -4.112 | 9.360 | -0.439 | 0.992 |
| | G1100 | -25.755 | 9.360 | -2.751 | 0.048 |
| | G1300 | -63.476 | 9.360 | -6.781 | < .001 |
| G900 | G1100 | -21.644 | 9.360 | -2.312 | 0.142 |
| | G1300 | -59.364 | 9.360 | -6.342 | < .001 |
| G1100 | G1300 | -37.721 | 9.360 | -4.030 | < .001 |

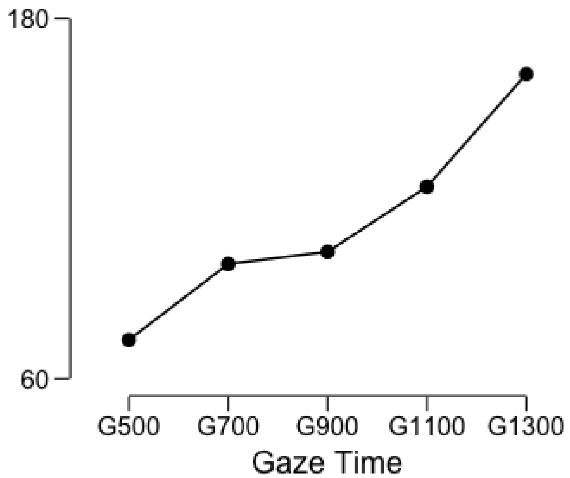



Figure 11: Kinect Movement Time for Different Distance

*Mouse Time-Distance*

In the Table 15, repeated measure ANOVA table indicates that time scores of the distances are statistically significant for the mouse modality (F (4,992) = 48.607, p < .001). And also interaction effect of mouse scores and participants' goal type is statistically significant (F (4,992) = 2.686, p < .03).

Table 15. ANOVA Table for Movement Time of the Mouse

| **Within Subjects Effects** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Sum of** | | **df** | | **Mean** | | **F** | | **p** | |
| Mouse Time | 4.031e +6 | [a] | 4 | [a] | 1.008e +6 | [a] | 48.607 | [a] | < .001 | [a] |
| Mouse Time * GOAL Type | 222733 | [a] | 4 | [a] | 55683 | [a] | 2.686 | [a] | 0.030 | [a] |
| Residual | 2.057e +7 | | 992 | | 20732 | | | | | |

*Note.* Type III Sum of Squares

[a] Mauchly's test of sphericity indicates that the assumption of sphericity is violated (p < .05).

Additionally, Post Hoc comparison using Tukey HSD test indicated all distance are different time score. Differences with respect to distance can be seen in the Figure 16.

Table 16. Post Hoc Comparison for movement time of the Mouse with respect to Distance

| **Post Hoc Comparisons - Mouse Time** | | | | | |
|---|---|---|---|---|---|
| | | **Mean Difference** | **SE** | **t** | **p** $_{tukey}$ |
| M500 | M700 | -35.55 | 12.89 | -2.758 | 0.047 |
| | M900 | -73.40 | 12.89 | -5.694 | < .001 |
| | M1100 | -113.19 | 12.89 | -8.782 | < .001 |
| | M1300 | -161.74 | 12.89 | -12.548 | < .001 |
| M700 | M900 | -37.84 | 12.89 | -2.936 | 0.028 |
| | M1100 | -77.64 | 12.89 | -6.024 | < .001 |
| | M1300 | -126.18 | 12.89 | -9.790 | < .001 |
| M900 | M1100 | -39.79 | 12.89 | -3.088 | 0.018 |
| | M1300 | -88.34 | 12.89 | -6.854 | < .001 |
| M1100 | M1300 | -48.55 | 12.89 | -3.766 | 0.002 |

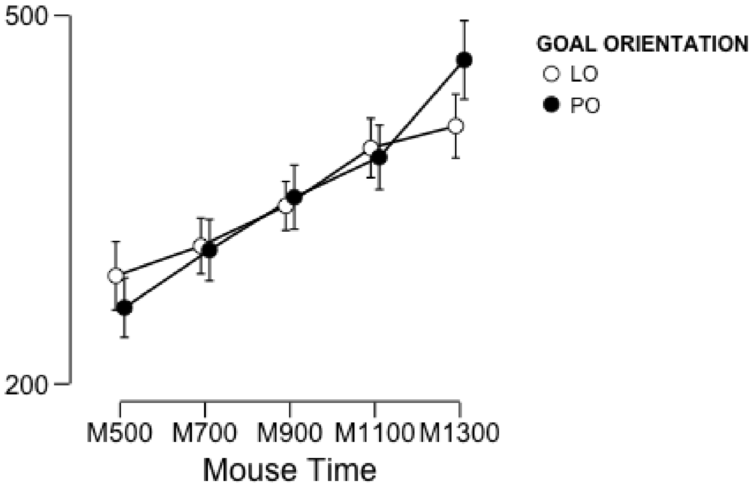



Figure 12: Mouse Movement Time for Different Distance

In the Figure 12, you can see the mouse time score of the participants that they have different time trend with respect to their goal orientation type however, it was found that is not statistically significant.

*The Relation between Order of Trial and Time Scores*

In order to understand whether any of modalities provides learning opportunities to participants a learning curve prediction has been done for each target location for each modality. Calculation of learning curve first described by Ebbinghaus in 1885; however, Wright (1936) published a theory, which was based on a repetitive production. According to Wright theory, any task completion will decrease by a constant percentage when the quantity of the production doubled. Since our task sequence includes 10 trials for each target location, the most doubled production point is the 8$^{th}$ trial for each target location. A simple learning curve calculator (P. Barringer & T. Bennett, 28 June 2005, Learning Curve Calculator,

www.barringer1.com/Papers_files/LearningCurveCalculator.xls) has been used to predict the learning curve of each target location. Basically, from the 1$^{st}$ trial to 10$^{th}$ trial a learning curve tried to be predicted in following procedure:

- The first step was standardization of the scores of each participant (for each modality each target location).
- The second step was finding means (for each modality, each target location and for each trial order) (e.g. mean for mouse condition target located at x =1300 and the first trial of the participants)
- The next step is placing the first mean into learning curve calculator.
- And then 8$^{th}$ trial completion time tried to be adjusted by manipulation improvement rate in the learning curve calculator.
- Finally, when the observed 8$^{th}$ trial completion time and calculator 8$^{th}$ production values become close to each other, then the curve assumed as the learning curve of this target location.

- Please note that after standardization, because of some values were negative standardization was sifted +2 points to omit the negative values.

You can see the calculator interface in the Table 17. Moreover, Table 18 and Table 2 represent an example of a learning calculation of M1100 condition. You can see that observed value placed in the first unit production cell in the learning curve calculator. And eight cell value and the eight observed value are almost same.

Table 17. Learning Curve Calculator

**Learning Curve Calculator**

| | | | |
|---|---|---|---|
| Improvement | -2% | <--Note: You can change any value in yellow | |
| Learning | 102% | <--Note: Everytime the quantity doubles, the previous doubled | |
| Unit Number | Unit Cost | Cum | Cum |
| 1 | 1.882882072 | 1.88 | 1.88 |
| **2** | **1.93** | 3.81 | 1.91 |
| 3 | 1.96 | 5.77 | 1.92 |
| **4** | **1.97** | 7.74 | 1.94 |
| 5 | 1.99 | 9.73 | 1.95 |
| 6 | 2.00 | 11.73 | 1.96 |
| 7 | 2.01 | 13.74 | 1.96 |
| **8** | **2.02** | 15.77 | 1.97 |
| 9 | 2.03 | 17.80 | 1.98 |
| 10 | 2.04 | 19.83 | 1.98 |
| 11 | 2.04 | 21.88 | 1.99 |
| 12 | 2.05 | 23.93 | 1.99 |
| 13 | 2.06 | 25.98 | 2.00 |
| 14 | 2.06 | 28.04 | 2.00 |
| 15 | 2.07 | 30.11 | 2.01 |
| **16** | **2.07** | 32.18 | 2.01 |
| 17 | 2.07 | 34.25 | 2.01 |
| 18 | 2.08 | 36.33 | 2.02 |
| 19 | 2.08 | 38.41 | 2.02 |
| 20 | 2.09 | 40.50 | 2.03 |

The log-log regressions will often show larger scatter in the early quantities and will not provide a "perfect" curve fit.

Table 18. Mouse 1100 Observed & Predicted Values

| | | **Observed** | **Predicted** |
|---|---|---|---|
| **1th** | -0.117117928 | 1.882882072 | 1.882882072 |
| **2nd** | -0.051450668 | 1.948549332 | 1.928071242 |
| **3rd** | 0.029097332 | 2.029097332 | 1.955006319 |
| **4th** | 0.048571894 | 2.048571894 | 1.974344952 |
| **5th** | 0.028808252 | 1.971191748 | 1.9894768 |
| **6th** | -0.035144692 | 2.035144692 | 2.001926471 |
| **7th** | 0.007063335 | 2.007063335 | 2.012513278 |
| **8th** | 0.027337882 | 2.027337882 | 2.021729231 |
| **9th** | 0.111277434 | 2.111277434 | 2.029893302 |
| **10th** | 0.077208758 | 2.077208758 | 2.037224243 |

In the Table 18, you can see the predicted values of the sequence of mouse 1100 condition, which correspond to the calculator sequences in the Table 17. In the graphs given below, horizontal axis represents the trial order and red line presents standardized mean value of the task accomplishment times. You will see that for each modality and for each target location there will be one predicted curve and corresponded observed values. Note that for each graph horizontal axis shows the trial number and the vertical axis represents the standardized task completion time.

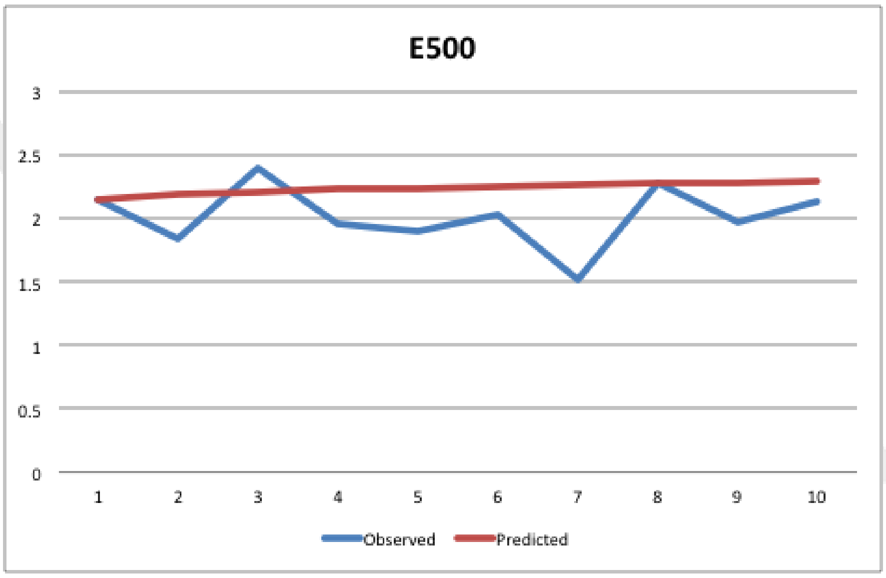



Figure 13. Eye Tracker Modality Trial Scores for Target Appeared at x=500

Learning Rate =102%

Residual = -2.204155283


Figure 14. Eye Tracker Modality Trial Scores for Target Appeared at x=700

Learning Rate = 100%

Residual = -0.280607037

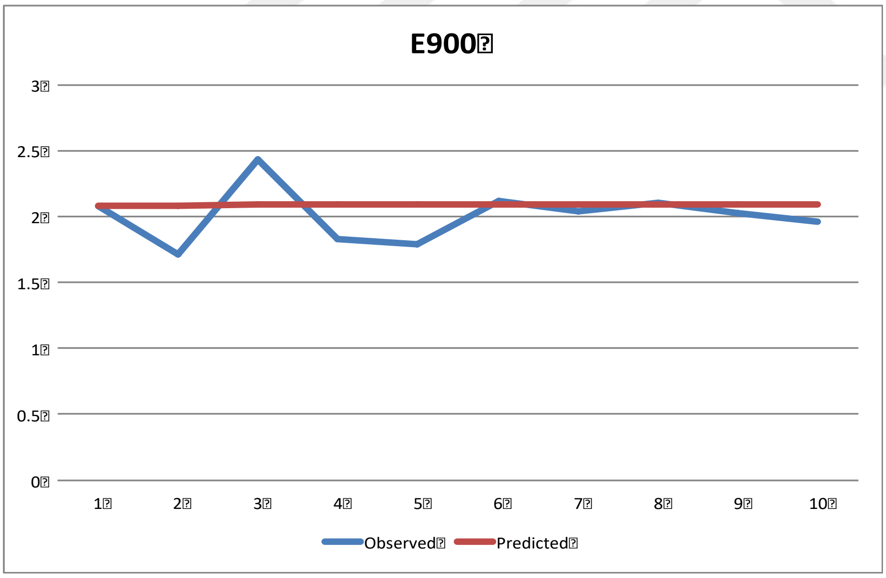



Figure 15. Eye Tracker Modality Scores for Target Appeared at x=900

Learning Rate = 100%

Residual = -0.779243472

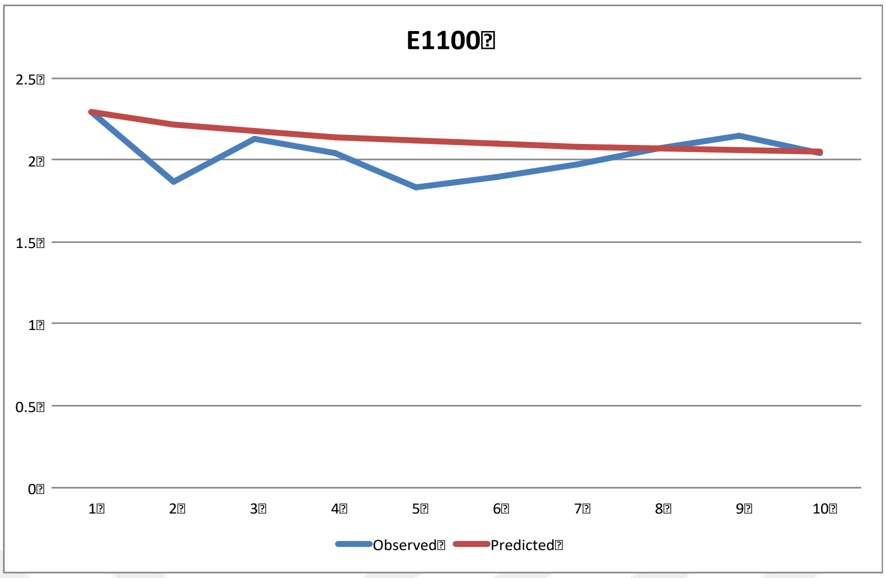



Figure16. Eye Tracker Modality Trial Scores for Target Appeared at x=1100

Learning Rate = 97%

Residual = -1.000409554

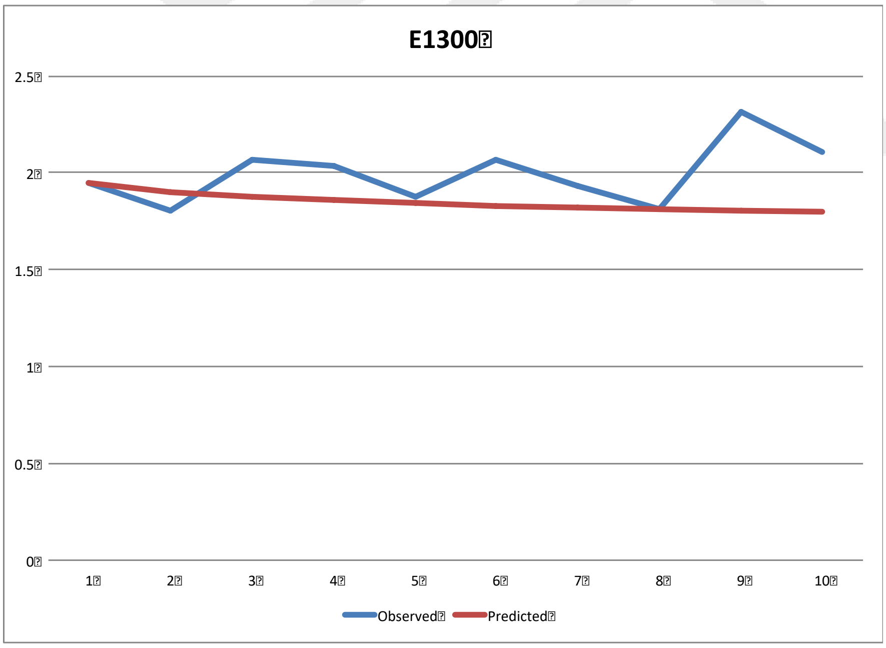



Figure17. Eye Tracker Modality Trial Scores for Target Appeared at x=1300

Learning Rate = 98%

Residual = 1.453760776

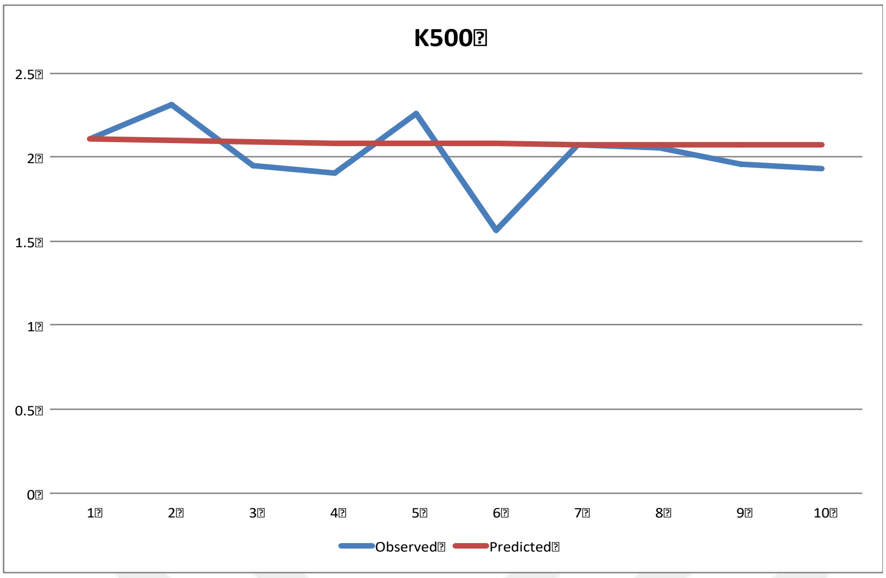



Figure 18. Kinect modality Trial Scores for Target Appeared at x=500

Learning Rate = 100%

Residual = -0.720951139

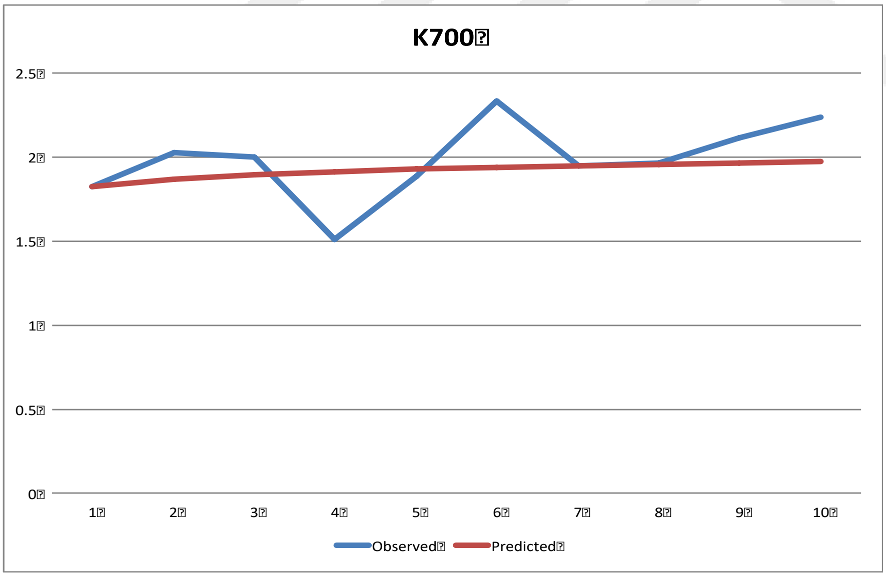



Figure19. Kinect Modality Trial Scores for Target Appeared at x=700

Learning Rate = 103%

Residual = 0.639740074

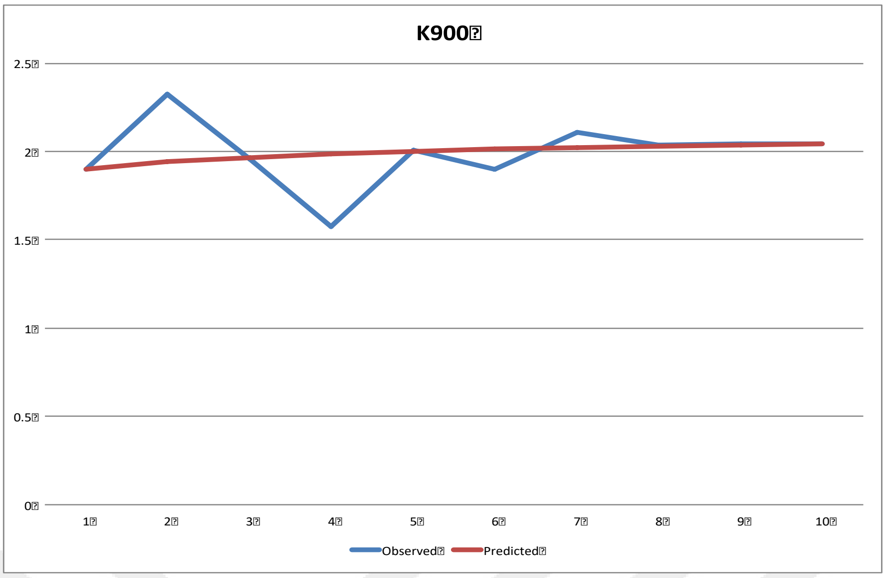



Figure 20. Kinect Modality Trial Scores for Target Appeared at x=900

Learning Rate = 102%

Residual = -0.033022437


Figure 21. Kinect Modality Trial Scores for Target Appeared at x=1100

Learning Rate = 95%

Residual = 2.567351635


Figure 22. Kinect Modality Trial Scores for target Appeared at x=1300

Learning Rate = 93%

Residual = 1.326103686

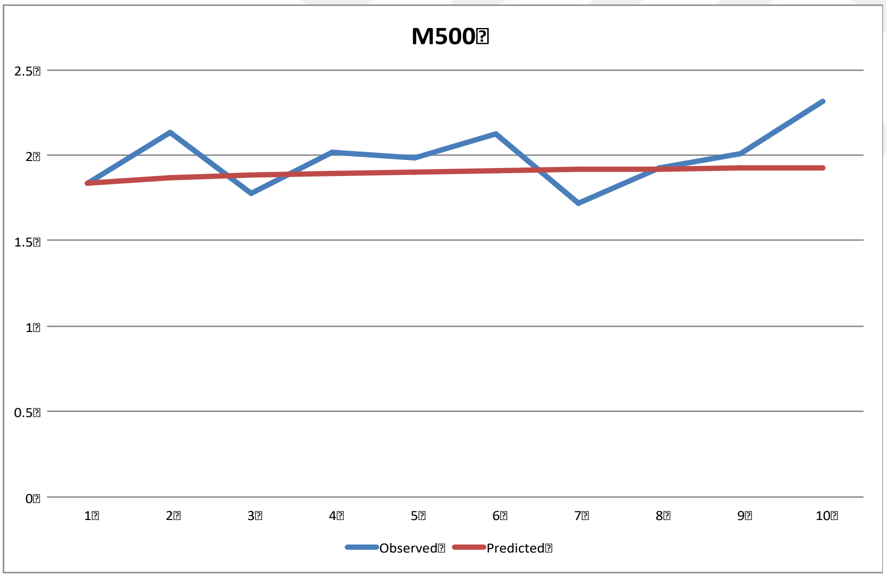



Figure 23. Mouse Modality Trial Scores for Target Appeared at x=500

Learning Rate = 102%

Residual = 0.866859445

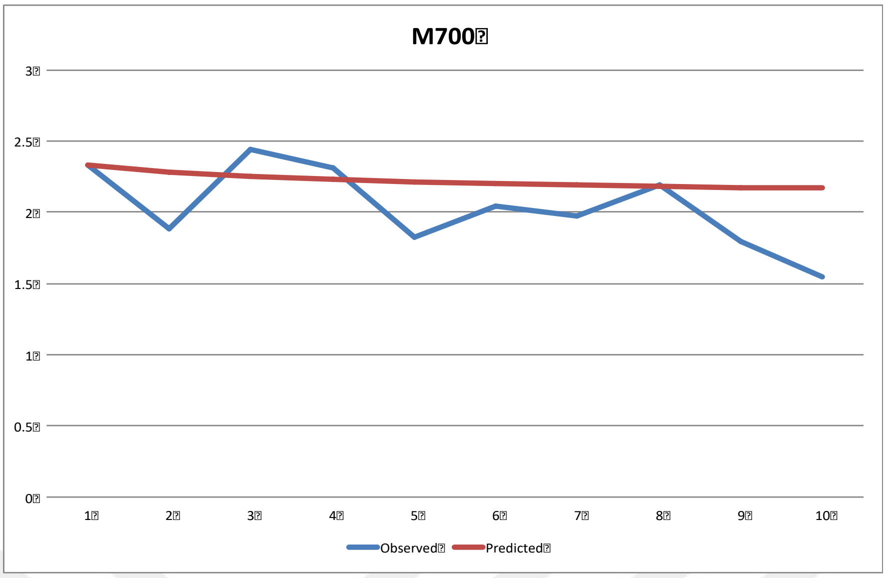



Figure 24. Mouse Modality Trial Scores for Target Appeared at x=700

Learning Rate = 98%

Residual = -1.899677152

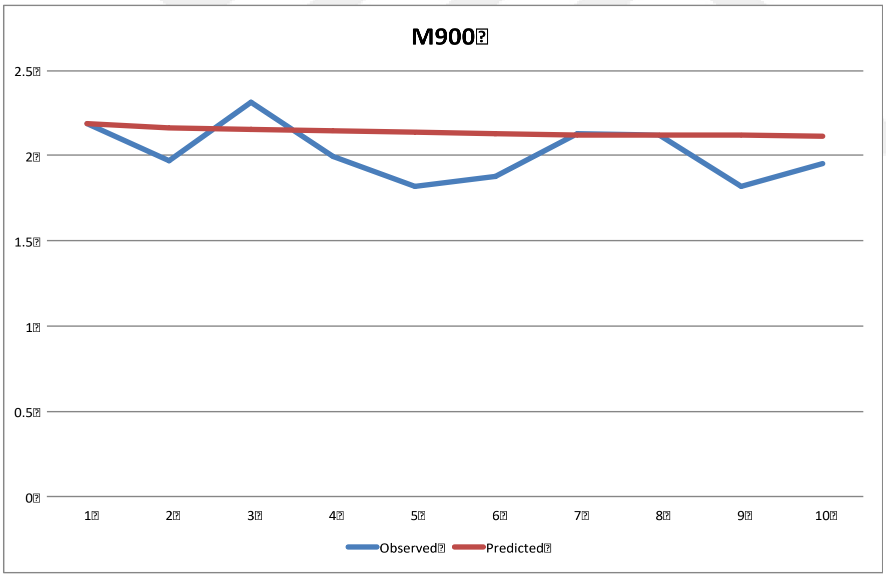



Figure 25. Mouse Modality Trial Scores for Target Appeared at x=900

Learning Rate = 99%

Residual = -1.192772648

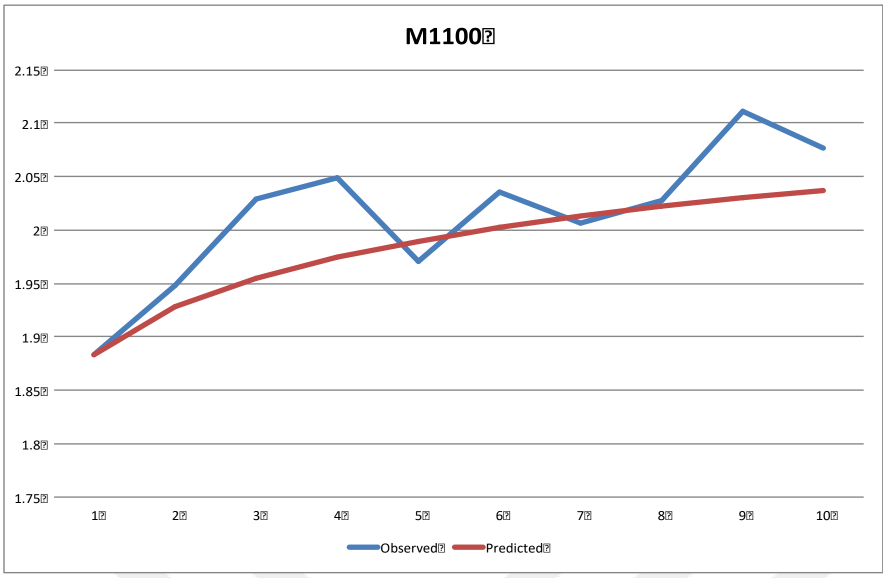



Figure 26. Mouse Modality Trial Scores for Target Appeared at x=1100

Learning Rate = 102%

Residual = 0.30525657

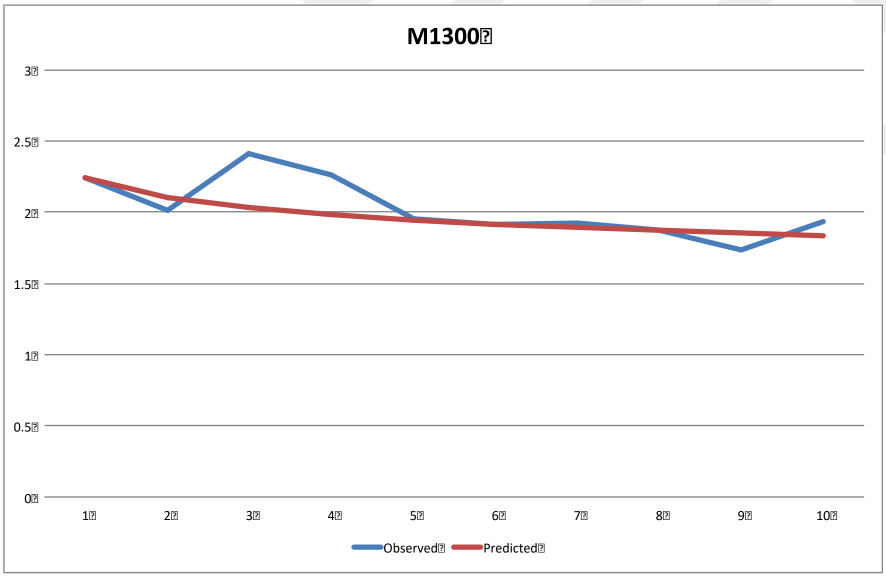



Figure 27. Mouse Modality Trial Scores for Target Appeared at x=1300

Learning Rate = 94%

Residual = 0.566315833

You can see from the graphs above that the most higher learning rate has been found on the Kinect 1300 (K1300) condition but the error between predicted and observed value is more than the mouse 1300 (M1300) condition. On the other hand, mouse 1300 (M1300) condition has 94 % learning rate and small error between the predicted curve and observed values (error sum = 0.556). Therefore it can be said that the only modality is mouse, which provides a learning opportunities to the participants. Please note that if the learning rate is equal or higher value than 100% then it is assumed as no learning at all.

### 5.3 Analysis of *Research Question* 3 and *Research Question* 4

In the Table 19, you can find descriptive statistics of participants' engagement scores of different modalities that are given with respect to goal orientation types of the subjects. According to Table 19, mean of the Gaze engagement scores of the individuals who are learning oriented is 88.33 *(M=88.33, SD = 9.605)*. Additionally, the mean of the Gaze-Engagement's scores of the performance-oriented individuals is *(M = 94.85, SD= 94.85)* 94.85. Kinect-Engagement's mean for learning oriented subjects is 86.58 *(M=86,58, SD = 13.670)*, and Kinect-Engagement's mean for performance oriented subjects is 86.69 *(M=86.69, SD= 12.614)*. And lastly, Mouse-Engagement's mean of the learning oriented individuals is 77.64 *(M=77.64, SD=9.977)* and performance-oriented individuals' mean for Mouse is 74.77 *(M=74.77, SD= 14.514)*.

Table 19. Descriptives of Engagement Scores

| Engagement | GOAL_TYPE | Mean | SD | N |
|---|---|---|---|---|
| Gaze | LO | 88.33 | 9.605 | 60 |
| | PO | 94.85 | 19.084 | 65 |
| Kınect | LO | 86.58 | 13.670 | 60 |
| | PO | 86.69 | 12.614 | 65 |
| Mouse | LO | 77.67 | 9.977 | 60 |
| | PO | 74.77 | 14.514 | 65 |

#### *5.3.1 Analysis of Research Question 3*

In order to understand the effect of modality on users' engagement, repeated measures ANOVA analysis was used. As repeated measure factors, eye tracker, Kinect and mouse engagement scores are defined. And the goal types are given as between subject factors. As an evidence for Research Question 3, you can see in Table 20 that, Engagement scores are statistically different for each modality that *(F(2,246) = 94.480, p<.001)* and also interaction of GOAL_TYPE and Modality is found statistically significant (F(2,246) = 5.179, p<.006).

Table 20. Repeated Measure ANOVA

| **Within Subjects Effects** | | | | | | |
|---|---|---|---|---|---|---|
| | **Sum of Squares** | **df** | **Mean Square** | **F** | **p** | **η²** |
| **Modality** | **15991.0** | **2** | **7995.49** | **98.235** | **< .001** | **0.432** |
| **Modality * GOAL_TYPE** | **991.5** | **2** | **495.76** | **6.091** | **0.003** | **0.027** |
| **Residual** | **20022.2** | **246** | **81.39** | | | |
| **Note. Type III Sum of Squares** | | | | | | |

Table 21. Repeated Measure ANOVA Between Subject Effects

| **Between Subjects Effects** | | | | | | |
|---|---|---|---|---|---|---|
| | **Sum of Squares** | **df** | **Mean Square** | **F** | **p** | **η²** |
| **GOAL_TYPE** | **252.7** | **1** | **252.7** | **0.626** | **0.430** | **0.005** |
| **Residual** | **49634.3** | **123** | **403.5** | | | |
| **Note. Type III Sum of Squares** | | | | | | |

In the Table 21, as between subjects factor Goal Type is found statistically significant. In Table 22, you can see the Post Hoc comparisons using Tukey HSD that each modality engagement scores are statistically different, which is an evidence for research question 3 that Gaze engagement mean is different than Kinect engagement mean *(p< .001).* Additionally, Gaze engagement mean also different than the Mouse engagement mean *(p <.001).* And Lastly, Kinect and Mouse engagements' mean are different than each other that the significant level is .001 *(p <.001).*

Table 22. Post Hoc Comparison for Each Engagement of Modality Scores

| **Post Hoc Comparisons - Engagement** | | | | | |
|---|---|---|---|---|---|
| | | **Mean Difference** | **SE** | **t** | **$p_{tukey}$** |
| Gaze | Kınect | 4.952 | 1.129 | 4.385 | < .001 |
| | Mouse | 15.372 | 1.129 | 13.613 | < .001 |
| Kınect | Mouse | 10.420 | 1.129 | 9.228 | < .001 |

*5.3.2 Analysis of Research Question 4*

As an evidence for research question 4, Repeated Measure ANOVA table given in Table 20, engagement scores of modalities and the goal orientation type interaction *(F(2,246) = 6.091, p<.003).* Additionally, in Figure 28, you can see that Kinect and Mouse modality scores are almost same that are not different than each other. However, learning oriented (LO) and performance oriented (PO) individuals' engagement means are graphically different within the Gaze condition.

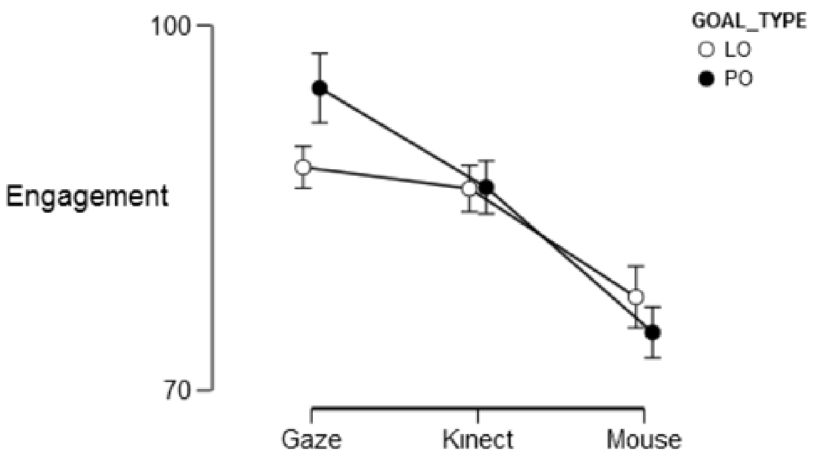



Figure 28. Descriptive Plot of Engagement Scores and Goal Orientation Types for Different Devices

Contrary to Research Question 4, except the eye tracker engagement score, Kinect and mouse engagement scores are not affected by the individuals' goal orientation types. However, ANOVA analysis shows that learning-oriented and performance-oriented individuals are engaged differently with respect to eye tracker modality.

### 5.4 Summary of Statistical Analyses

As a compendium of this chapter, there are significant differences between modalities that different modalities have an effect on task completion time. Although possible reasons are presented in Chapter 6, it could be summarized, as kinematic requirements of the interaction devices are the source of the differences on task completion time. Since the task completion time is significantly differ, an ANOVA test conducted to analyze each modality to see whether there is a characteristic time distance relationship or not? Firstly, each modality represents different internal time distance relationship. For instance, for the mouse modality except the pair (500,700), the rest of the distances indicate different task completion time. However, in Microsoft Kinect condition, time distance relation show different significant results with respect to pairs. Since explanation about these differences needs detailed investigation of kinematic patterns of these devices, any explanation would be crude within the present study. On the other hand, it is found that there is significant time-distance relationship between order of trial and the task completion time for the target located at x=1300. This significant relation probably effects of familiarization of the task that participants become more competent to complete the task which has a target located on x = 1300.

Lastly, for the eye tracker conditions results indicated that there is an effect of goal orientation of user that they have different engagement scores for eye tracker modality. Furthermore, it is found that the modality altered the participants' engagement scores that eye tracker has the highest engagement score whereas the mouse the lowest. Microsoft Kinect V2 has the higher score than mouse but lower than eye tracker.

# CHAPTER 6

# DISCUSSION

The main aim of the study was to investigate the role of modalities on users' engagement while they interact with computer-based tasks. The second purpose was to understand whether users' goal orientation types have an effect on their task engagements. Beside, understanding time and distance relationship of each modality and extracting efficiency information based on the task completion time for different modalities were the minor purposes of the study. Nevertheless, minors were necessary to reach the main purpose of the study.

Goal orientation predicted for different task engagements such as easier task result with higher engagement score and difficult task result with lower engagement scores for the performance-oriented individuals. On the other hand this prediction was in opposite direction for the learning-oriented individuals. Result of the analysis revealed that performance oriented individuals engaged more, for the task, which completed with the eye tracker. Since the performance-oriented people focus on their ability, they probably appraised the usage of eye tracker as they have ability. On the other hand, eye tracker is a modality of interaction that does not provide any competence or any chance to increase the skill of the user. Therefore, learning-oriented individuals probably show lower engagement scores than performance-oriented individuals that learning-oriented individuals consider their progress and mastery. Nevertheless, engagement scores of the participants did not turn out to be as expected for Kinect and mouse. Kinect and Mouse engagement scores were not significantly different with respect to individuals' goal orientation types.

The effects of the different modalities are predicted for different engagement scores. Furthermore, task completion time assumed as a determinative factor for the efficiency of the interaction. According to analysis of movement time, different interaction efficiency predicted for different modalities of interaction that eye tracker has lower time scores. Kinect has the highest time scores and the mouse has the lower time scores than Kinect but higher scores than eye tracker. As the last prediction, different time and distance relationships predicted for different modalities.

In the following sections, detailed discussions of the findings are presented. Firstly, results related to engagement of the users and goal orientations elaborated. Secondly, the findings related to efficiency of the interaction and different time distance patterns of these interaction modalities are discussed. At the end of this Chapter, limitations and possible future works are presented.

### 6.1 Effect of Interaction Modality on Users' Engagement

The first Research Question of the study was about the engagement of the users. The capacity of the devices differ several factors related to engagement of the users such as the efficiency of the interaction, flow of the task, kinematic pattern of the users, effort of the users, need of attention for the task and satisfaction of the users. Therefore, it is predicted that different modalities of interaction reveal different user engagement scores. There are not similar studies in the literature that provide converging evidence for the finding about engagement of the users. Nevertheless, User Engagement Scale (Wiebe et al., 2014) specifically measures mentioned factors except the kinematic pattern and effort of the users. Additionally, Möller and his friends (2009) reported several factors for assessment of quality of service and quality of experiences between human and machine. In Figure 13 you can see that there are number of factors reported related to quality of experience (bottom of the figure). In this study, some of these experience related factors, which are claimed by Möller and his friends, considered within the user engagement scale. Additionally service related factors reported as interaction performance aspects describing user and system performance and behavior. This service quality description especially some of System related factors measured within the present study with the completion time of the task. For example, Input performance corresponds to task accomplishment time scores of participants and perceptual effort of users have also measured within the user engagement scale.

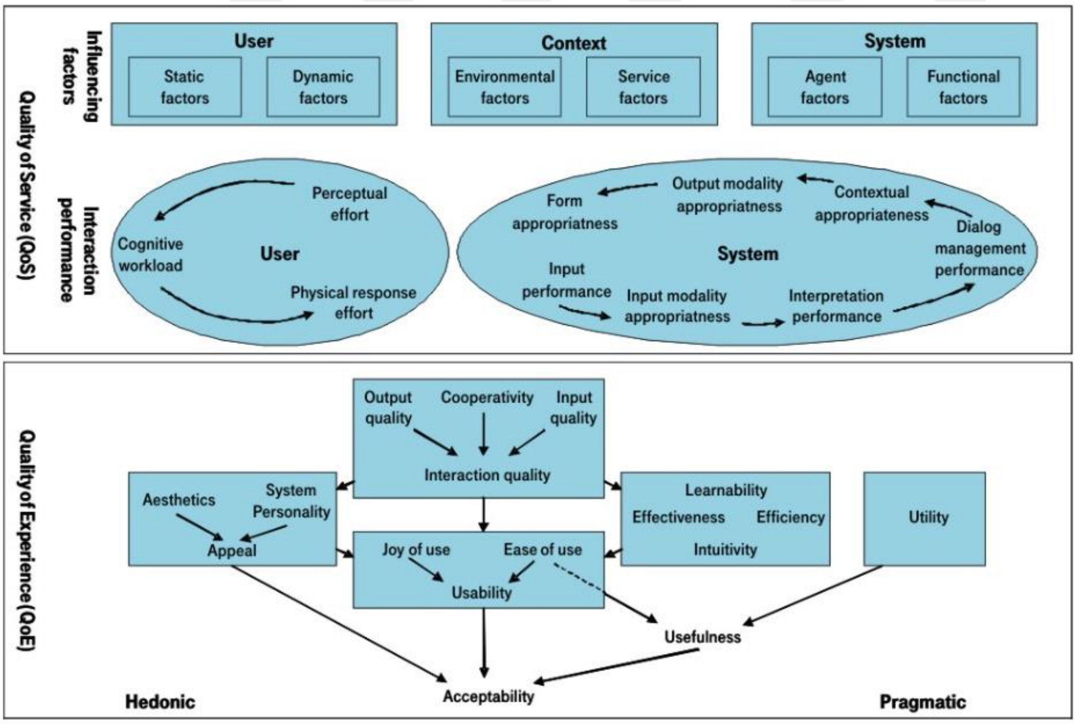



Figure 29. Illustration of Service Quality and Experience Quality Factors (Möller et al., 2009)

Different kinematic pattern of the modalities and variation of effort of the users can be observed by the completion time of the task. This variation can also represent the efficiency of the interaction such as the more efficient interaction modalities revealed smaller standard deviation.

As a result, different engagement scores were observed and they were found statistically significant. And the related factors for the engagement of the user sourced by the different modalities of interaction.

### 6.2 Goal Orientation Effect on User Engagement

The second Research Question of the study was about the goal orientation of the individual. Goal orientation is an effective factor for individuals' motivational behavior (Dweck, 1986). According to Dweck and Leggett (1988), the learning oriented individual focuses on their mastery and progress, where as performance oriented individuals only focus on his or her ability. Since different types of interaction modalities alternate the task difficulty and possible outcomes of the task, it is predicted that different modalities reveal different motivational behavior.

Motivational changes of the users were observed with derived User Engagement Scale that measures the hedonic and utilitarian motivational behavior of the user (Wiebe et al., 2014). Findings related the goal orientations are consistent with the findings of the Dweck (1986) that performance-oriented individuals and learning-oriented individuals show motivational differences. Due to efficiency of the interaction, perceived difficulty of the task alternated, the goal orientation related research question of study consistent with the Dweck (1986) goal orientation theory.

Nevertheless, the findings were partially true for the goal orientation. Indeed, not all of the modalities differentiate the engagement scores of the participants who have different goal orientation types. There is only one device namely eye tracker interact with the goal orientation of the participants and they have interaction effect on user engagement. However, Kinect and the mouse's engagement scores were not different than each other. Possible reasons behind the effect of eye tracker was, learning-oriented individuals consider the progress and mastery opportunities of the task and performance-oriented individuals focus on their ability, in this context the most distinguishing interaction modality is the eye tracker where learning-oriented individuals found nothing with respect to mastery whereas performance-oriented individuals are competent to use their eyes that they perceived the task in the range of their ability.

### 6.3 Effect of Interaction Modality on Task Accomplishment

In the present study, an application was developed for providing an identical task for three different modalities. And task accomplishment times were recorded to compare whether different modalities reveal different time trend or not? As a result of quantitative measurement, there is no doubt about the different time trend of modalities. Since the modalities force to user behaves in different kinematic pattern, different modalities of interaction result different task completion times.

## 6.4 The Relation between Time and Order

In the given graphs in Figure 13, 14, 15, 18, 16, 17, 18, 19, 20, 21, 22,, 23 you can see that the eye tracker conditions' learning curves are small than others. Since the learning-oriented and performance-oriented individuals have significantly different engagement scores, and also the eye tracker does not let individuals to significantly improve their task accomplishment time, it can be roughly claimed that differentiation of goal orientation was occurred because of the lack of learning opportunities provided by eye tracker.

On the other hand, in the mouse condition, there is a 94 % learning rate for mouse 1300 condition, which means that the mouse provide an opportunities of learning.

Additionally, it can be seen in the Figure 20 that, the mouse condition engagements' means are insignificantly different than each other with respect to goal orientation of the participants. Since it was observed that mouse has a learning rate for the target located at x=1300, and also since the engagement scores of the users are insignificantly not equal, it can be stated that the number of participants or the number of the trial could be an obstacle to see the significant result of the differentiation of the different goal type users on mouse modality.

Lastly, Kinect need more kinematic requirement to complete the task, probably the effect of the learning cannot be seen because of the exhaustion of the participants. It is found a higher learning rate on Kinect condition but the error between the predicted curve and the observed values was higher than the mouse condition, and also Kinect condition more likely to fluctuate negatively or positively.

## 6.5 Contributions and Limitation of the Study

This study contributed to the existing literature by understanding the effect of modalities on users' engagement. And this study suggests a new factor for efficiency studies that researchers should consider the goal orientation of the users. Additionally, different task completion times were observed with different modalities; however, by considering the engagement scores of the users and their task completion time' scores, it can be concluded that task completion time does not always predict the efficiency of the interaction. Note that Kinect was the slowest interaction modality and its engagement score was higher than the mouse where the mouse timing was far better than Kinect.

This study is believed to be unique that the goal orientation of the users and different interaction modalities were not integrated to understand their interaction effect on the engagement of the users. And also comparison of these three devices' efficiency, in terms of the time course of the point task, is also a novel research for the literature.

This study may provide novel factor for the future research that the engagement of the user for different modalities of interaction affected by the goal orientation types of the users that the researcher should consider the performance and learning oriented individual differently.

Moreover, as an extension of this research, task difficulty could be changed opposite direction for the eye tracker such as a smooth pursuit task can be designed which can increase the difficulty of the task for eye tracker and decrease or does not change the difficulty of the task for Kinect and mouse. This scenario can provide converging evidence: if the eye tracker engagement scores of the users turn out to be opposite direction that learning oriented individuals probably show higher and performance oriented individuals provide lower engagement score for the smooth pursuit task.

Furthermore, the study can be extended with number of different task that the task may be designed for different directions or diagonal movements. Because of the reading habits, opposite direction may result with different completion time and different time-distance relationship.

The drawback of the study is the number of the participants. 25 participants may not be enough to observe failed research question of the study. On the other hand, the accuracy problem of the eye tracker forced the experimental design to apply different procedure for the eye tracker. Future studies could use more accurate eye tracker. Another important limitation of the study is related to goal orientation scale that was a translation of the original scale. The reliability and validity research may be conducted in the future studies. The same limitation is also true for the User Engagement Scale that Turkish adaptation of the scale may want to be used in future studies.

Finally, this study shows that goal orientation of the user has an effect on their task engagement. Additionally, this study reveals that there is a main and interaction effect of modality and goal orientation of users on users' engagement. And different time courses of the task completion indicate that the eye tracker is the fast and efficient device for a pointing task that the user's engagement score of the eye tracker was the highest score of the study. There may be number of different factor related to user engagement and interaction efficiency such as the different modalities may change the magnitude of the task difficulty more than used devices within the study. Therefore, future research should also take into account other modalities and possible factors as well.

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# APPENDIX A

| Aşağıdaki ifadeler oynadığınız oyunla ilgili olarak insanların hissettikleri veya düşündükleri geri bildirimlerdir. İfadelerin hemen sağındaki ölçeği kullanarak, bu ifadelere ne kadar katıldığınızı belirtiniz. Her ifade için sağdaki kutucuktaki sayılardan birini yuvarlak içine almanız yeterli olacaktır. Sayıların anlamları aşağıdaki gibidir. | | | | | |
|---|---|---|---|---|---|
| | Hiç katılmıyorum (1) | Katılmıyorum (2) | Ne katılıyorum ne de katılmıyorum (3) | Katılıyorum (4) | Tamamen katılıyorum (5) |
| Oyunu oynarken, dış dünya ile bağımı yitirdim. | 1 | 2 | 3 | 4 | 5 |
| Oyunun kontrol cihazıyla etkileşime geçtiğim anda dış dünya ile bağımı kopardım. | 1 | 2 | 3 | 4 | 5 |
| Oyunu oynadığım süre boyunca zamanın nasıl geçtiğini anlamadım. | 1 | 2 | 3 | 4 | 5 |
| Oyunda görevi tamamlarken tükendiğimi hissettim. | 1 | 2 | 3 | 4 | 5 |
| Oyundaki görevime öyle yoğunlaştım ki zamanın nasıl geçtiğini anlamadım. | 1 | 2 | 3 | 4 | 5 |
| Kendimi tamamen oyuna kaptırdım. | 1 | 2 | 3 | 4 | 5 |
| Oyunu oynarken kendimi tamamen kaybettim. | 1 | 2 | 3 | 4 | 5 |
| Oyundaki görevime tamamen yoğunlaştım. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazını teşvik edici bulmadım. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazı ile oyunu oynarken rahatsız oldum. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazı oyunu oynarken bana yük oldu. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazını kullanmak çok sıkıcıydı. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazı beni hayal kırıklığına uğrattı. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazı ile istediğim gibi oyunu kontrol edemedim. | 1 | 2 | 3 | 4 | 5 |
| Oyun çok zahmetliydi. | 1 | 2 | 3 | 4 | 5 |
| Oyun tahmin ettiğim gibi çıkmadı. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazının yeteneklerini beğendim. | 1 | 2 | 3 | 4 | 5 |

## APPENDIX A Cont.

| | Hiç katılmıyorum (1) | Katılmıyorum (2) | Ne katılıyorum ne de katılmıyorum (3) | Katılıyorum (4) | Tamamen katılıyorum (5) |
|---|---|---|---|---|---|
| Bu kontrol cihazı oyunu oynarken yeteneklerimi artırdı. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazının yetenekleri ilgimi çekti. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazını kullanmak oldukça hoş bir deneyimdi. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazını kullanmak oldukça çarpıcıydı. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazını kullanmak oldukça teşvik ediciydi. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazını merakla kullanmaya devam edebilirim. | 1 | 2 | 3 | 4 | 5 |
| Bu kontrol cihazını çevreme tavsiye edebilirim. | 1 | 2 | 3 | 4 | 5 |
| Bu cihazla oyun oynamak değerliydi. | 1 | 2 | 3 | 4 | 5 |
| Oyundaki görevim ile oldukça ilgilendim. | 1 | 2 | 3 | 4 | 5 |
| Oyunu oynamak tatmin ediciydi. | 1 | 2 | 3 | 4 | 5 |
| Oyun eğlenceliydi. | 1 | 2 | 3 | 4 | 5 |

## APPENDIX B

Wiebe and his friends' Game Engagement Scale (Wiebe et al., 2014)

| | | | | | |
|---|---|---|---|---|---|
| When I was playing the game, I lost track of the world around me. | 1 | 2 | 3 | 4 | 5 |
| I block out things around me when I was playing the game on this website. | 1 | 2 | 3 | 4 | 5 |
| The time I spent playing the game just slipped away. | 1 | 2 | 3 | 4 | 5 |
| I was absorbed in my gaming task. | 1 | 2 | 3 | 4 | 5 |
| I was so involved in my gaming task that I lost track of time. | 1 | 2 | 3 | 4 | 5 |
| During this gaming experience I left myself go. | 1 | 2 | 3 | 4 | 5 |
| I lost my self in this gaming experience. | 1 | 2 | 3 | 4 | 5 |
| I was really drawn into my gaming task. | 1 | 2 | 3 | 4 | 5 |
| I felt discouraged while on the website. | 1 | 2 | 3 | 4 | 5 |
| I felt annoyed while visiting the website. | 1 | 2 | 3 | 4 | 5 |
| Using the website was mentally taxing. | 1 | 2 | 3 | 4 | 5 |
| I found the website confusing to use. | 1 | 2 | 3 | 4 | 5 |
| I felt frustrated while visiting the website. | 1 | 2 | 3 | 4 | 5 |
| I could not do some of the things I needed to do on the gaming website. | 1 | 2 | 3 | 4 | 5 |
| The gaming experience was demanding. | 1 | 2 | 3 | 4 | 5 |
| This gaming experience did not work out the way I had planned. | 1 | 2 | 3 | 4 | 5 |
| I liked the graphics and images used on the website. | 1 | 2 | 3 | 4 | 5 |
| The website appealed to my visual senses. | 1 | 2 | 3 | 4 | 5 |
| The website was aesthetically appealing. | 1 | 2 | 3 | 4 | 5 |
| The screen layout of the website was visually pleasing. | 1 | 2 | 3 | 4 | 5 |
| The website was attractive. | 1 | 2 | 3 | 4 | 5 |
| The content of the gaming website incited my curiosity. | 1 | 2 | 3 | 4 | 5 |
| I would continue to go to this website out of curiosity. | 1 | 2 | 3 | 4 | 5 |
| I would recommend playing the game on the website to my friends and family. | 1 | 2 | 3 | 4 | 5 |
| Playing the game on this website was worthwhile. | 1 | 2 | 3 | 4 | 5 |
| I felt interested in my gaming task. | 1 | 2 | 3 | 4 | 5 |
| My gaming task was rewarding. | 1 | 2 | 3 | 4 | 5 |
| The gaming experience was fun. | 1 | 2 | 3 | 4 | 5 |

# APPENDIX C

| **Aşağıdaki ifadelerin her biri, insanların görev ortamında karşılaşabilecekleri çeşitli durumlardaki tercihlerini ifade etmektedir. Her ifadeye ne kadar katıldığınızı belirtmek için o ifadenin yanındaki boşluğa uygun olan rakamı yazınız.** Verilen ifadeye ne kadar katılıyorsunuz? | | | | | |
|---|---|---|---|---|---|
| | Hiç katılmıyorum (1) | Katılmıyorum (2) | Ne katılıyorum ne de katılmıyorum (3) | Katılıyorum (4) | Tamamen katılıyorum (5) |
| Kendisinden çok şey öğrenebileceğim zorlayıcı bir görevi seçmeyi isterim. | 1 | 2 | 3 | 4 | 5 |
| Sıklıkla yeni bilgi ve beceriler edinebileceğim fırsatlar ararım. | 1 | 2 | 3 | 4 | 5 |
| İşte yeni yetenekler edineceğim zorlayıcı ve meydan okuyucu görevlerden hoşlanırım. | 1 | 2 | 3 | 4 | 5 |
| İş yeteneğimi geliştirmek, risk almaya değer. | 1 | 2 | 3 | 4 | 5 |
| Yüksek seviyede yetenek ve beceri isteyen durumlarda çalışmayı tercih ederim. | 1 | 2 | 3 | 4 | 5 |
| İş arkadaşlarımdan daha iyi performans gösterebileceğimi göstermek benim için önemlidir. | 1 | 2 | 3 | 4 | 5 |
| İşyerindeki kişilere yeteneğimi kanıtlayabilmenin yollarını bulmaya çalışırım. | 1 | 2 | 3 | 4 | 5 |
| İşyerindekilerin işimi ne kadar iyi yaptığımın farkında olmalarından hoşlanırım. | 1 | 2 | 3 | 4 | 5 |
| Kabiliyetimi başkalarına kanıtlayabileceğim projelerde çalışmayı tercih ederim. | 1 | 2 | 3 | 4 | 5 |

## APPENDIX C Cont.

| | | | | | |
|---|---|---|---|---|---|
| Eğer diğerlerine yetersiz görünme ihtimalim varsa, yeni bir görev almaktan kaçınırım. | 1 | 2 | 3 | 4 | 5 |
| Az yetenekli görünmekten kaçınmak, benim için yeni bir beceri öğrenmekten daha önemlidir. | 1 | 2 | 3 | 4 | 5 |
| Eğer bir görevdeki performansım az yeteneğe sahip olduğumu gösterecekse, o görevi alma konusunda endişelenirim. | 1 | 2 | 3 | 4 | 5 |

## APPENDIX D

DEMOGRAFİK BİLGİ FORMU

Adı:

Soyadı:

Yaşı:

Okul:

Bölüm:

Hangi elinizi kullanıyorsunuz: Sağ ☐ Sol ☐

Çalışmada gözlük yada lens kullandınız mı: Evet ☐ Hayır ☐

# APPENDIX E

## Bilgilendirilmiş Onay Katılım Formu

## (Informed Consent Form)

Bu çalışma, ODTÜ Enformatik Enstitüsü Bilişsel Bilimler yüksek lisans programı kapsamında çalışmalarını yürütmekte olan Mehmetcan Fal'ın tez projesi için hazırlanmıştır. Çalışma Yrd. Doç. Dr. Cengiz Acartürk'ün gözetiminde gerçekleşmektedir.

Çalışma, insan-bilgisayar iletişiminde kullanılan bazı araçların verimliliğini anlamak için tasarlanmıştır. Çalışma boyunca gösterilecek materyal genel olarak kişisel rahatsızlık verecek içeriğe sahip değildir. Sizden beklenen, cihaz ekranında gösterilen yönergeleri takip etmektir. Ancak, katılım sırasında gösterilen materyalden ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz çalışmayı yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda çalışmayı yürüten kişiye, çalışmayı tamamlamadığınızı söylemek yeterli olacaktır.

Çalışmaya katılım bilgilendirilmiş onay (informed consent) esasına dayanmaktadır. Çalışma boyunca, sizden istenecek kimlik bilgileri verilerle eşleştirilmemektedir. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir; elde edilecek bilgiler bilimsel yayınlarda ve Mehmetcan Fal'ın tezinde kullanılacaktır. Çalışma sonunda, varsa çalışmayla ilgili sorularınız cevaplanacaktır.

Katılımınız için şimdiden teşekkür ederiz.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

***Bu çalışmaya bilgilendirilmiş olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayınlarda kullanılmasını kabul ediyorum*.**

Adı Soyadı Tarih İmza

----/----/-----