USING EYE TRACKING DATA TO ANALYZE A COMPUTER GAME LEARNING EXPERIENCE

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

SERKAN ALKAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
COMPUTER EDUCATION AND INSTRUCTIONAL TECHNOLOGIES

JANUARY 2006

Approval of the Graduate School of Natural and Applied Sciences.

Prof. Dr. Canan Özgen
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. M. Yaşar Özden
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Kürşat Çağıltay
Supervisor

Examining Committee Members

Assoc. Prof. Dr. Soner Yıldırım	(METU, CEIT)	
Asst. Prof. Dr. Kürşat Çağıltay	(METU, CEIT)	
Asst. Prof. Dr. Zahide Yıldırım	(METU, CEIT)	
Asst. Prof. Dr. Erdinç Çakıroğlu	(METU, EME)	
Asst. Prof. Dr. Sadi Seferoğlu	(Hacettepe Ünv., BÖTE)	

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Name, Last name: Serkan Alkan

Signature :

ABSTRACT

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Alkan, Serkan
M.Sc., Department of Computer Education and Instructional Technology
Supervisor: Asst. Prof. Dr. Kürşat Çağıltay

January 2006, 110 pages

This study aims to explore how novices learn computer games. In order to observe the characteristics of learning a novel computer game, an eye tracking method was integrated with usability studies' methods. Data was collected from 16 undergraduate university students. Every student played the game for 10 minutes. Their eye movements were recorded with an eye tracker. Subjects' behaviors were also videotaped while playing the game. Results showed that eye tracking can be used as measure to study learning experience of games. Theoretical implications and applicability of the findings to the use of computer games for educational purposes were discussed.

Keywords: Computer games, Eye Tracking, Usability, Learning computer games

ÖZ

BİLGİSAYAR OYUNU ÖĞRENME SÜRECİNİN GÖZ HAREKETİ VERİLERİ YARDIMIYLA ANALİZİ

Alkan, Serkan
Yüksek Lisans, Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü
Tez Yöneticisi: Y.Doç.Dr. Kürşat Çağıltay

Ocak 2006, 110 sayfa

Bu çalışmanın amacı, oyuncuların bilmedikleri bir bilgisayar oyununu nasıl öğrendiklerini analiz etmektir. Yeni bir bilgisayar oyunu öğrenme özelliklerinin incelenmesi için kullanılabilirlik metodları, göz hareketlerinin kaydı teknolojisi ile entegre edilmiştir. Veriler 16 üniversite öğrencisinden toplanmıştır. Öğrenciler 10 dakika bilgisayar oyunu oynamışlar, bu esnada video ve göz hareketleri kayıtları alınmıştır. Sonuçlar göz hareketlerinin bilgisayar oyunu öğrenme sürecini incelemede kullanılabileceğini göstermiştir. Bulgular bilgisayar oyunlarının eğitim amaçlı kullanımı amacına yönelik olarak teorik ve uygulanabilirlik açısından tartışılmıştır.

Anahtar Kelimeler: Bilgisayar Oyunları, Göz Hareketleri, Kullanılabilirlik, Bilgisayar Oyunlarını Öğrenme

ACKNOWLEDGMENTS

I would thank to Kürşat Çağıltay, my advisor, for his unconditional and constructive reinforcement. I hope that his variable interval reinforcement schedule makes me consistent about studying without giving long breaks.

Thanks to jury members, Soner Yıldırım, Erdinç Çakıroğlu, Zahide Yıldırım and Sadi Seferoğlu for their constructive feedbacks about my thesis draft. Their critics made my thesis coherent and more readable.

If Mehmet Göktürk did not let me use his laboratory at Gebze Institute of Technology, the study even would not have been initiated. Thanks to GYTE students accepting to join my study without any demand.

Dilan and Çelebi are my young friends who made a great job by writing codes in C++.

I am grateful to Aydın Tiryaki and 6th floor fellows for their tolerant and supportive friendships. Fatoş T. Yarman Vural constantly encouraged me to work on my work.

My family merits the greatest portion of indebtedness; Neş'e, Father, and Brother. It is wonderful having such a family.

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CHAPTER I

INTRODUCTION

This study aims to explore how novices learn computer games. In order to observe the characteristics of learning a novel computer game, an eye tracking method was integrated with usability studies' methods.

1.1. BACKGROUND OF THE STUDY

The number of studies about games and their relation to education is quite remarkable. However, the consistent and applicable outcomes of these studies are questionable. Squire (2003) pointed that educationalists' discussions were generally about social outcomes of computer games rather integration of them into education. Most of the studies were concentrating on violence and consequences of violence in computer games, or how computer games' engagement aspects can be transferred educational settings.

Computer game investigations can be categorized into three. Some of the studies examine physiological changes during play, some of them concentrated on post behavioral effects of computer game playing. The last category of computer game play studies is about incidence of use and patterns of play (Newman, 2002). The present study integrates the first and the third approaches.

With the spread of computers the play patterns of children (in fact youngsters and adults) changed irreversibly. Computers, computer games or computer games have penetrated into everyday life, business world, education etc. On the other hand, science of education became adherent of those developments rather being originator of them.

A recent OECD (2005) report about the online computer and video game industry mentions the market size of the video games. Computer and video game industry surpassed the film industry in 2001 and will be expected to surpass recorded music industry soon. The report underlies the rapid growth of online games. According to report the development of the off-line PC and console games reach their steady states. However, wireless platforms and online games are being expected to show strong growth in following years.

Mitchell and Savill-Smith (2004) have reviewed the literature of the use of computer and video games for learning. In their review they discussed the impact of the use of computer games on young people. Afterwards they listed the reasons and ways to use computer games for learning with examples. They also mentioned young people’s experiences and preferences in using computer games for learning and for leisure. Lastly, they recommended some plan and design guides for educational computer games to integrate them into education.

Since computer games are played in front of computers or similar devices, the tools or methods of human computer interaction studies are suited well to apply computer game researches in laboratory conditions. Eye tracking technology is one of the most precious tools of the HCI methods.

Eye tracking technologies have been experiencing an increasing interest in a broad range of researchers from different backgrounds. The increasing frequency of published research on this topic is the sign of rise of interest (Duchowski, 2003). Eye tracking studies can be either top-down or bottom-up. Top-down studies informed by cognitive theories whereas, bottom-up approaches analyze the data without having any prior theories relating eye movements to cognitive activity (Ramloll, Trepagnier, Sebrechts & Beedasy, 2004).

1.2. STATEMENT OF THE PROBLEM

Newman (2002) pointed out that computer game industry has been unaware that the interactions, connections and relationships between of players and computer game systems. He suggested that nature of the reported experience of play and understanding of player interactions have to be interrogated to create a bridge between players and computer games beyond abstract input-output mechanisms of Human-Computer Interaction research.

The number of studies undertaken with young adults using computer and video games is insufficient. Their level and longitudinal change of basic cognitive and social skills relating to education needs to be explored. Some possible research topics about computer games and education are mentioned by Mitchell and Savill-Smith (2004) as follows:

> "… long-term impact of interactive games on cognition and academic achievement, … simulated impact on children's and adolescents' developing identities and sense of reality … how the physical characteristics of a computer game may affect cognitive and physiological responses … how expertise is acquired by different learners … what it is relation to implicit knowledge and how it can be used more adequately as a valuable instructional tool through the use of computer games … to investigate the usefulness of games for students with marginal skills or marginal motivation (p. 61)".

The number of the studies about computer games and instructional technology is accumulating. Although there is a continuous accumulation of the information in the area of computer games and education, these two disciplines seem to stand apart and do not utilize each others' knowledge.

1.3. PURPOSE OF THE STUDY

OECD's (2005) report emphasizes the discrepancy between R&D intensive supply and consumer side in the computer and video game world. In the same manner, Mitchell and Savill-Smith's (2004) review showed the state-of-the-art of the computer games in education and requirements of further research on these areas. The main purpose of this study is to provide attentional and cognitive data by the help of eye tracking techniques about processes of learning experiences of computer games.

Foreman (2003) argued that classical lecture style might be replaced by immersive digital computer-games; and the worlds of computer games and education are converging day by day. Gee (2005) proposed that computer games can be guide to design environments to teach complex and difficult scenarios to children. He describes game designers as practical theoreticians of learning, because they can convince children to solve complex and difficult problems on a voluntary base. He compared the features of games and the principles of learning such as active role of participants, different styles of learning, deep learning and commitment, interconnection of cognitive constructs, problem solving. He explains each principle with the help of games.

A group of researches try to integrate eye tracking technology and adaptive e-learning strategies. Gütl, Pivec, Trummer, Garcia-Barrios, Mödritsher, Pripfl, Umgeher, (2004) thought that eye tracking can provide real time feedback to personalized learning content with dynamic background library.

Previous studies about computer games which used eye tracking technology showed that eye tracking is an appropriate method to study computer games since eye movements can be operationalized and computer games have measurable effects on eye movements. Therefore, the aim of this study can be put as "how novices learn to play a computer game? To investigate this question eye tracking method was integrated with usability studies' conventional methods during computer game learning experience.

The approaches of Gütl and colleagues (2004) and Gee (2005) to new instructional styles require further data to reach any conclusions. The results of this study will reveal information about computer game players' interest areas during playing a computer game. Specifically this study will try to answer the following research questions.

- What are computer game playing patterns of students?
- Which strategies are used to learn a new computer game?
- How does attention of students change during game playing at different levels and different parts of the computer game?
- What are the usability issues of the computer game played by students?

1.4. SIGNIFICANCE OF THE STUDY

Descriptive outcomes of this study can be used by game designers and instructional technologists. Game designers can use gamers' fixation and eye movement to design better environments. Instructional designers can use the data to design more optimized game like learning environments to create attraction and flow. Eye tracking patterns can provide information to designers about their target client characteristics. Cognitive scientist can use data to obtain some clues about recognition and decision making.

Sennersten (2004) proposed that future studies in eye tracking and computer games can be integrated into a behavioral scheme to create a "visual grammar (p.40)". This grammar can be used in systems of learning, communication or linguistics. Any contribution to the visual grammar can be applied to design of educational environments.

Games have surface and deep structures (Gredler, 2003). Surroundings and observable mechanics constitute surface structure, psychological mechanisms, on the other hand, are base for operations during experience. Both deep structures and surface structures can provide a conceptual framework to study theoretically games. Describing convergent and divergent features of structures can help better understanding of games.

CHAPTER II

REVIEW OF LITERATURE

Computer games and their use in education has been a popular but controversial issue. Their relation to each other is interwoven. In order to better understand this relationship, historical overview of play, games, and education will be visited. The effects of recent developments on the relationship between play and education will be investigated after historical background, which include development of computers and computer games, their relationship with humans and the available methods of human-computer interaction.

2.1 FROM PLAY BEHAVIOR TO GAMES

Play behaviors were used as one of the earliest methods for instruction. The use of play behaviors for educational purposes can be dated even earlier to prehistoric times. It is known that animals -e.g. big cats, dogs, and primates- can benefit from plays to transfer their survival skills to their offspring. This perspective indicates evolutionary value of play behaviors in education. Play behavior can be asserted as the natural form of instruction if such a natural form ever exists. It has been used long before spoken language was evaluated as a form of communication to transfer the skills to next generations. Play behavior is mandatory for animal and human existence (Bower, 1974). In his classic study titled Homo Ludens which was first published in 1938 Huizinga (1955) indicated plays' long anthropological history. He claimed that play is not only a biological phenomenon but also a cultural phenomenon. Play has a crucial role in the development of culture and civilizations. He explained the effects of play on language, stages of civilization, and in the culture in terms of law, war, poetry, philosophy, and art. Huizinga points that all the components of play is a serious and essential phenomena for culture with its all aspects.

As compared to animals, the role of play behavior in human society has undergone some changes. Although play was a unique tool for animals, human kind invented and preferred speech and later writing as tools for education. Although, play behaviors had loosed their evolutionary value, children still play, and learn much from games spontaneously without any formal instructional plan.

Huizinga (1955) used the term "play" rather than game, and he defined the play as free activity that is apart from daily life and thought to be as not being serious. His concern is about play includes functions and higher forms. These are contest or representation of something which were inherited in games. Games are described as more structured actions based on play behavior. Webster's New World Dictionary's (1988) game and play entries are given below.

> game (n) 1. Any form of play or way of playing; amusement, recreation; sport; frolic; play 2. a) any specific contest, engagement, amusement, computer simulation, or sport involving physical or mental competition under specific rules, as football, chess, or war games b) a single contest in such a competition [to win two out of three games]. (p.554)
>
> play (vi) … 2. To amuse oneself, as by taking part in a game or sport; engage in recreation 3. To take active part in a game or sport (p.1035)

Despite their amusement or entertainment characteristics, games have generally contest towards a rival or several self trials to reach best score. Although games tend to have rules, routines, scores etc. play refers to as a collection of behaviors and actions which were conditional for games. As result of intertwined characteristics, games and play behavior can be used interchangeably throughout this study without any clear cut borders. Games, however, are taken into account generally as more developed and higher order complex forms of playing which are unique to human kind.

Caillois (1958) criticized Huizinga's (1938) conceptualization of play for ignoring diversified forms of play. According to Caillois, an activity must have some characteristics to be defined as play. These characteristic are, free will to join, having limits in terms of time and space, uncertainty for results, unproductivity, governing by rules, and having the quality of artificial awareness and semi-acceptance about genuineness. He classified games based on their dominant and fundamental features; competition (agon), chance (alea), simulation (mimicry) and vertigo (ilinx). Football or chess are examples for competition, a lottery or dice for chance, a theatre performance for simulation, and whirling dervishes for vertigo respectively. He also implied that some of the games do not imply rules such as playing with dolls, soldiers or any other toys.

Table 2.1. Classification of games

PAIDIA (Play)	AGON (Competition)	ALEA (Chance)	MIMICRY (Simulation)	ILINX (Vertigo)
Tumult Agitation Immoderate laughter	Racing Wrestling Etc Athletics	Counting-out rhymes Heads or Tails	Children's initiations Games of illusion Tag, Arms, Masks, Disguises	Children "whirling" Horseback riding Swinging Waltzing
Kite-Flying Solitaire Patience Crossword puzzles	Boxing, Billiards, Fencing, Checkers, Football, Chess	Betting Roulette Simple, complex and counting lotteries		Volador Traveling carnivals
	Contests, Sports in general		Theater Spectacles in general	Skiing Mountain climbing Tightrope walking
LUDUS (Game)				

(Calliois, 2001, p:36)

Caillois suggested an additional dimension for activities to depict degrees of game vs play characteristics which both have. He used paidia (play) and ludus (game) as the two principles that refer the opposite sides of a continuum. (See Table 2.1) These attempts to define games and play showed that although play and games are among well-known concepts, definition of them is not an easy job.

2.2. GAMES AND EDUCATION

Throughout the history, the games and education affected each other at various degrees. Kilpatrick's remark (as cited in Mitchell and Mason, 1937, p.86) "in all educational discussion there is scarcely a word upon whose meaning there is so little general agreement" has been a hindsight and a foresight of endless efforts to integrate games into education for previous centuries and seems it will continue for a while.

There are many examples about use of games in education. In ancient times Plato considered children's play to maintain or not to maintain laws. Furthermore, Aristotle pointed the necessity of children's amusement experience during playing. Comparison of Aristotle's and Plato's point of view of games in terms of education requires a physical orientation rather than a philosophical one (as cited in Mitchell & Mason, 1937). Cohen (1993) mentioned that French philosopher Rousseau was perhaps the first thinker who proposed games for educational and cognitive purposes. Rousseau's work "Emile" which was related to education and published in 1762 accounted as first study which contained the features of game by Cohen. According to Rousseau, play is all for children, and they cannot differentiate between game and work. Plays make children nicer and they also have right to play. Cohen argued that the thoughts of Rousseau were inspiration for educators like Pestalozzi, Froebel, and Montessori who were prominent figures in childhood education.

From the educationalists point of view play has been a part of curriculum since the times of Friedreich Froebel who established kindergarten in childhood programs. Maria Montessori also integrated play in her curriculum. However, their purposes to use play in educational settings were different. While Froebel used play to make children acquired with spiritual meanings, Montessori used play to achieve better understanding objects and some specific skill for children. (Sarocho & Spodek, 1998). The wide meanings of play make it difficult to define. Classical theories of play try to explain why play exists and what its function is.

On the other hand, modern theories of play try to understand the content of the play. Freud's and Piaget's theories can be accounted for models of modern theories (Ellis, 1973; Sarocho & Spodek, 1998).

Gillespie (1974a) traced the use of games for academic purposes at RAND Corporation's studies. RAND Corporation's[1] studies were primarily related business and military worlds, but soon they realized that those studies can be extendable to all levels of education. Gillespie proposed a model to draw a frame for research and curriculum applications beyond early reports about success stories of game in education. His model based on structural and functional analysis of games in which play considered individualistic and games considered with their social orientation. Distinction between game and play is also valid in education. According to Gillespie (1974b), this is main functional discrepancy between play and games. Structurally play is spontaneous event which has uncertain range scope and course. Games, in contrast, have boundaries, rules, and repeatable quality as far as desired. Interestingly lack of systematic research on games before 60's pointed a disparity between prevalent occurrence of games in education and research on it.

Simulations are another category which coexists with games, but should not be mixed. Gredler (2003) stated that "the use of games and simulations for educational purposes may be traced to the use of war games in the 1600s (p.571)". The use of simulations starts with war like environments and in 1950's they became standard in Pentagon, business and medical education. In simulations, gamers do not have to win or contest something or someone else. Rather in simulations, the number of variables is huge which effect outcomes.

Definition of relationship between games and simulations is not clear. Tansey and Unwin (1969) claimed that drawing a border between games and simulations is not beneficial, Jones, in contrast, (1987, cited in Gredler 1994) argued that they are unmixable like water and oil. Additionally Brougere (1999) pointed to

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[1] www.rand.org – where more corporation information can be found

different approaches towards elements of play among children and gaming or simulation among adults. Brougere claimed that theoretical basis of play related to education was studied rhetorically even if their scientific justification is uncertain. Moreover, gaming or simulations of adults have no theoretical framework apart from adapted psychological theories which were originally developed for children. Similarly Cohen (1993) pointed that previous studies of psychologists such as Piaget (1951) were far away from suggesting terms for adult games. Piaget considered adult games as a continuum of games of children. As a result those theories are inadequate to produce empirical data for adult gaming and simulation.

Gredler (1994) defines five characteristics of simulations which were present in both types of simulations namely tactical-decision simulations and social process simulations. First of all, simulations are problem-based units of learning. Secondly, the problems in simulations are ill defined and they do not have clear answers. Third, participants' role, setting, and functions are connected. The chance factor is nothing to do with outcome in simulations. The last factor is the participants' level internalization of role is linked with simulations structure. Games, on the other hand, have their own rules and regulations specific to them. Design of game is limited to the creativity of human mind. The outcomes of the game, such as defeat the component, solving the problem are well defined compared to simulations (Gredler, 1994).

Approaches towards game or play are not always encouraging among researchers. Oliver and Klugman (2003) point some possible problems, how play may be problematic in educational settings. One of them is that play may not be joyful for all of the children for all of the time. Secondly, some children can exhibit mean behaviors towards others while playing. Last but hottest debate about games is for violent content in games whether it is transferred out of games or not. Unfortunately studies have not revealed consistent results yet. It would be safe for researchers to consider those mentioned possible challenges of games, if they have been planning to use games in their studies.

Cited studies showed that defining the play or games is not an easy and necessary job. The use of plays and games without and widely accepted definition or classification in educational setting has still high potential. There are abundant researches about use of games in education, and most of them favoring games to use somehow in education.

2.3. COMPUTER GAMES AS EDUCATIONAL TOOLS

Computational developments after 50's have created new horizons for all aspects for life. Spread of computer lead researchers think about how computers can be integrated into education. And to some extend they could have been accomplished this aim. Education without computers is almost not conceivable today. The generations after 80's had born into era of PCs', Internet, GSM etc. and they cannot imagine the world without those technological instruments.

At the early stages of electronic devices, researches were aware of potential use of them in education. Tansey and Unwin (1969) devoted a chapter about computers and simulations quite before spread of computers into the consumers' everyday life. They outlined the possible benefits and applications of computers, but complained about demarcation lines between disciplines even though inclination among behavioral scientists towards computes almost four decades ago.

But inclination of behavior scientist toward computers may not be case as Tansey and Unwin (1969) implied. It can be quite optimistic observation. Allen and Ross's (1974) study titled "The Simulation of Computer Assisted Instruction Program for Teaching A-Non Simulation Game: MEEMI-EQUATIONS AUTO-MATE IMP (Instructional Math Play) Kit #1" reported an instructional game which imitated CAI and can be played without computers. Although Allen and Ross (1974) pleased with studies conducted about use of games for education among independent research groups and universities, they did not seem to share the idea of necessity of computers to play games. Their view reflected that computers are only tools which lead to quantitative changes rather qualitative ones.

Computers and computer games diffused into daily life suddenly as compared to long lasting history of studies about games or education. In a way education professionals were caught unprepared. Although their mass efforts to join common points of computer games and instruction remains unsolved. According to Foreman (2005), huge industry and business behind computer and video technology invent tremendous money to this area, whereas educationalist cannot create projects to produce funds to integrate computer games and instructional technologies. James Newman (2004, cited in Esposito, 2005) gives the reasons to study computer games. These are “the size of the computer games industry; the popularity of computer games; computer games as example of human-computer interaction”. Hitherto, this study is aiming to contribute to this unknown area by presenting descriptive data about learning computer games.

2.3.1. HISTORY OF COMPUTER GAMES

Although, the history of games is as old as history of humankind, the history of board games before digital era could have been traced back to only about 3000 B.C. Different sources give slightly different dates about emergence of ancient board games, Royal Game of Ur from Mesopotamia and Macala from Sahara, Senet from Egypt can be accounted being among earliest (History of Games, 2005).

Ralph Baer was the originator of video game idea at 1951 when he was working for Loral Television Company. Unfortunately he could not convince his superior engineer at the company to produce TV’s with games. One year later, in 1952, A.S. Douglas created first graphical computer game to receive his Ph.D. at human computer interaction at University of Cambridge, UK. This game was a version of Tic-Tac-Toe game and run on EDSAC vacuum tube computer. 1958 William Higinbotham created another video game in for an oscilloscope in Brookhaven

National Laboratory named Tennis for Two which can be played by two persons. Steve Russell and friends created Spacewar game at 1962. They programmed Massachusetts Institute of Technology's DEC PDP-1 Computer with randomly appearing stars, gravity and spaceships. This was astonishing realism at those days (Bellis, 2005; Winter, 2005).

Winter (2005) opposed the idea that the games mentioned above were video games. He argued that those games should be classified as computer games, because they are not available apart from expensive and rare mainframes. According to Winter, the history of video games start at 1966, with Ralph Baer's studies who was cited as the owner of video game idea. Baer designed a series of playable video games; chase game, ball and paddle games, target shooting games, and etc. After several demonstrations to producers his first game system was released at 1972 called Odyssey. This was the initiation of PONG like arcade games across USA and Europe.

By the establishment of Atari and arcade games, the times of video games were unveiled. Arcades and derivations were dominated the market until mid of 80's. At 80's PC's and its forerunners such as Commodore 64 or – Sinclair ZX Spectrum in Europe – were available in market (Yılmaz & Çağıltay, 2004). At 80's those arcade games were very popular to spend pocket money for generations above 35 years of age like author of these words. After 80's PC games became more prevalent and arcade saloons were lost their popularity. But at the same time the popularity of computer games were increased. At the first half of 90's the increase in the power of multimedia capacity lead the games graphically more complex and unobstructed by computational bottlenecks.

2.3.2. TYPES OF COMPUTER GAMES

A comprehensive but concise definition of computer games would be safe opening to introduce the subject matter, but no coherence on this issue, alas, could be achieved yet. Being known by everybody or being contemporary issue did not make them easier to define. On the other hand, lack of widely accepted and cited definition does not mean it is a vague to everyone.

One of the proceedings of DiGRA (Digital Games Research Association) 2005 Conference was aiming to define "what a video game is". In this proceeding Esposito's (2005) recent possible video game definition is as follows;

> A video game is a *game* which we *play* thanks to an *audiovisual apparatus*, and which can be based on *story* (italics original). (p.1)

Esposito (2005) underlines four elements for video games emphasized by italics. Afterwards he explains those four elements. Video games are still games, and everybody knows what a game is. Play contains activities of game systems. Audiovisual apparatus refers electronic system to compose human-computer interaction such as mouse, keyboard, or monitor etc. The video games may base on a story, but this is not a core element for video games. The video game such as Tetris can be an abstract challenge. He argued that having a good definition of video games would have been useful to construct academic works on it.

Smed and Hakonen (2003) preferred more analytical approach to provide a definition to computer games. Smed and Hakonen started their article by repeating the essentials of game theories that were mentioned as somewhere earlier, which were challenge, conflict and play. "A computer game is a game that is carried out with the help of a computer program" (p. 3). The critical point in this definition is the locating the games out of the computers. Computers act as facilitators in this definition. In this regard Smed and Hokonen's definition is compatible with Esporitos' (2005) definition.

Smed and Hakonen (2003) are figured out the story component of the computer games by help of state diagrams which were directed graphs and often used to "represent the transformations of the internal state of the machine" (Sudkamp, 1997, p. 156). State diagrams are useful in solving computational complexities.

Smed and Hakonen pointed that the more branching in graphs, the more freedom player felt.

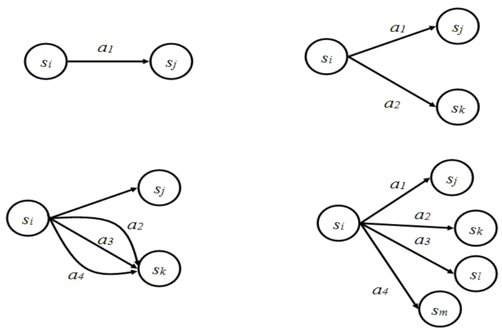

Figure 2.1. State diagram of story in computer games.
(Smed & Hakonen, 2003; Kaukoranta, Smed, & Hakonen, 2003)

In academia accumulation of works on a topic lead reviews in literature. More frequent emergence of books, reports and reviews about in computer games are a sign of increase and maturation in computer game studies. Dempsey, Rasmussen, and Lucassen, (1996) systemically reviewed and grouped 99 related articles about instructional games. In their article, a table presented which includes statistical analyses, categories, environments, and purposes about those 99 articles. However, their report includes only instructional games which can be classified a subclass of computer games. Strover and Pelletier (2003) bring together studies which have potential effects on future research. The bibliography contains studies which have theoretical significance; be survey oriented. Final criterion to appear in the bibliography was the presenting data about cognitive development or learning acquisition related to computer games.

A recent review by Kirriemuir and McFarlane (2004) about games and learning categorized computer games. As Kirriemuir and McFarlane said there is no standard categorization in computer games industry; computer game developers, review sites or dealers can use different categorizations. They prefer and used the categorization Herz's (1997, cited in Kirriemuir and McFarlane, 2004) in his well known study Joystick Nation. This categorization should take into account as an example of possible proper categorizations.

Table 2.2. Categorization of computer games

Action Games	These can be categorized into shooting games and platform games and other types of games that are reaction based.
Adventure Games	In most adventure games, the player solves a number of logic puzzles in order to progress through some described virtual world.
Fighting Games	These involve fighting computer controlled characters, or those controlled by other players.
Puzzle Games	Such as Tetris
Role-Playing Games	Where human players assume the characteristics of some person or creature type, e.g. elf or wizard.
Simulations	Where player has to succeed within some simplified reactions of a place or situation e.g. mayor of a city controlling financial outlay and building works.
Sports Game	
Strategy Games	Such as commanding armies within recreations of historical battles and wars.

(Herz, 1997; cited in Kirriemuir, & McFarlane, 2004)

This categorization belongs to 1997, since then there have been many games in the market which were not compatible with this taxonomy such as football manager games. (Kirriemuir & McFarlane, 2004). Another classification in a report by McFarlane, Sprarowhawk, and Heald (2002) offered the list genres of games in eight headings. These are adventure/quest games, simulations, race games, maze games, edutainment activities, creative/model building, shooting/arcade games, and traditional games.

2.3.3. USING COMPUTER GAMES IN EDUCATION

Educationalists were aware of computer's potential since their invention. However this is not valid for computer or video games. On the other hand, attention on using computer games for educational purposes has increased as time passed. However, it is not clear whether unavoidable rise of computer games gathers researcher's attention, or researchers became conscious about traditional games were converted into computer games and they should study computer games henceforth of their own volition. Whether computer games should be regarded as either threat or opportunity for the forthcoming generations, clearly, they cannot be disregarded.

Computer games were used for drill and practice activities which were already existing instructional programs. Simulations used as cheaper equivalents of very expensive military or aviation systems. And some simulations were mimicking only some facets of very complex conceptual frameworks. Second types of simulations should not be only computer based; they can be traditional war games. Mistakes in simulations would not result in life loss or irreversible faults in systems (Squire, 2003).

Since early 80's, researchers have been aware of and using computer games for educational purposes. For example Bowman (1992, cited in Squire, 2003) inspired from Pac-Man to develop instructional tactics in classroom. White (1984) designed some game like programs to help physics students to better understand Newton's laws of motion at Massachusetts Institute of Technology.

Computer game is still a game although they are played in front of a console or a computer. Whether traditional or computer based, it is clear that games have common characteristics and functions. Gredler (1994, 2003) mentions two structures for games: surface and deep. Surface structure refers to observable characteristics and equipments of games; deep structure, in contrast, refers unobservable cognitive and behavioral components of games. There are many shared surface and deep structures among games. In order to integrate games into the instruction instructional professionals have to refine the shared functions of deep structures of games. Cognitive structures and effects of computer games on players will be mentioned later in the text.

Foreman (2004) spoke with four well-known thinkers in the area, James Paul Gee, J.C. Herz, Randy Hinrichs, Marc Prensky, and Ben Sawyer. He asked their views about simulations, game-based communities, promises of computer games for better learning environments and necessary paradigm shifts in the education. Foreman asked why computer games improve learning. Herz answered that discourse is important point. Simulations can be used for discourse. Hinrichs' answer is the obtaining fluency in language and activities by the help of games. Gee's point is that cognitive readiness. He emphasized big gap between presented material of instruction, and demands of children in all stages of education. Games are very powerful in terms of reflecting learning principles when needed. Principles of up to date cognitive science are engaged in computer games. Prensky underlined the frequent decision making demand of computer games as the most important factor of computer games.

Additionally Foreman (2004) asked what required changes are in instructional system and what they will suggest to implement game-based learning to improve learning. In general all of them agree that administrators are not aware of the world of computer games. Sawyer mentioned that today's computer game players will became computer game creators and computer game communities of the future. Gee implied that current senior human resources should be retired.

Prensky (2005) has pointed another issue in his forthcoming article: the size of games. He divided games into two classes: mini games and complex games. According to Prensky mini games are not beneficial for educational purposes. Most of the games before computers were mini games and they were not required deep thought or high levels of learning except for few examples such as chess or bridge. Mini games were easy to learn and nothing to do with educational aims. Complex games, on the other hand, might have been used for educational aims which developed parallel to computers. Complex games generally required minimum ten hours to master. And most of the games sold in the market were complex games which were not experienced by adults quite possibly. To describe complex games "multiplayer, creative, collaborative, challenging, and competitive (p. 4)" concepts which were close to educationalists were used. Prensky argued that when adults talking about computer games they refer to mini games such as

Tetris, Solitaire etc. But they have to learn and grasp the meaning of complex games which are accounted as new species for computer games and how they can be integrated to instruction. Prensky cited Sim City, Civilization III, Rise of Nations and some other games as examples of complex games.

Although Prensky (2005) undervalued mini computer games as trivial, there are available data which support playing computer games for instructional and educational purposes. Next section will be concentrated on more specific on cognitive and social outcomes of computer game playing.

2.3.4. INDIVIDUAL OUTCOMES OF COMPUTER GAME PLAYING

Computer games can affect children who played them quite diversely. Aspects of the computer games can be a guide to outline outcomes of computer game playing. Computer Games in Education Project (BECTA; British Educational Communications and Technology Agency, 2001) represents aspects of games as follows.

Table 2.3. Aspects of computer games

Technological	Narrative	Personal
Graphics	Novelty	Logic
Sound	Story line	Memory
Interactivity	Curiosity	Reflexes
	Complexity	Mathematical skills
	Fantasy	Challenge
		Problem solving
		Visualization

(BECTA, 2001, p. 1)

According to BECTA's (2001) report, visualization is a key cognitive strategy to integrate games into education. Moreover problem solving skills, strategic planning, and memorization are critical aspects of computer games to educate self-governing and creative generations. Motivation is another feature of computer games that brings power and strength to them. The report lists the research areas of computer games and possible investigation subjects about computer games. Development of resources for instruction, social issues, and classroom dynamics are research areas. Multi-user computer games, networks, asynchronous games, collaborations, recording computer game playing patterns and behaviors for later analysis are main prospective research areas.

Cognitive research about computer game players suggest that action games modifies both visual selective attention (Green & Bavelier, 2003), with different levels such as increased attentional resources and preattentive processing (Riesenhuber, 2004). These effects of computer game playing can be considered as products of deep structures (Gredler, 1994) of computer games.

Transfer of expertise from one field to another has always been problematic in instruction. There are incompatible findings about transfer of expertise and skills to future. Sims and Mayer (2002) tested Tetris players whether they can transfer their expertise to other spatial abilities. Although Tetris players were performed better in mental rotation procedures when tested same of similar Tetris shapes, the performance difference were lost with other shapes. Those results suggest that expertise in computer games is domain specific. Gopher, Weil, and Bareket (1994) conducted a study to test the transfer skills from a those days complex computer game to the flight performance of trainees in the Israeli Air Force. They found that ten hours of training in computer game produced better performances in test flights.

Pillay (2003) found that playing recreational computer games may affect performances of computer-based learning tasks of children. This influence is depending on type of games played before learning phase. Linear strategies increased the possibility of means-end analysis and adventure games increased the possibility of proactive thinking.

Prensky (2001) speculated that the brains of Digital Native’s are physically different from others due to their expositions to digital input. Although, he listed a bulk of pro evidence from neuroscience, social and cognitive psychology such as thinking differently, expanded attention spans and parallel processing abilities etc, his charming proposition ought to be handled cautiously.

Another wish about computer games is that availability of them public libraries, because many children spend more time in front of them compared to books. Since computer games might be change the perception of literacy among children in the future, it would be better idea - or study topic at least – to get ready adopt libraries forthcoming generations (Robertson, 2004).

The effects of computer games has not limited to only players but also their social environments. The pattern of interaction has undergone change since the invention of computer games. Kirriemuir and McFarlane (2004) condensed the whole story about social impacts of computer games as follows.

> A research into the wider context of games play indicates that, contrary to populist media opinion, games are often a facilitator to social, communication and peer activities. This has always been the case; in the early years of computer gaming, a 'playground culture' of discussing, swapping, buying and selling games emerged. (p.10)

Computer game players reported that interaction with others is one of the reasons in addition to challenge and fun aspects of the games (Kirriemuir & McFarlane, 2004).

A recently a posted news indicated an interesting effect of computer game playing. This news emphasized that computer game players may display exceptional business skill. Although it is not definitive whether playing computer games is a cause or result, owners of companies want to see computer game players at their work environments (Antonucci, 2005).

2.3.5. COMPUTER GAMES AND INSTRUCTIONAL DESIGN

Cognitive and social outcomes of the computer games have been reviewed in previous section. Popularity and effective nature of computer games on individuals have directed the researchers to form models for instruction and computer games. Since models offer theoretical outlines to study computer games, creating models which incorporate all advantageous aspects of computer games can be accepted ultimate goal of computer game studies by education scientists.

Instructional models which use computer games are not frequent among computer game studies. For example, Akilli (2004) in her thesis conducted a formative research. She proposed an instructional design/development model called Fuzzified Instructional Design Development of Gamelike Environments (FID^2GE). She expects that her model may be used for creation of game-like learning environments for computer games.

At the same manner, Dickey (2005) pointed that instructional technologists are disposed to borrow techniques from various newly developed techniques such as film, television and comics. Computer games, however, ignored in terms of developing new methods for instructional models despite a body of research about computer games or availability of edutainment material in market. Dickey's research investigate how computer games help instructional technologists to create engaging learning environments convenient to several instructional theories such as constructivism, problem based or project based learning.

There is no consensus on evaluating effects of computer games or novel educational technologies in general. Margolis, Nusbaum, Rodriguez, and Rosas (2004) suggested a methodology to investigate effects of novel technologies. They used portable computer games to test their three stepped methodology: Benefit analysis, followed by a well designed experiment, cost analysis, and feasibility analysis. They concluded that, although using handheld games cost effective, corporation of feasibility analysis into general methodology indicated possible challenges in implementation.

Another recent study by Kiili (2005) encompassed experiential learning theory which requires immediate feedback of the participants. Kiili's study based on flow theory. Flow theory (Csikszentmihalyi 1975; Csikszentmihalyi 1991 cited in Kiil,

2005) mentioned at last but not least was one of the central concepts in computer games. Csikszentmihalyi's studies have provided basis many studies in computer games motivation, engagement, entertainment etc and can be used increase the effects of computer games. General structure of Csikszentmihalyi's flow theory is depicted in Figure 2.2. Kiili's assumed that experiential gaming theory can be used in analyzing and designing computer games.

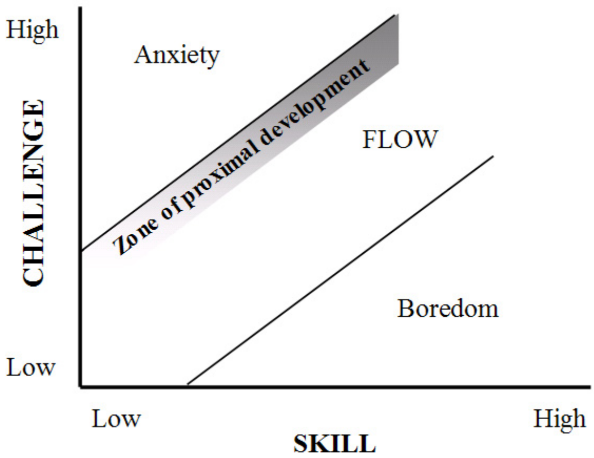

Figure 2.2. Three channel model of flow
(Csikszentmihalyi, 1975 cited in Kiili, 2005)

According to Rieber, Smith and Noah (1998) long lasting involvement, motivation and higher order creative activities reaches at their climax while playing. Rieber, Smith and Noah claimed that learning and motivation and instructional technology are complementary parts of the same issue. According to them play can be a perfect model to build bridge between human cognition and educational applications of technology which has an interdisciplinary history in humanities fields and apparent compatibility with interactivity and environments created by the help of computers. The paradigm changes in the field of IT, from behaviorism to cognitive approaches and dominance of constructivist orientations with the availability of computers can be sign of appropriate of time of reconciling computer games, and known motivation and learning theories (Rieber, Smith and Noah, 1998).

Computer game studies have prompted an old four blind Indian story. Four blind Indians try to describe an elephant and each of them describes elephant differently as far as they experienced. Computer games are outsized to study in a research project. Their development speed is far faster than their investigation studies. At this point researchers should be aware of the fact that they are far from taking the whole picture of what is going on in the computer games world. Since the worlds of computer games are a mammoth, this study is conducted to provide a little more information about one of descriptions of four blind Indians. This Indian describes the computer games mammoth by using the methods of usability studies.

2.4. HUMAN COMPUTER INTERACTION AND COMPUTER GAMES

ACM SIGCHI (Hewett, Baecker, Card, Carey, Gasen, Mantei, Perlman, Strong & Verplank, 1992) defines Human Computer Interaction (HCI) or Computer-Human Interaction (CHI) which preferred in US frequently (Faulkner, 1998) as follows:

> Human-computer interaction (HCI) is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use, and with the study of the major phenomena surrounding them.
>
> …
>
> Human-computer interaction is concerned with the joint performance of tasks by humans and machines; the structure of communication between human and machine; human capabilities to use machines (including the learnability of interfaces); algorithms and programming of the interface itself; engineering concerns that arise in designing and building interfaces; the process of specification, design, and implementation of interfaces; and design trade-offs.

The development of human computer interaction field has two sides. Former is research side, which consist of designers, programmers, producers etc. Latter is human side. Psychology, design, human factors and ergonomics contribute to human side of interaction. Most of the common and current technologies have developed in university and corporate research laboratories. Technologies such as, mouse, windows, text editing, manipulation of graphical objects were parts of research projects at universities or labs, long before they were commercially available at market (Myers, 1998).

Three concepts: usability, universality, and usefulness are essential for HCI studies' future. A system must cover these there features. A novel system must be reliable and usable for new users. Additionally the newly developed system must be accessible for different backgrounds such as culture, language skills, and social norms. The last feature usefulness refers the vital importance of the system for humans. E-healthcare, e-learning, e-business, and e-government are examples for urgent applications (Shneiderman, 2003). On the other hand Dillon and Watson (1996) underlined that in order to gain predictive power for HCI studies, more than 100 years are required in individual differences studies. To clarify their point it would be helpful to recall that measurement of individual differences constitutes the preliminary studies of experimental psychology.

Faulkner (1998) refers twelve disciplines as the building blocks of the HCI. They are Computer Science, AI, Anthropology, Ergonomics, Linguistics, Philosophy, Art, Sociology, Design, Psychology, and Engineering. If these disciplines are the building blocks of HCI, some other disciplines constitute the implications of HCI. First of all, -although its is rare- outcomes that effect well being in general imply the health issues of HCI, The results related to cost of products points the importance of HCI in economics, and the learning performance, attitude and decision making data obtained by HCI studies can be integrated to education.

Karvonen and Parkkinen (2003) reported novel methodologies for HCI studies. Those are, tracking eye movements, psychophysiology in laboratories and contextual design, focus groups, user experiences and quantitative measures combined with qualitative measures away from usability laboratories.

2.4.1. EYE TRACKING STUDIES AT LARGE

Tracking eye movements is important because, eye tracking is an operational measure for attention which was one of the major components of sensation-perception-cognition span. Eye tracking studies extent from psychology of reading to dyslexia, scene perception to problem solving and language processing.

Rayner (1998) classified eye tracking research into three eras. Javal's initial observations about role of eye movements in reading in 1876 accounted as first studies about eye movements. Up to 1920's essential facts about eye movements were discovered. Those are saccadic latency, required time to start an eye movement, saccadic suppression, inability to perceive any information during eye movement, and perceptual span, which was area of effective span. In the second era of eye tracking, research were generally about application of eye tracking technologies rather than inference to cognitive processes. Until mid-1970's eye-tracking studies were repressed by behaviorist approaches in view of the fact that eye tracking may refer to cognitive concepts. After mid-1970's eye tracking research has started to investigate cognitive processes. For a comprehensive review for a century of eye tracking literature Rayner's (1998) paper should be visited. Rayner pointed out that although data obtained by eye tracking experiments hold some generalization problems, they are valuable in terms of providing detailed data in information processes and they will be used to observe cognitive processes.

Earlier studies of eye tracking were invasive and sometimes required direct connection with cornea. The data collection procedures were become almost unobtrusive after 1970s. Eye tracking techniques generally used to usability and human factor studies generally in military settings to collect descriptive data about how eye operates and how eye movements can be linked to cognitive processes until 70's. They used only in usability and human factors studies before 80's, because there are no available computers except few labs around to study human computer interaction (Jacob & Karn, 2003) Afterwards spreading of commercially available eye tracking equipments and computers, eye tracking equipments gather attention again for HCI oriented studies.

Duchowski (2003) describes current position of theory and practice of eye tracking methodology for practitioners and graduate students who want to use eye tracking technology in their studies gratefully. He starts his book by considering attention historically and cites Von Helmholtzs "where" which stands for peripheral and James "What" which stands for foveal vision. Intentionality is another feature proposed by Gibson for visual attention in 1940's that describes "how" aspect of eye movements. There are several other approaches to attention cited by Duchowski (2003). These are, namely, Broadbent's "selective attention", Deutsch and Deutsch's "importance weightings", Yarbus and Noton and Stark's "scanpaths", Posner's "spotlight", Treisman's "glue", and Kosslyn's "window".

Speed of saccades has been reported differently by researchers. Whereas, Rayner (1998) report about 500 degrees in one second, Crowder and Wagner (1992) reported degrees about 100 to 200 in second. Wilder, Hung, Tremaine and Kaur (1999) accepted 70 to 600 deg/sec as the values of range of saccades. Whatever its total degree in second, saccades behaves like bullets, when they are initiated their directions cannot be changed. Duration of saccadic eye movements last about 10-20 milliseconds and he proportion of saccades constitutes only 6% of total time during an activity of eyes (Crowder & Wagner, 1992). Wilder and colleagues reported values of saccade durations between 30 to 70 msec depending on task of eye movements. Approximate values for fixation and saccades which differ according to type of activity are given in Table 2.4. As seen in table eye fixations are about one fourth of second and saccades are about two degrees in several reading conditions.

Table 2.4. Approximate values for eye movements

Task	Mean Fixation duration (ms)	Mean saccade size (degrees)
Silent reading	275	2 (about 8 letters)
Oral reading	275	1.5 (about 6 letters)
Visual search	275	3
Scene perception	330	4
Music reading	375	1
Typing	400	1

(Rayner, 1998)

Well known conceptualization of duality for human information processing is also valid for attention measured by eye tracking studies. The data obtained by eye tracking experiments support both bottom-up and top-down processing. Foveal visual attention seems driven by bottom up factors, in contrast to parafoveal attention which seems governed by top-down dynamics. Top down studies are theory driven which were based on theories and cognitive processes, bottom up approach, in contrast, attempts to analyze data provided by eye tracking without any theoretical base (Ramloll, Trepagnier, Sebrechts, & Beedasy, 2004).

Results of eye tracking experiments were analyzed differently. Some of the equipments which collect data at up to 60 Hz. called “fixation pickers”. And some equipments work at 250 Hz. which were sensitive to saccades and velocities of eyes, and they called as “saccade pickers” (Karn, 2000, p.87). The most frequent reported eye tracking metrics were fixation, gaze durations –cumulative or average of fixations on a specific spatial location –, scan paths or derivatives of these there measures. A full list of reported measures can be found in Jacobs and Karn (2003).

To sail in safe waters, theoretical and practical considerations of eye tracking will be skipped. Interested readers can apply to Duchowski’s article (2002) and his book (2003) to find out descriptions about human visual system, discussions about theoretical approaches about vision and attention, information about eye tracking equipments and software, different data analysis techniques of huge data provided by eye trackers, or applicability of eye tracking results in neuroscience, psychology, industrial engineering, human factors, marketing and computer science.

2.4.2. EYE TRACKING AND HUMAN COMPUTER INTERACTION

Schiessl, Duda, Thölke, and Fischer (2003) point out why eye tracking data need to be used when traditional usability techniques worked well previous human computer interaction studies. They underlined several inconsistencies between self reported data and quantitative data provided by eye tracking equipments throughout attention shifts which were assumed important in computer applications. They concluded that eye tracking equipments make available additional value in settings of usability testing. Since the eye tracking used as a method for attention almost a century in psychology literature, it likened phoenix, revisited by researchers each decades especially after 1950's. (Jacob & Karn, 2003; Senders, 2000). Time interval of revisits, however, may be reduced to every five years by some researchers (Wilder, Hung, Tremaine, & Kaur, 1999). Jacob and Karn (2003) surveyed the past work and reported that the most frequent use of real time eye tracking in the field of human computer interaction are studies that conducted with disabled typically quadriplegic persons who could not move any parts apart from eyes. For disabled persons, eye movements can be used as an input instrument to communication etc. But eye tracking or computing gaze technology is not reliable enough to implement those studies outside laboratory. Morimoto and Mimica (2005) suggested that remote eye gaze tracking with improved usability will solve calibration and head movement problems soon, and remote eye gaze tracking technology can be applied to interactive applications of general computer usage.

A research note by Namahn group (2001) draws a general outline, how eye tracking methods can be used for usability testing. The note discriminates eye tracking techniques into two: active and passive modes of studies. In passive modes subjects were monitored while performing a given task. These are, for example, a researcher can follow a pilots eye movements in a control room, or a psychologist can examine fixation patterns during reading, or a marketing researcher can observe which features of an add gathers attention on a screen etc. New environments can be created where disabled people can make help of eye movements to control their immediate environments. This is an example of active use of eye movements. As examples shown, eye tracking techniques can be used conveniently in usability, human factors, or human computer interaction studies.

Two recent articles by Russell (2005a, 2005b) are examples of combining eye tracking technology and usability of web page designs. Russell used eye tracking as supplement to traditional usability test measures. He proposed that eye tracking equipments can be used to determine areas of interest at web page. The areas can grouped being eye catching, informative, ignored, and distracting. Resolving the attention structure of the page can provide supplementary information in design issues.

Another study inquires the usability issues of search result about two different interface designs. Although subjective data provide no differences between tabular or list type search results, eye tracking results supplemented with error and time measures can offer designs including flexibility can yield better solutions (Rele & Duchowski, 2005).

Cowen (2001) investigated different web pages in an exploratory experimental study. Cowen found that different search types of search and processing behaviors can yield different eye movement patterns. Hornof and Halverson (2003) proposed that detailed modeling studies about visual and perceptual search strategies on web can provide the chance of a priori predictions about eye movements in before data collection procedures.

Computational modeling cognitive processes assume continuous visual input. They were not proper for intermittent input of fixations or attention shifts. Salvucci’s (2001) Eye Movements and Movement of Attention (EMMA) model is an example of that attempt to incorporate traditional cognitive models and data from eye tracking and shift of attention. The number of models which use state-of-art data will increase steadily as information accumulation continues.

Aaltonen (1999) mentions possible pros and cons of using eye tracking in usability testing. According to Aaltonen eye tracking methods were superior to think aloud protocols, because eye tracking is a direct measure of attention, whereas think aloud protocols may contain certainty problems. Additionally eye tracking can provide data to analyze gaze durations, scan paths which were required extensive effort in video recording settings. On the other hand researches should be aware of eye tracking can prone to noise during testing since attention can be easily interrupted by unpredicted factors. Re-calibration needs also may be arise if testing session exceed a certain time. The success rate in subject is another problem in eye tracking studies. Schnipke and Todd (2000) found that only 37.5% of the participants can be successfully eye-tracked. Besides problems, eye tracking equipments have great potential for usability studies and they should be used in laboratories in the future (Aaltonen, 1999; Schnipke & Todd, 2000).

2.4.3. COMPUTER GAMES IN THE LIGHT OF EYE TRACKING

Since the existence of computer games has been bounded to computers or consoles, it is not questionable to discuss their inherent human-computer interaction traits. It is known that the number of players and money spend for games is increasing constantly, and minor nuances has the tremendous potential to create unexpected commercial outcomes in the market. So, usability issues in computer games can not be ignored.

Designing games has certain aspects which were unique to computer game design. User centeredness, for example, has underlined a team from Microsoft Game Studies (Pagulayan, Keeker, Wixon, Romero, & Fuller, 2003). Pagulayan and colleagues mentioned that games and software products have some differences. Although everybody can easily distinguish a game and a productivity application, it is not easy to articulate differentiations between the two. Possible variations between productivity applications and games proposed by Pagulayan et.al. are listed at Table 2.5.

Table 2.5. Games versus productivity applications

Games vs Productivity Applications
Process vs Results
Defining goals vs importing goals
Many alternatives vs few alternatives
Generating variety vs being consistent
Imposing constraints vs removing or structuring constraints
Mood vs function
View of world or view of outcome
Individual as buyer vs organization as buyer
Form follows function vs function follows form
Novel input devices vs standart input devices

(Adapted from Pagulayan, Keeker, Wixon, Romero, & Fuller, 2003)

Despite difference between games and productivity applications, methods of usability studies about productivity applications can be utilized in computer game studies. Pagulayan, et.al. (2003) pointed out that traditional usability techniques can be used to observe the variables which were important for game design. However, traditional methods are not capable of explaining particular features of computer game playing such as pervasiveness or continuity in play. They conclude that "relationship between theories of game design and traditional HCI evaluation methods yet to be defined but definitely yields exciting future" (p. 904).

Decisions made during game playing can be branched into deep or wide. A simple tic-tac-toe game includes almost 30.000 possible moves. Possible moves of chess are far away from imaginations. Fortunately decisions in everyday actions did not wide or deep like games. They are generally shallow such as a restaurant menu or narrow such as a cookbook recipe (Norman, 1988).

Decision making in games requires pattern recognition. Recognizable phenomena in the games are the building blocks of patterns (Kaukoranta, Smed, & Hakkonen, 2003). Moreover, attention is a prerequisite for recognition and one of the best methods for quantifying attention is eye-tracking. Yoon and Narayanan (2004) found that visual representations in a given problem help the subjects to solve problem and reduce the cognitive load.

The capabilities of users are important in everyday actions. The physical capabilities are out of scope of this study. However, mental capabilities and predispositions are the important factors for the design of games and their use in education. The structure or types of memory and the game are directly related. Long term memory, working memory, short term memory and sensory memory are in touch with immediate environments of people. Distinctive features of memory such as digit span and perceptual phenomena namely closure, chunking, and primacy and recency effects must be taken into account in any entity interact with human (Faulkner, 1998). This approach to memory can be named as information processing approach. The capabilities of human mind can be observed by eye tracking methods. The movements of eye can be used as an observable measure of human mind. The designers should follow some features while they are developing an interface. The time passed to react and attention can provide feedback to designers. Eye tracking is the one of the measures of attention other than self report. Those observations lead the researchers to define some general guidelines in design of an interface.

Stewart and Travis (2003) reviewed the existing guidelines, standards, and style guides. They said that these guidelines exist because they impart consistency, good practice, common understanding, and appropriate prioritization of interface issues. They listed the headings of guidelines by Shneiderman (1998) and Neilsen (2005) which were available at his web page. The eight guidelines of Shneiderman underline the principles of interactive designs; Neilsen's usability heuristics covers most of the problems that obtained from his factor analytical studies. Although, Nielsen's ten guidelines are appropriate for experts' inspection based evaluations, they can be applied to evaluate the results of user-based approaches on an ad hoc basis.

Roles of software technologies in advancing research and theory in educational psychology have been reviewed by Hadwin, Winne, and Nesbit (2005) in a recent article. They sampled about 1500 articles published between 1999 and 2004. They grouped those articles into four areas which were "innovative ways of operationalize variables, changing nature of instructional interventions, new fields of research in educational psychology, and new constructs to be examined" (p.1). The first classification is important for current study, because of investigating computer games, which was well known by almost everybody, by the help of eye tracking methods, which were familiar to cognitively oriented researchers from different background, with glasses of instructional technologists is the novelty for current literature.

Recently, few pioneering studies appear to investigate computer games with eye tracking technology. Sennersten (2004), for example, studied eye movements in an action game tutorial. Sennersten found that not only eye movements dependent on tasks but also they can comparable with other actions such as car driving. Another eye tracking study conducted by Kenny, Koesling, Delenay, McLoone, and Ward (2005) is investigated into eye gaze data of in a first person shooter game. In their study the eye gaze data of playing a First Person Shooter (FPS) has been recorded like current study. Their study showed that a computer game could be synchronized with an eye tracking system. Results of their study showed that players of the FPS computer game spend most of their fixation time around the centre of the screen.

CHAPTER III

METHODOLOGY

3.1. DESIGN OF THE STUDY

This study consists of several phases. First phase was searching a computer game to fulfill studies' expectations. The chosen computer game has to have some characteristics. First, it should not be widely known. Because, if the game is known by everybody, it would be very difficult to find subjects who were familiar computers and computer games, but unfamiliar to target game. Second, chosen game should not include violence or should include acceptable level of violence, because of not to face with negative critics about violent nature of computer games which were unrelated to the aims of study. Third, the game should have free license or would be demo version because of copyright issues. The last characteristic was that it should be studied with an eye tracker easily which should have levels and distinct areas of interests. In the light of these criteria, "Return of the Incredible Machine: Contraptions" (Copyright by Sierra On Line Inc at 2000) was chosen as the most appropriate game for the purpose of this study. The information about game is given in materials section. Second phase of the study composed of pre-test sessions. Pretest-sessions were administrated to control, how people react to the design of the experimental conditions and to see if any modifications might be required during the experiments. Third phase of the study was the main study where the subjects joined the experiment.

3.2. SUBJECTS

Subjects were 16 undergraduate university students (15 male and 1 female) at Gebze Institute of Technology, Departments of Computer Engineering, Electronical Engineering, Material Science Engineering and Mathematics. The mean age of the subjects was $\overline{X}$ = 21.5 and SD = 1.32. All of the subjects participated in the experiments on a volunteer base. Each test lasted about 30 minutes and conducted individually. All of them reported that their English knowledge is sufficient to play the game. Although some of subjects use eye glasses, none of them reported vision handicap to prevent them seeing computer screen. Female subject was eliminated from subsequent analysis to control gender factor constant.

3.3. MATERIALS

During the study an eye tracking system bounded to a desktop computer, IBM Pentium4 Laptop with external microphone to record voices, and a digital Sony H8 video camera to record images were used. Eye tracking equipment recorded the eye movements of the subjects during playing computer game titled "Return of the Incredible Machine: Contraptions"

The questionnaire (See Appendix A) to collect subject's demographic data, computer and video game use patterns before test session was adapted from Onay (2004). The questionnaire has been reported as valid based on previous studies and has reliability of .80 (Onay Durdu, Tüfekçi & Çağıltay, 2005). After the test session, an interview was conducted with subjects. The aims of interview were to observe the attitudes of subjects toward computer game; try to obtain hints about their cognitive processes roughly and to find some clues about their strategies of learning the game.

3.3.1. EYE TRACKING SYSTEM

In the study Eyegaze system produced by LC Technologies[2] were used. This Eyegaze system includes basic video equipments -which were camera, light source with 880 nanometers (near infrared) wave length, supplementary display to track calibration-, computer hardware installed Windows NT/2000 environment, and Eyegaze software and C/C++ development libraries necessary to build and run eye tracking application programs. Although Eyegaze system supplies software to draw raw gaze and fixation gaze trace graphics, researcher used another C++ software to draw eye movements on screen shots which were written specially for this study.

General technical specifications of eye tracking system described at official web sites as follows: Eyegaze system indicates whether or not the eye ball is visible to the camera and a valid gaze point is calculated; x-y coordinates of the subject's gaze point on the computer screen; pupil diameter, 3-dimensional location of the eyeball center within the camera field-of-view, an indicator of head location and movement, and fixation and saccade analysis. The Eyegaze system generates raw gaze point location data at the camera field rate of 60 Hz (60th of a second).

The Eyegaze system uses the pupil-center/corneal-reflection method to determine the eye's gaze direction. The image processing functions in the Eyegaze System is implemented in software. The eye tracking functions compute the raw gaze point coordinates each 60th of a second in synchronization with the field rate of the video camera.

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[2] For more information please visit www.eyegaze.com © 2003, LC Technologies, Inc.

3.3.2. RETURN OF THE INCREDIBLE MACHINE: CONTRAPTIONS

"Return of the Incredible Machine: Contraptions" Downloadable Demo was released at 2000. In demo there are 10 levels from easy to quite complicate. Each level must be achieved before going to next level.

The game runs on Windows © 95/98/2000 system. Minimum requirements of system are, Pentium 90, 32 MB RAM, 4x CD-ROM drive, 50 MB of free hard drive, 800 x 600, 16-bit video resolution, DirectX(Trade Mark of Microsoft) 7.0.

Contraptions demo runs at 800 x 600 pixels in size and switch the color bit depth to 16 bit. But the Eyegaze system runs on at 1024 x 768 pixels in size. Although Contraptions demo adjust to full screen automatically while playing, resizing screen captures from 800 x 600 to 1024 x 768 required during analysis processes. Demo version of Contraptions does not have any digital voices.

Demo starts after two advertisement screen which include announcements. To go to next screen clicking anywhere on the screen is enough. Afterwards main menu appears (Appendix B, Main Menu). When player pressed “Play Contraptions”, first level appears (Appendix B, Level 1). The aim of the level is written in a box left-upper side of the screen just below start button that is “Get all the mice to a piece of cheese”. To achieve this aim player has two objects; cat and cheese. There are two clues, which are represented as interactive hands pointing where cat and cheese must be placed. Hands behave as hints about functions of objects in game and produce new windows when clicked on. If the player decides to place cat and cheese to correct locations, the game proceed next level after clicking start button at the very left-upper position on screen.

Other levels have also contraptions and more objects which have different functions. To solve contraptions, player must decide correctly which object should be placed in which location.

3.3.3. INTERVIEW

After the eye tracking recording session, an interview conducted with every subject. The aim of the interview was to collect data about attitudes and cognitive processes of the subjects. The interviews lasted about 5 minutes and included 5 questions. These interviews were digitally recorded and transcribed after data were collected from all of the subjects.

The questions in the interview were as follows:

Q1: Is it easy to learn this game? How do you describe this game?

Q2: How did you learn this game? Could you compare its learning style with other games that you play?

Q3: Could you compare it with other games that you play?

Q4: Do you remember the name of the game?

Q5: Do you remember the last contraption that you try to solve?

3.4. PROCEDURE

Before deciding which game will be used in the study, game genres and examples of these genres were investigated to find out which genre is appropriate for the aims of the study. Each candidate game was pretested with convenient subjects in terms of familiarity, attitudes toward game, and ability to learn in a self paced schedule. Some of the games were eliminated since they are simple, others eliminated because of they are complicated to show progress in planned 10 minute test session. Some of them eliminated because of intense keyboard use requirements which can result movement in head and interference with eye's calibration. After a passionate search, "Return of the Incredible Machine: Contraptions" was chosen, because it has no violence, requires decision making and problem solving constructs which are applicable in educational settings, it can be played only by a mouse, and not widely known among computer gamers. Additionally it is a 2D dimensional game that can reveal clearer results for X and Y coordinates on screen. 3D games would generate unexpected contamination on data.

The data collection procedure for each subject was completed in one session in the Computer Vision, Graphics and HCI Laboratory at Gebze Institute of Technology. Each subject was tested individually. Before the participants interacted with the computer game, they were asked to answer a questionnaire which includes questions about demographics, patterns of computer use and computer game playing. The second step was introducing eye tracking equipment and the game. Eye tracking equipment, calibration procedure and computer game was presented briefly. No information about game's characteristics was given to subjects except name of the game whether they know or heard about the game. None of the subject reported that they had played the game before. After giving the instructions about the game and equipment, the introduction about test session was worded as "Assume that you downloaded this game to your computer from the Internet and decide to play it first time alone. How do you learn to play this game? Try to think aloud what you are thinking or doing while trying to learn the game. Try to be natural and not to be anxious, because I do not care your competence in game playing, instead I wonder how people explore and react to a novel game without any previous information about a game".

After instructions were given, calibration of eye tracking equipment (Eyegaze) was made. Subjects were sitting at a distance about 60 cm from the computer screen. Subjects were told that they do not need to use the keyboard. The game can be played with a mouse easily. For each subject, 10 minutes eye tracking and Digital H8 videos recordings were kept. Although they were said that they were expected to perform a "think aloud" protocol during playing game, almost all of them forgot to perform it due to deep concentration. Hence, subjects were not interrupted to force them to perform their "think aloud" protocols during game although they have told at the beginning of the test.

At the end of the recording phase, interviews were conducted. During this stage the researcher tried to learn subjects' attitudes about the game and "how the subjects learn or could not to learn to play Contraptions".

Although the researcher was present during test session just behind of the subjects, to keep interruption level at minimum he tried to be stay in an unobtrusive manner except at the time of appearing risk of loosing calibration due to change in position of head involuntarily or help wanted such as asking a meaning of a word.

The data were analyzed in three steps. The demographics of the subjects obtained by questionnaire was the first step. The second step was the quantitative comparisons of the eye tracking data in terms of grouping variables such as coordination of fixation or level information. The last step was the qualitative analysis of post interview with subjects.

3.5. LIMITATIONS OF THE STUDY

Present study is not purely descriptive or experimental and quantitative or qualitative one. Its scope is so wide to control all variables and design an experimental study or so straightforward to develop a questionnaire which might lead a factor analytical study to find out its loading variables.

This study is a mixed study but not a motley one. It aims to observe the patterns of natural behaviors in an experimental setting as possible as in an unobtrusive manner. To keep the volume of the study in a manageable size, some of the possible variables were eliminated in planning phases. The questionnaire, for example, conducted before test session includes only key elements related to subjects' demographics, computer use, game habits etc. The interview which was conducted after test session includes only noteworthy few questions about the game.

The limitations during test session are related to technical restraints. The lack of second video recording device to record subjects' mimics or faces made not possible to analyze subjects' emotional responses during the game. Another technical issue at the design of the study is the synchronization of eye tracking device and video recording tool. Since they are synchronized manually, data collection and analyze procedures are not error free. Digitally controlled eye tracking and video recording might reveal more precise results about specific actions in contraptions game.

The study does not contain any sampling procedures. Subjects had been heard about the study by the announcements made by the instructors of their classes. All of the subjects participated in the study voluntarily. All but one of the subjects was male. Gender issue is another limitation of this study.

There are many types of computer games in the market. Although it is believed to be quite appropriate for the aims of the study, the chosen game might carry some limitations for the study. For example, it is not sampled from a universe. It was picked up from available sources.

The level of English proficiencies of subjects was not assessed by the experimenter. Although subjects were asked whether their foreign language level is enough to play, it might have affected the results.

There is no appropriate model or theory which can draw the general theoretical outlines of this study. Since this study aims to obtain descriptive data about learning experiences of a computer game from different sources, none of the approaches mentioned above covers the major part of the study.

On the other hand, these limitations can be converted to the strengths of the study, if the results can reveal consistent results or lead subsequent studies.

CHAPTER IV

RESULTS

During the study three sets of data were collected. In the first set 25 item questionnaire filled by subjects. The second set of data consists of eye tracking data produced by Eyegaze System. The third set of data obtained during interviews after test session. The data from the study were analyzed in both qualitatively and quantitatively. The qualitative part included interview results. In the quantitative part, the dependent variables of the study are the coordination of eye fixations on screen, duration of eye fixations and the traces of saccades. The entire eye tracking data were analyzed with H8 recordings coherently. Video recordings give the chance of analyzing on which specific time a level or action starts or ends.

4.1. SUBJECTS' DEMOGRAPHICS AND COMPUTER GAME USE

In this part the demographics and the descriptive data about subject's previous game and computer use habits are presented.

16 subjects were participated in the main study. 15 of them were male, and 1 of them was female. Female subject was eliminated from subsequent analysis to control gender factor constant. All of the 15 students were from engineering departments. 14 of them (93%) have PC's at their home. The distribution of computer use of subjects according to locations is given in Table 4.1.

Table 4.1. Access to computers according to location

PLACE	Home	School	Internet Cafe	Office
Number	14	8	4	13
%	93	53	27	87

The mode of subjects' age to start computer use is between the ages 10 to 15. If we consider that the subjects are beginning of their twenties, the time they meet with computers corresponds late 90's. The distribution of becoming computer literate age is given in Table 4.2.

Table 4.2. Starting age of using computers

AGE	5-10	10-15	15-20
Number	2	7	6
%	13	47	40

The mean frequency of playing computer games among those who report playing the computer games regularly is 3 days per week and 2 hours per day. The weighted mean of playing game of eleven subjects is equal to 6.64 hours per week. Two subjects did not answer how many days per week they are playing game and two of them did not respond the question how many hours they are playing per day. Since eleven subjects spend at least 14.55 hours with computer per week their proportion of playing game to computer use is almost 46%. The frequencies of other activities Table 4.3. As seen in the Table 4.3. the most intensive activity among subjects is computer use.

Table 4.3. Hours spend on several activities

	< 1	1-5	5-10	10-15	>15
Computer Use		1	2	1	11
Watching TV*		1	4	5	4
Reading for Leisure	3	4	5	3	
Social activities with others	2	1	8	4	

(* There is one missing value in this raw)

Eleven plus one (one of the subjects think that computer games can be either positive or negative, it is up to style of use) of fifteen subjects reported that their attitudes toward games are positive. They think that playing computer games has positive effects on quality of life. Their responses can be listed as follows: increase creativity (n=1), increase attention (n=2), increase the speed of reasoning (n=1), quick decision making (n=3), decrease stress (n=1), increase concentration (n=1), improve English (n=1), act as a fellow with books when other friends not available (1), you can follow recent technological developments (n=1), it is an requirement of current time (n=1), increase intelligence (n=1), having recreational effects (n=1), increase personal skills (n=1), increase imagination (n=1), can fulfill self-confidence (n=1).

Although the list seems to be distributed, expected outcomes can be grouped into wider concepts such as cognitive (intelligence, attention, reasoning, decision making, imagination, concentration, n=10) and psycho-social (self-confidence, stress, recreation, social needs, n=8).

The other subjects who approach the games from negative side, argue that games are just waste of time (n=3), it is a useless activity; it would be better to spend time to other activities such as studying. One of the subjects did not respond the question of what he thinks about games' effects on life.

The cross tabulation of year of playing computer games and level of competence is given Table 4.4. As seen from the Table most of the subjects saw themselves as average players.

Table 4.4. Cross tabulation of year of playing computer games and level of competence

LEVEL OF COMPETENCE YEARS OF PLAY	Novice	Average	Well	Master	Total
< 1					
2-3		2			2
4-5		2			2
6-7		1	2	1	4
> 8	1	3	2	1	7
Total	1	8	4	2	15

Only three of the subjects reported that they prefer single player games. Another three subjects, on the other hand, reported that they prefer only multiplayer or network games. Rest of the subject reported that they play both types of games. Nine of the subjects have network group to play together. The mean of network group size is $\overline{X}$ = 4.89 and SD = 1.90.

When they were asked about source of information about computer games, they indicated friends as the most frequent source. All of the subjects declare that their main source of information is friends. The following sources for information are periodicals (n=9) and the Internet sites (n=8). Rarely reported (n=1) sources are e-groups, help of games and trial & error strategies.

The most popular game type among subjects is strategy games (n=13). Race (n=12) and action/adventure games (n=10) are other group of popular games. The whole list is presented in Table 4.5.

Table 4.5. Favorite game types of subjects.

Type of Game	n
Strategy	13
Race	12
Action/Adventure	10
Shooter	8
Sports	8
Arcade games	4
FRP (Fantasy Role Playing)	4
Fight	4
Card or dice games	2
Traditional board games	2
Puzzle	2
Quiz	2
Simulation	2

The favorite themes for games are listed in Table 4.6. Most of the subjects prefer adventure games (n=12). Trail, discovery, and rescue (n=7) themes are followed adventure theme. The least favorite theme for games was love among subjects; none of them checked this item.

Table 4.6. Favorite themes for games among subjects.

Theme	n
Adventure	12
Trail	7
Discovery	7
Rescue	7
Escape	5
Good-bad	5
Victim	2
Revenge	1
Metamorphosis	1
Love	0

Subjects reported that the major reason for playing games is to decrease stress level (n=12). Although almost the entire group (n=14) have tendency to solve problems, and puzzles, they placed “mental exercise” reason to second place. The complete list is presented in Table 4.7. Two subjects, who checked other choice, first write down “to kill time” and second did not write any explanation.

Table 4.7. The reasons to play computer games.

The aim of playing	n
Coping stress	12
Mental exercise	7
Recreation	7
Fantasy	4
Competition	4
Challenge	2
Social Interaction	2
Other (Time killing)	1+1

Subjects asked to reply the questions of “At which age s/he used computer for the first time” and “At which age s/he play a computer game for the first time” in the questionnaire. It can be expected that the given age to former question should be younger than later one. But, Figure 4.1. showed that four of the subjects told that they experienced computer games earlier than their computer experiences.

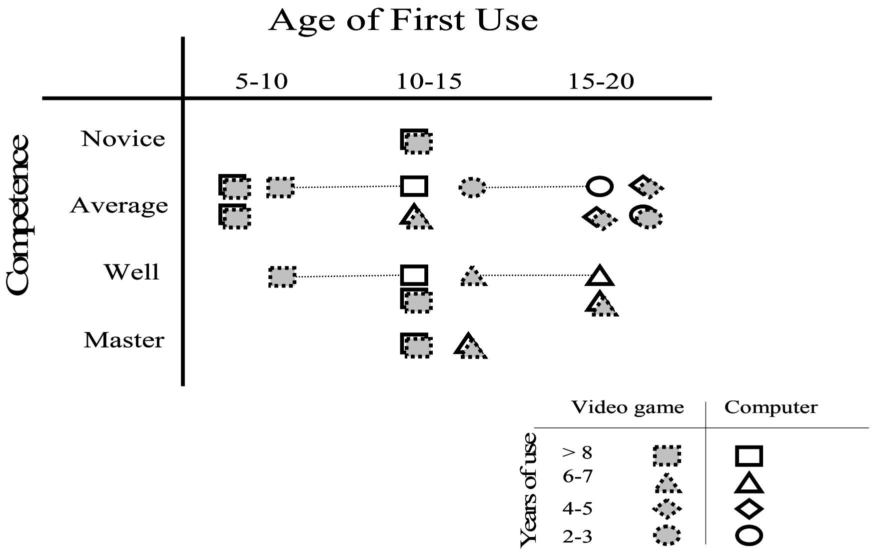


Figure 4.1. The comparison of first use of computers and computer games.

This lack of coherence between first use of computers and computer games can be result of several factors. First of all, the subject could have been reported this false information without notice. Other possibility is that their report can be true, but they might mean console or handheld computer games. Third possibility is that their memories could have been changed pertaining to computer games.

4.2. CONTRAPTIONS AND EYE TRACKING RESULTS

Eye movements consist of two phases: Fixations and saccades. During fixations the position of the eyes are relatively stable. The duration of fixation can be last 10 ms to infinite-theoretically-. The upper limit of the fixation is not reported anywhere. Movement of the eye is called as saccade. The saccades constitute small portion of gaze. The mode of the fixation is 10 Hz which is equal to 167 ms and the mode of the saccade is 1 Hz which is equal to 16.7 ms.

Two of 15 subjects were eliminated from subsequent analyzes due to unnoticed errors occurred during data collection sessions. One of the errors is in output file of the subject eight. Since the file contains impossible saccade durations (e.g.

11,310 and 13,706 ms) and produced only 40 fixations which was very low when compared to expected about 1500 fixations, hence subjects' playing Contraptions session and eye tracking data skipped in subsequent analysis. Second error is the result of carelessness of researcher. It had been realized that during transcription of video cassettes, after calibration of eye tracking equipment, one of the subjects started to play previous subjects stopped game which was forgotten to close down and running at background. Since this subject started game from third level without noticing, thirteenth subject's data eliminated also.

The most successful subject could reach to fifth level in the game in 10 minutes. Two of the subjects could not solve the problem given in the level 1 during eye tracking session. The subjects' time spend on levels during playing is given Figure 4.2. Mean duration spend on level 1 is $\overline{X}$ = 4.19 minutes and SD = 2.59 minutes. Mean duration spend on level 2 is $\overline{X}$ = 2.41 minutes and SD = 2.37 minutes. Whether or not subjects finished the level due to time constraints their values included mean and SD calculations. Those time values are calculated based on H8 video recordings.

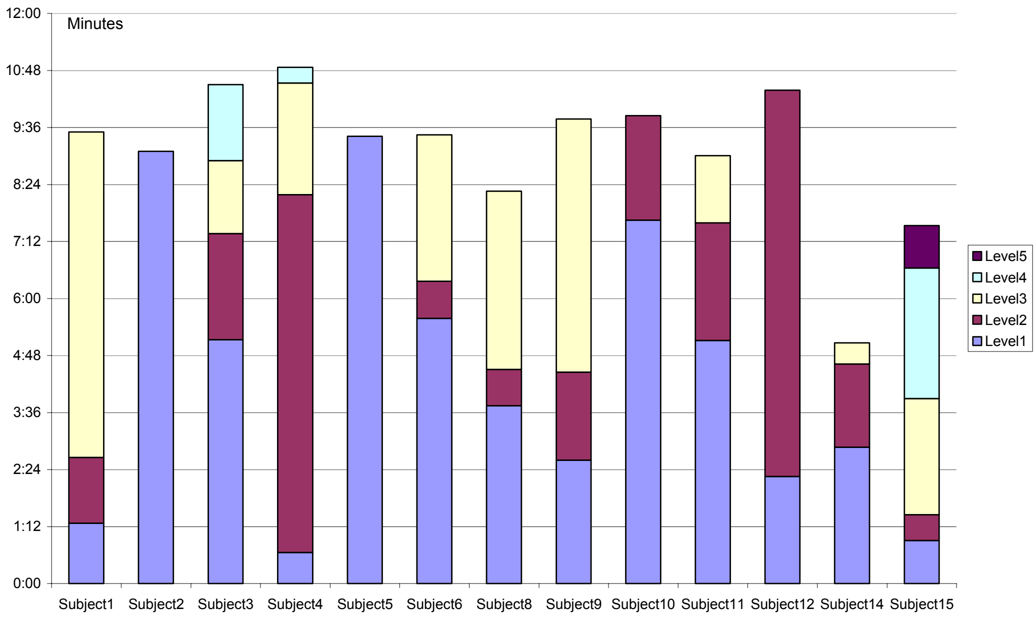


Figure 4.2. Level-subject distribution

Eyegaze system produces two types of text outputs in one file. Upper part of the data contains sample index, logical value for eye found, coordination of gaze point on screen, pupil diameter, eyeball-position, focus range, and fixation index (See appendix C). After DetectFixation() function inherent in Eyegaze system analyzes the eye movements to identify saccades and fixations. This function appends fixation index, coordination of fixation, saccade duration, fixation duration, and fixation start sample at the end of the file. A sample output of DetectFixation function is given appendix D.

Total duration of thirteen subjects' eye movement records is reached 121 minutes which corresponds 18,287 fixations. The mean duration of fixation is $\overline{X}$ = 20.29 and SD = 18.29, and the mean saccade duration is $\overline{X}$ = 3.72 and SD = 55.41 based on 60 Hz. Since the camera field rate of 60 Hz, average of fixation corresponds about 330 ms or one third of a second. Values related to fixation and saccades are given Table 4.8 in respect of subjects.

Table 4.8. Fixation and saccade values of subjects

Subject's No*	Count of Fixation	Average of Fixation	SD of Fixation	Average of Saccade	SD of Saccade
1	1313	21.41	21.64	3.18	5.97
2	1499	21.85	23.67	2.16	3.94
3	1409	22.16	19.77	3.39	14.31
4	1785	17.74	14.62	2.43	8.48
5	1611	18.07	15.07	4.28	25.95
6	1512	20.58	17.54	3.23	7.74
8	1016	19.86	19.44	12.45	205.86
9	1179	21.34	18.18	9.20	97.28
10	1534	21.15	16.95	2.31	6.99
11	1744	17.17	12.86	3.41	6.44
12	1584	21.11	14.90	1.62	2.94
14	1003	17.94	13.79	2.04	2.86
15	1098	25.40	26.58	1.85	3.03
Total	18287	20.29	18.29	3.72	55.41

(* Seventh and thirteenth subjects eliminated due to errors occurred during data collection procedure)

As seen from Table 4.8. standard deviation values of fixations are quite high. This can be resulted from having either a platykurtic distribution or extreme values at tails. Tabachnick and Fidell (1996) suggested that traditional and conservational alpha levels (.01 or 001) should be used to evaluate significance of skewness and kurtosis with small to moderate samples. If the sample is large enough (N>200) it would be better look at the shape of the distribution instead of using formal inference tests. To visualize distribution a frequency polygon is given in Figure 4.2. X, Y, Z axises present frequency of calculated fixations, duration of fixations, and subjects respectively. To increase readability of graph extreme values of fixation durations greater than 120 Hz which corresponds 2 seconds were skipped as input data for graph. The number of skipped fixations was 85 which constitute 0.46% of total 18,287 fixations. Figure 4.3 showed that the distribution of fixations is positively skewed. Skewness of the distribution is 4.46 and kurtosis is 34.94. Seeing as the distribution is not normal, the mode and median can be more informative to depict averages. The mode value of distribution is 10 Hz and the median is 15 Hz. These values correspond 167 ms and 250 ms respectively.

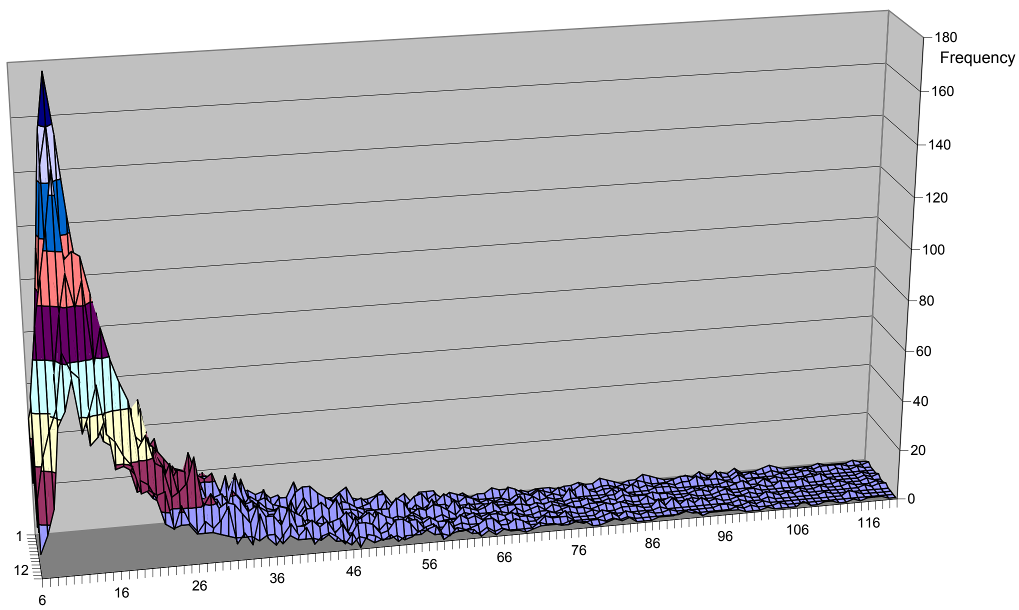


Figure 4.3. Frequency polygon of fixations with respect to subjects.

The same procedures are followed to depict the frequency distribution of the saccades. The only difference is the grouping variable. The frequency of fixations polygon uses subjects as grouping variable, whereas frequency of saccade polygon uses levels as grouping variable. The reason behind this choice based on only aesthetic preferences. Extreme values of saccade durations which are greater than 20 Hz were skipped as input data for the graph. The number of skipped fixations was 307 which constitute 1.67% of total 18,287 fixations. Figure 4.4 showed that the distribution of saccades is positively skewed. Skewness of the distribution is 3.08 and kurtosis is 12.20. The mode and median value of distribution is 1 Hz. These results showed that the distribution of the saccades and fixations are alike.

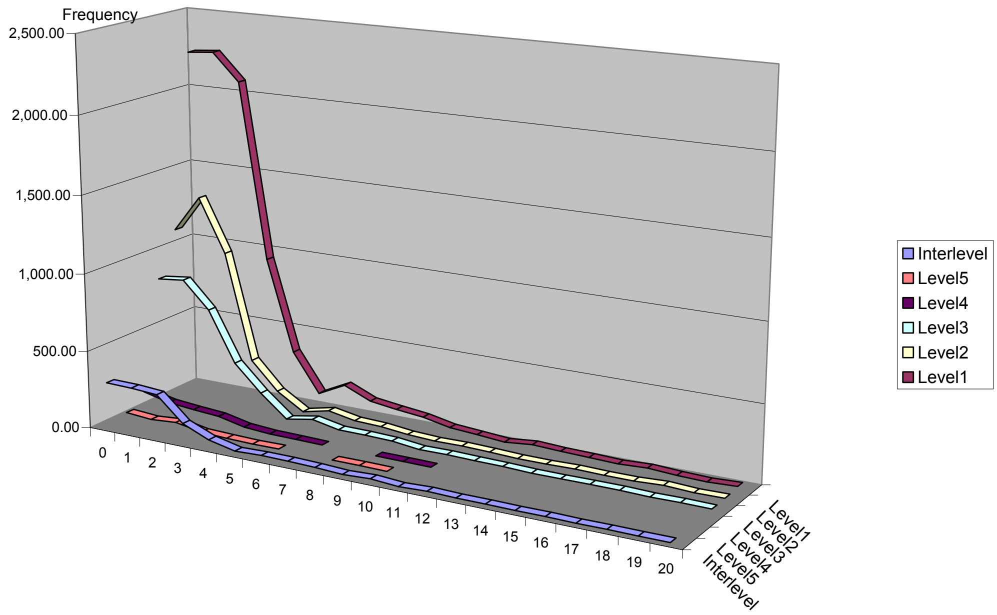


Figure 4.4. Frequency polygon of saccades with respect to levels.

To draw gazetrack data of the subjects a C++ program was written. This program produces a 1024 x 768 bitmap output file and use DetectFixation() functions as inputs. It can produce the maps of fixation, gazetrack or both on the specified bitmap file. An example output of program is given Figure 4.5. This example is the first subject's gazetrack and fixation output data during level 1 produced by program. Subject 1 has passed level 1 in 1.16 minutes. His fixation count was 146

($\overline{X}$ = 22.66, SD = 26.78). By overlapping data from video and outputs of eyegaze equipment, subjects's level distribution Table was constituted (See Table 4.9). Durations spend on levels can be slightly different from durations given Figure 4.2. Because time spend on welcome screen of game, transition between levels, and time lost starting or finishing parts of the testing are presented an artificial raw called interlevel in which software of eyegaze equipment works at background.

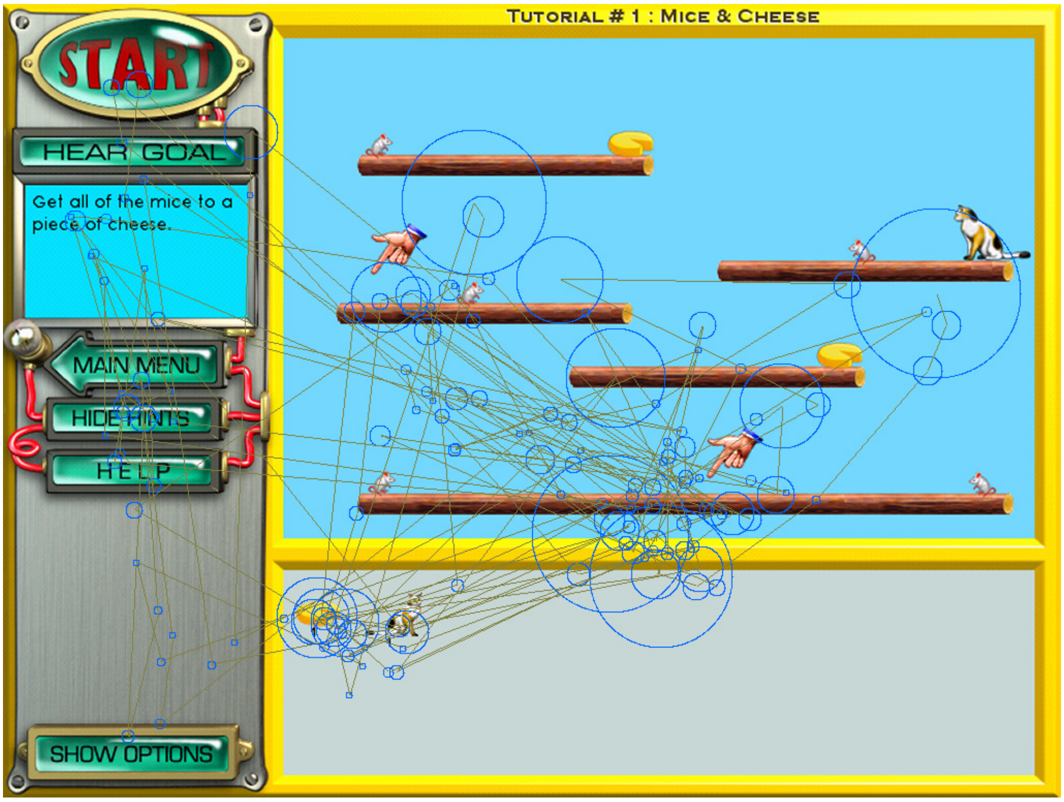


Figure 4.5. An example of gazetrack and fixation output of program

The map of gazetrack points out the areas of interest of subjects on screen. Diameter of the circles points the duration of fixations. Greater the diameter means greater the duration of fixation. Lines connect sequential fixations. All of the gazetrack maps are given in appendix E. The gazetrack map of fourth subject's level 4 can not be produced, since eye tracking records limited to 10 minutes. Although it can be shown in Figure 4.2., eye tracking record had been ended before subject reaches fourth level. Total number of gazetrack maps of subject is 36.

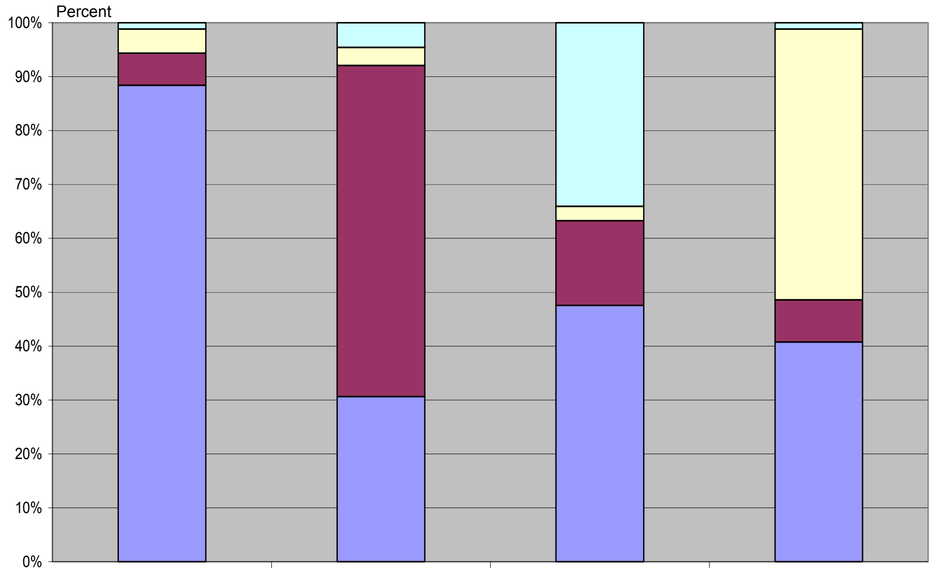
Table 4.9. Duration and fixations of levels.

	Level 1		Level 2		Level 3		Level 4		Level 5		Interlevel	
Subjects	Duration (Seconds)	# of Fixations	Duration (Seconds)	# of Fixations	Duration (Seconds)	# of Fixations	Duration (Seconds)	# of Fixations	Duration (Seconds)	# of Fixations	Duration (Seconds)	# of Fixations
1	67	146	80	195	369	922					22	50
2	525	1264									75	235
3	308	726	136	318	92	204	24	49			40	112
4	49	140	451	1366	88	246					11	33
5	586	1565									14	46
6	334	866	46	119	144	320					76	207
8	253	405	50	29	225	524					19	58
9	155	304	111	283	314	541					20	51
10	579	1480	3	8							18	46
11	307	905	148	440	84	240					59	159
12	135	386	447	1152							18	46
14	172	528	105	316	26	86					31	73
15	54	141	32	88	146	287	164	339	53	142	50	101
	3524	8856	1609	4314	1489	3370	187	388	53	142	454	1217

Subjects' gazetrack maps can be analyzed in terms their areas of interest for each level. Each level in contraptions includes three areas and outrange which showed one of the fixation parameters is out of screens range of 1024 x 768. The number of fixations on outrange is 452 which is 2.47% of total fixations. First area in contraptions screen is menu at the left side of the screen, contraptions area at the right upper of side of the screen, and the movable objects called tools area at the right lower side of the screen. 75.38% of the fixations occurred at the contraptions area. 14.30% of the fixations are on the menu area and the 7.85 of the fixations occurred at the tools area. The mean of sequential fixations within the same area as follows. $\overline{X}_{contraptions} = 8.40$ and $SD_{contraptions} = 10.78$; $\overline{X}_{menu} = 2.57$ and $SD_{menu} = 2.67$; $\overline{X}_{outrange} = 1.52$ and $SD_{outrange} = .98$; $\overline{X}_{tools} = 1.99$ and $SD_{tools} = 1.70$. Sequential analysis of the fixations showed that fixations generally occur within same areas of interest. For example 88.39% of the fixations in contraptions area are followed by another fixation in the same area. This percent is 61.45 for menu area. The other values are given in Figure 4.6.

Table 4.10. Sequential distribution fixation areas.

Areas	# of Fixations	# of Sequences	Mean	SD
Contraption	13785	1641	8.40	10.78
Menu	2615	1018	2.57	2.67
Outrange	452	297	1.52	0.98
Tools	1435	720	1.99	1.70



	Contraptions	Menu	Outrange	Tools
Outrange	1.17%	4.59%	34.07%	1.18%
Tools	4.46%	3.33%	2.65%	50.24%
Menu	5.98%	61.45%	15.71%	7.80%
Contraptions	88.39%	30.63%	47.57%	40.77%

Figure 4.6. Areas of interest: Locations of consequent fixations

Comparing subjects' fixation means across areas of interests produces Figure 4.7. Figure shows that the mean of fixation on menu produce smaller values than fixation on contraptions. Figure 4.7 shows that the mean of fixation on tools area varies if it is compared to means of contraptions and menu area. Fixations on contraptions area have higher values for the subjects 2, 3, 5, 8, 10, 11, 12, and 15.

The mean values of fixations are higher for subjects 1, 4, 6, and 9 in the tools area. Menu area produces minimum fixation mean values for subjects, 1, 2, 3, 4, 5, 6, 9, 10, and 12. Fixations on outrange area can be ignored and they can be regarded as errors or noises which occurred during data collection.

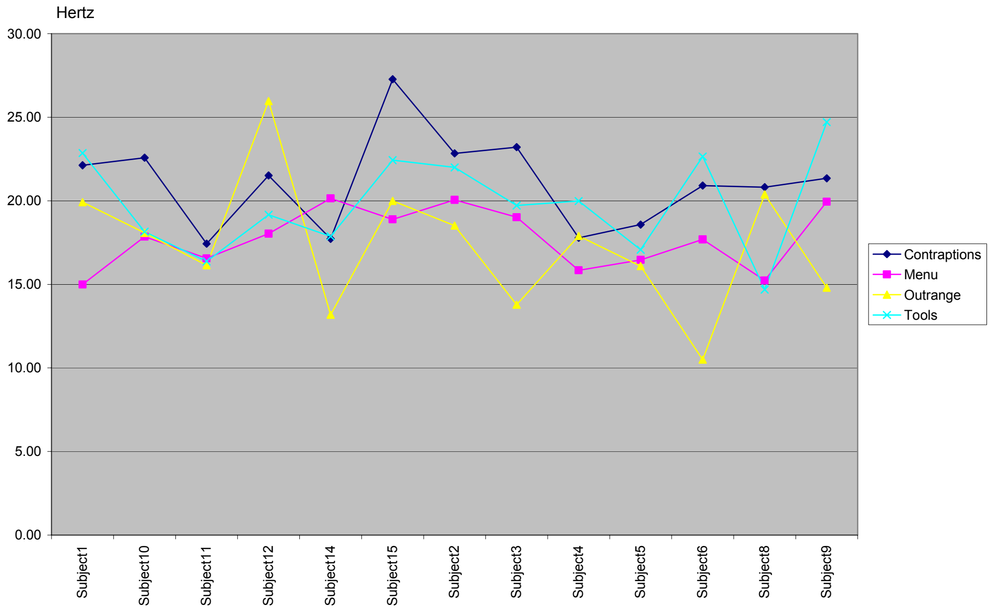


Figure 4.7. Subject's fixations on areas of interest

Comparison of means in terms of level and subject is given in Figure 4.8. To compare fixations with respect to subject and level, fixations on outrange area is omitted. Level means calculated from 17,835 fixations. It is shown that the mean of fixations across subjects is quite variable. On the other hand, crossing lines between levels showed that fixation means of levels are changed across subjects. Some of the subject has higher values for level 1 (Subject 1, 3, 8, 10, 11, and 15) and others have higher fixation means for level 2 (Subject 4, 6, 9, 12, and 14). But the variance of means across levels is smaller than the variance between subjects. This pattern can be observed from Figure 4.8's zigzagged outline.

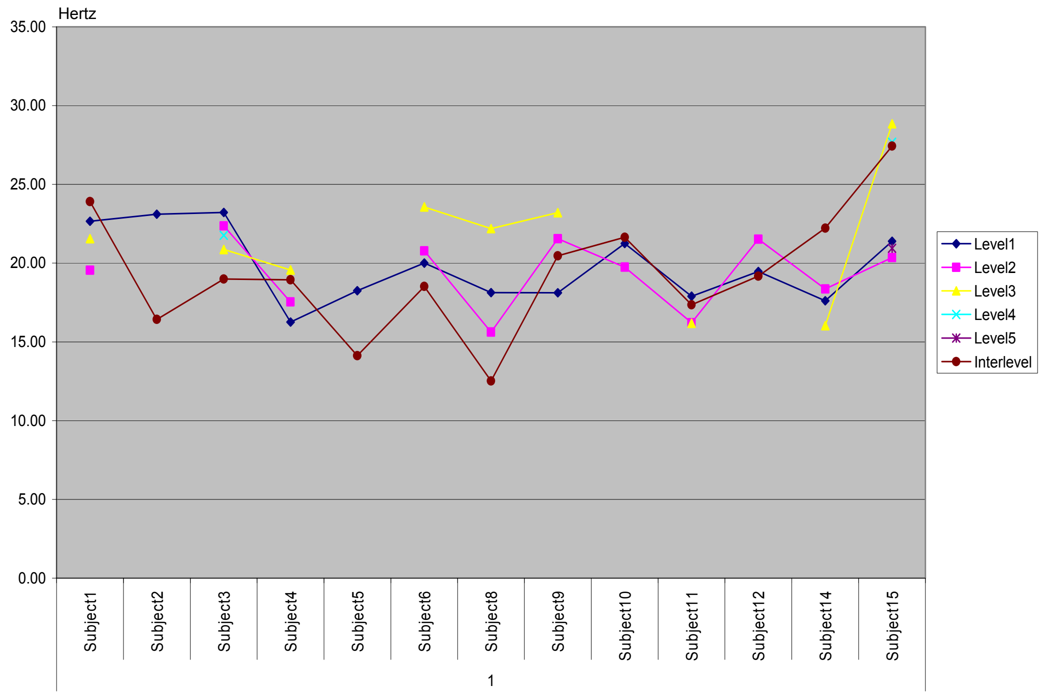


Figure 4.8. Mean fixations with respect to subject and level

Gazetrack data analyzed in terms of their angles with respect to left edge of the screen. Data showed that frequency of eye movements increased during horizontal movements. 0 degree implies movement from top to bottom of screen. 90 degree implies movement from left to right of screen. 180 degree means the direction of the movement is bottom to top and 270 degree means a movement from right to left. The distribution of movement angles is given Figure 4.9. The directions of movements are become more frequent when the degree approaches to horizontal axes. Eyes seem to be scan the screen horizontally rather than vertically.

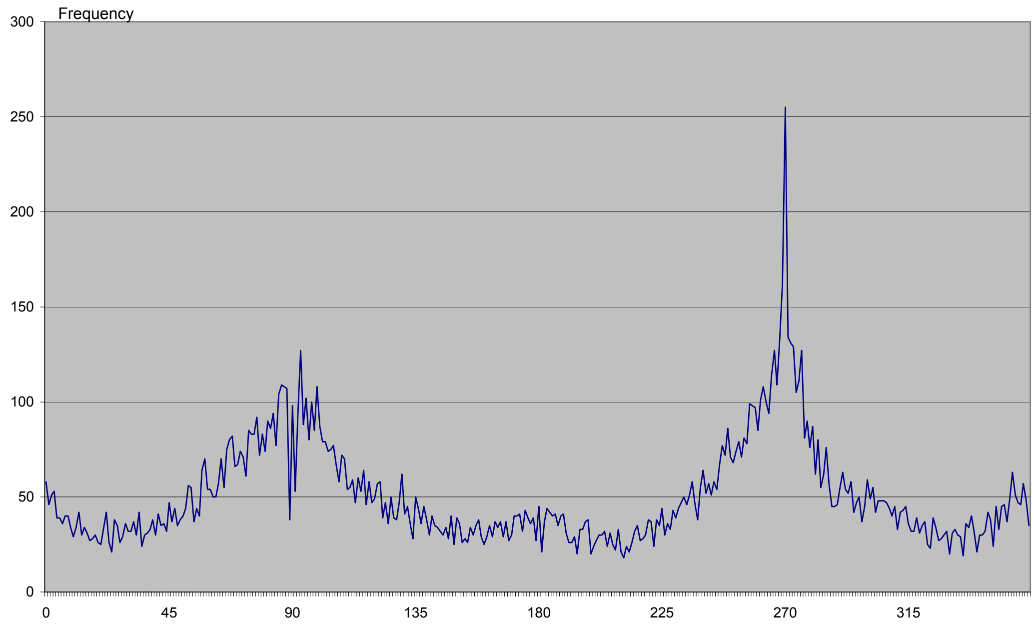


Figure 4.9. Distribution of movement angles

4.3. INTERVIEW RESULTS

Post test interviews revealed that most of the subjects did not remember the details of the game just played. When they asked whether it is easy to learn this game, all of them answered that it is an easy game to learn, but four of them underlined the importance of hints to solve the problems.

When they were asked to compare learning styles of this game and other games that they played at home, they answered that the learning styles are the differentiated with other games. Whereas, four of the participants reported that that reading the hints is the key element to observe solution, video records showed that, all of them prefer trial and error strategy to observe the game. None of them except one reported a systematic strategy to solve the contraptions such as “first of all I read the goal, than a clicked on the hints to see what I should do, and place the tools to the appropriate places”.

Three of the subjects reported that they misunderstood the contraption at the first level. They said that, they try to “prevent the mice to get the cheese” rather than “get all the mice to piece of cheese” at level 1.

When they were asked how they can classify this game, they replied that this is a game requires intelligence, reasoning and problem solving skills. They classified this game as educational game and one of the participants said that “it is a game for children”.

When they asked to compare the Incredible Machine and other games that they played, they mentioned that they prefer more complex action and strategy games. They reported that other games have quite more complex structures than Incredible Machines. They can learn the complex games step-by-step. Other games guide them, and they can move in the games forward and backward like “real life”. But Incredible Machine is work with only none-or-all principle; you cannot advance in the game without a full accomplishment of the problem.

Two of the players confessed that they played earlier versions of Incredible Machine before. Another confession during interviews is that one of the subjects reported that he had trouble to understand the clues given in the game.

Some of the players cannot realize the need to press start button to work out the solution of contraption. Some of them cannot apprehend the functions of objects in tools menu.

4.4. USABILITY ISSUES OF CONTRAPTIONS

The interface of the game looks like simple but subjects’ performance showed that that it is not that much simple. They could not become competent in ten minutes testing session. The interface of the game includes few variables and few possible moves. And there are apparent hints about where should moveable objects placed. For example, in the first level there are only one cat and one cheese and there are only two hands which point where these two objects should be placed. To solve first level cat and cheese should be dragged appropriate places, and than start button should be clicked (Figure 4.10). But the results showed that the mean time spent on the first level is about 3.55 minutes. A person who knows the solution can succeed this level in a few seconds. The difference between possible solution time and observed solution time of level 1 is quite remarkable. Potential reasons, which were played a role in delay to succeed levels, whether they are resulted from design and usability issues or characteristics inherited in presented problems, will be discussed in next chapter.

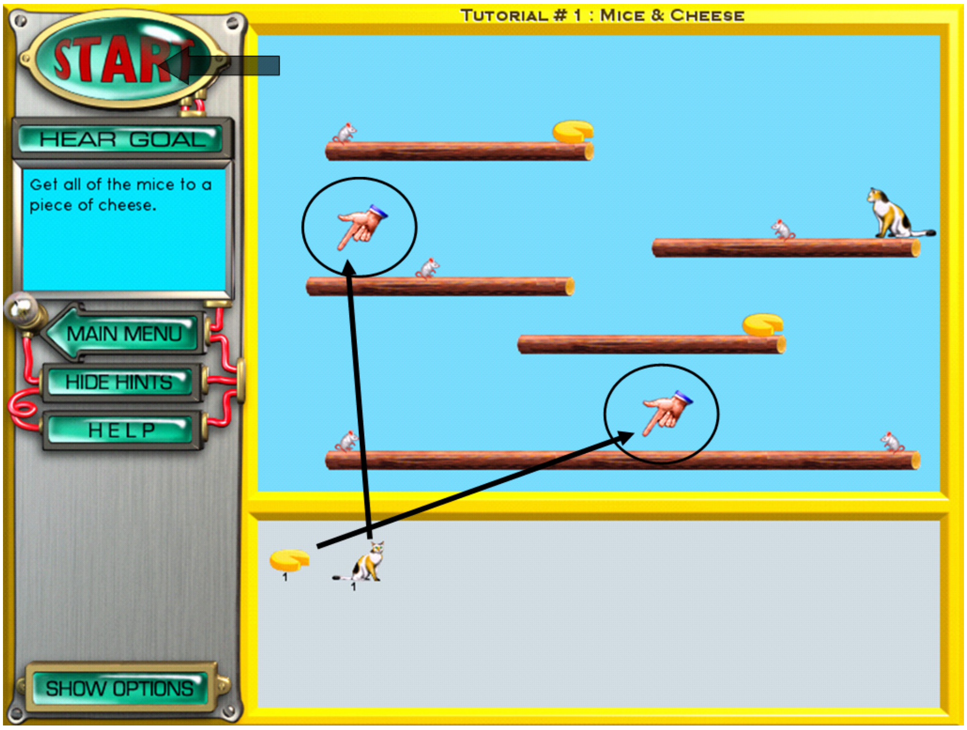


Figure 4.10. Three compulsory actions to be held to solve level 1.

Second level is easier than level 1 if required number of movements is taken into account. Two movements in level 2 are enough to solve this level (Figure 4.11). Alligator named Edison should be placed correct place, and than start button should be clicked. Although the structure of level 1 and level 2 is be alike, the mean time of 11 subjects who succeeded in level 1 spend on level 2 is 1:56 minutes (Subject 10 is skipped from calculations, since he could not solve the problem in given 10 minutes during test). This level, also, can be solved only in few seconds. It is easier because, its structure is alike level 1, and it requires less actions. Since the level 3 can be accomplished by only two subjects, the usability issues of this level are skipped due to few numbers of players.

When usability of the levels is investigated in terms of its design, several factors draw attention. Design of game can be evaluated from the point of explanatory view. For example, the placement, colors, or designs of key elements in the game can be assesses by attention which they collect fixations on them. The other measure of the attention can be first fixation or click on the target region. Former can be measured by eye tracking data and the latter can be measured by video recording data. The differences between two can be a sign of the difference between looking and seeing which can be important discrepancy in problem solving. The mean of first gaze on start button is $\overline{X}$ = 11 seconds and SD = 20.30. The click time on start button is five times greater than first gaze. Its mean is $\overline{X}$ = 49.17 seconds and SD = 104.83.

The key elements in contraptions to solve the problem are the start button and hints which are pointing where the supplementary tools should be placed. Results showed that conceiving the function of the start button is problematic. This can be resulted from either its placement or function attributed to the button itself. It works at none or all principle. Once its function is discovered, start button gains all its functionality. On the other hand, it is not valid for hint hands circled at Figure 4.10. Although subject discover that they give some information when they clicked on, it is hard to grasp for almost all subjects that they are pointing exact places of where the supplementary tools should be placed.

All of the subjects clicked on hands on the screen at least ones, a circle appear when mouse was on the hand. But, the hints given by hands were not utilized; whereas they are given explicit information about which tool should be placed there for which reason.

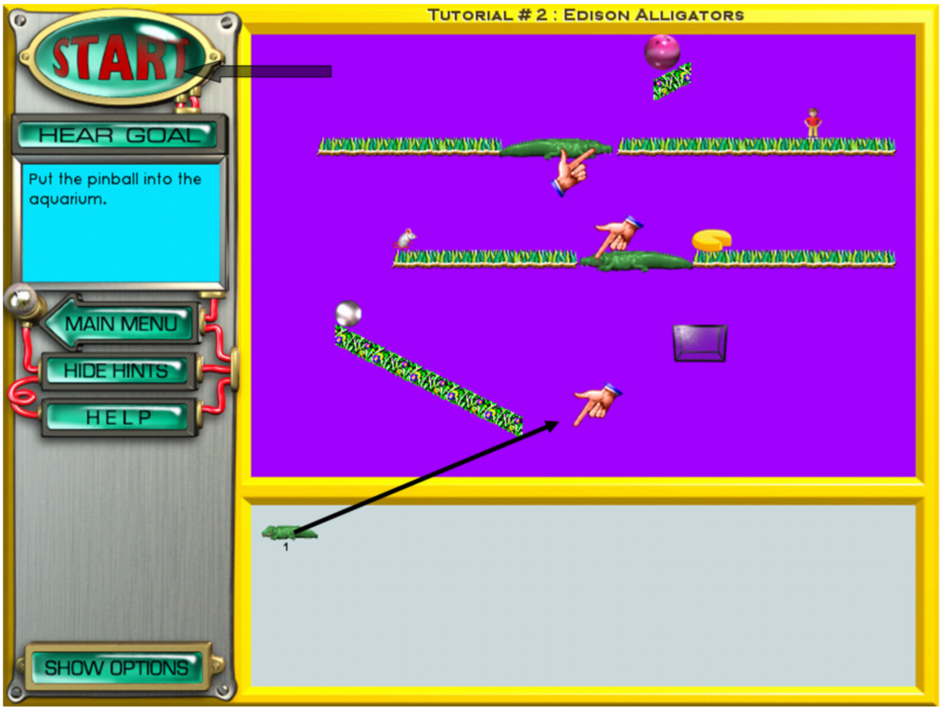


Figure 4.11. Two actions are enough to solve level 2.

In level 2, two hands at above were given information unrelated to the solution of the contraption. However, the information given by the hand at below include the alligator should be placed there. Where as the level seem to be easy when explained, it is not the observed case. Since the subjects did not comprehend the functions of hands, they can not solve the problem without any trouble.

The results showed that the problems that subjects faced are matter to discussion in terms of heuristics of usability issues. The results will be discussed in the next chapter in the light of literature of usability and education.

The dominant strategy to solve the problems is the trial and error. Subjects seem to prefer almost random actions rather then systematic and planned ones. And they are not utilized documentation given in the game although all of them aware of.

CHAPTER V

CONCLUSIONS AND DISCUSSIONS

The results of the study revealed the information about how computer game players' explore a computer game that they do not know how to play, in a naturalistic manner.

5.1. COMPUTER GAME PLAYING PATTERNS

The dominance of the males who participated in the study is not in accordance to the world of computer game players. A survey conducted by Interactive Digital Software Association reported that 43% of the game players are women in the USA (Saltzman, 2003). In Turkey, the proportion of female student among gamers in universities is not as high as it is in the USA. It is about 30% (Onay Durdu, Tüfekçi, & Çağıltay, 2005). When the announcement was made for participants wanted for a computer game study, no gender was mentioned. But, the content of the study seem to be attracted only male students.

The computer use is the most frequent activity among subjects; participants spent their hours on a computer screen rather than a TV screen. So this shows that the participants can be considered as net-generation.

Results also revealed that computer gamers have a positive attitude towards computer games but factors contributed to this attitude were not specified by the participants. Therefore, it is not clear whether their positive attitude makes them video players or their attitudes become positive because of their habits of computer game play. Whatever the reason, they seem to rationalize the hours spent by playing a computer game. They have beliefs that computer game playing increases and foster cognitive performances and make players healthier in terms of psycho-social variables. However, their most frequent reason to play computer games to decrease stress which is parallel what Onay Durdu, Tüfekçi and Çağıltay (2005) have found.

Their self view of competency about computer games seems to be regressed to mean. The hours spend in computer game playing and self reported competency about computer games seems to be incoherent. This can be observed from the subject responses. Majority of them checked second item (“average”) in a Likert type question with four levels (1 = Novice, 4 = Master). Another possibility for the selection of second item can be the wording of the items. The underlying reason to prepare Likert type question with even number of items rather than an odd one was to force the participants to make choice other that mean, but the wording seem to problematic in this question. So the results must be analyzed carefully.

5.2. STRATEGIES USED TO LEARN A COMPUTER GAME

Participants of the study reported that they use same strategy to learn all of the games: trial and error and they use friend as sources of the information about games. The insufficient use of documentation to reach information is worth to consider. This result seems to be consistent with Mehlenbacher’s (2003) three myths about documentation. These are: nobody reads documentation, humans use documentation poorly, and transparent interfaces will eventually eliminate the need for documentation. Although Mehlenbacher considers these methods as myths, the results of this study showed that participants do not use documentation and they prefer self exploration to solve the problems they face.

This result can be supported by another pattern in the game. All of the subjects clicked on the hands which contained hints about the game, including exact information such as “place cat here” or “place Edison here”. The results showed that none of the subjects follow the instructions given in the hints. Therefore, it can be concluded that, use of documentation in the computer game does not guarantee to the understanding of information given to the users. Another point which supports the insufficient use of documentation is that almost none of participants clicked on “how to build contraptions” menu at welcome screen and “help” menu in game except one. Moreover, none of the participants mentioned that it would be easier if those choices would have been reactive.

Interview results address one of the cultural factor in designing computer games. The misunderstanding of the aim in the first level points the importance of the language use in the games. Although the aim was clear at the first level, some of the subjects tend to interpret the goal more traditionally. In daily life people do not feed mice with cheese, on the contrary they try to catch them with the help of cats. So, conditions which are vulnerable to cultural factors have to be studied carefully.

5.3. EYE TRACKING MEASURES OF THE COMPUTER GAME

The quantitative results of the study also consistent with the descriptive results and seem that they can be used to investigate the interaction between user and the game. The video recording and eye tracking data can operationalize the actions of the gamers clearly. Specifically, the differences between fixation times and patterns of gaze at different areas of interest showed that type of cognitive processes of participants changed subconsciously. The highest values of fixation times are obtained in contraptions area where the participants think about the possibilities of the solution. The menu has the lowest values in terms of fixation times because of there is nothing to do in menu area to solve the contraptions except start button. Appendix E presents that, participants used mostly start button and hear goal in the menu area, but their fixation values are smaller than the contraptions and tools area. The variance between levels is resulted from mainly subjects’ characteristics. This variance is depicted in Figure 4.8. Although the contraption is different, subjects have tendency to produce similar means across levels. But this pattern was not observed in results of areas of interest (Figure 4.7). This finding seems to be contradicting with the studies of Pelz, Canosa, and Babcock (2000) who found that complex tasks elicit shorter fixation times. Unlike their study, this study contraptions area contains complexity produces longer fixation times. This inconsistency can be explained by the definition of the complexity in tasks. Pelz, Canosa, and Babcock defined complexity with the sub-tasks. For example, the process model building divided into three sub-tasks: reading, searching, and manipulation. According to these researchers, reading and searching are more complex than manipulation. Since the manipulation requires lesser actions, it produces longer fixation. In this study, the longer fixation durations in contraptions area can be compared to manipulation sub-task of Pelz, Canosa, and Babcock's experiment. The concentration level increase and the number of objects to process decrease.

When the gaze patterns examined, we can see the perseverance as most salient characteristic. Although saccades have ballistic nature, their targets generally have occurred within the same area. Menu area holds 75% of the fixations. Most of the attention is devoted to the contraptions area with 8 sequential fixations. Mean of sequential fixations in the areas of tools and menu is about two. This can be interpreted as, subject attention on these areas are temporary. When their gaze located on menu and tools areas, it turns back contraptions area as soon as possible.

Fixation durations of subjects are also significantly different. This shows us that individual differences can be measured by eye tracking methodology. Unfortunately in this study there are not sufficient and detailed control variables of the game to analyze these differences among subjects.

The results reveal that the direction of the eye movements on the screen is generally horizontal. Right to left or left to right movements are more frequent than top to bottom or bottom to top. This result can be interpreted as eyes move horizontally instead of vertically. The distribution of direction can be applied to menu designs if a controlled experiment conducted in this issue.

Velichkovsky, Dornhoefer, Pannasasch, and Unema (2000) conducted a study to find out the relationship between fixations and level of attentional processing. According to Velichkovsk and his colleagues the visual fixations and saccades contain a bundle of information about attention and its cognitive counterparts. They proposed that strong left skewed or log-normal nature of both saccade and fixation distributions hide a series of different modal distribution. Urlich and Miller (1990, cited in Velichkovsk et.al.) mentioned three possible causes this consistent log-normal distribution: “Exponentially transformed random normal variables, products of random normal variables or a combination of both” (p.79). Velichkovsk et.al mentioned that these different modalities in distribution are affected from preattentive scanning and attentive processing. They admitted that their findings are based on post hoc analyses, than added, more hypotesis-testing studies should be designed rather than explorative ones.

Since present study is also an explorative study, the results obtained in this study are coherent with the findings of Velichkovsky, et.al’s. (2000) studies. This is a strong indication that a computer game can be a good interface for a study which aims cognitive elaboration. A part from the studies which investigated the games in terms of design, evaluation or user centered approaches; additional studies are to be needed to transfer that knowledge to instructional design.

It is known that computer games have many distinctive features to explore. They are popular for a large portion of youngsters. It is consistent that they are affected mental and social life of their target population. Since, they are heavily diffused in everyday life at last two decades, the requirement for systematic research about computer games from the perspective of cognitive experimentation become inevitable.

To speculate, it can be argued that games and simulations can be used as tools which act as a mediator between artificial settings in laboratories and real life outside of the laboratory since games have many features which were barrowed from real life. For example, they might have stories; easily elicit emotional responses. Cognitively oriented studies can provide further information about surface and deep structures of (Gredler, 1994, 2003) of the games.

5.4. USABILITY ISSUES OF THE COMPUTER GAME

The usability of the game is another important factor in this study. The usability issues of the Incredible Machine game have been mentioned at the results section. The usability of the game is especially important in the design of the present study. Since the participants explore the game in a free format, their natural experiences can give valuable clues about the characteristics of the game. Publisher's note about Return of the Incredible Machine as follows (ZDNet, 2003):

> you are the inventor as you attempt to solve over 250 wildly imaginative puzzles. Create incredible machines out of a diverse assortment of crazy and colorful parts, ranging from ropes, pulleys, and bowling balls, to cheese driven mouse motors. And after solving the puzzles, make your own with the built-in puzzle editor.

There are vast amount of review in Internet about the Incredible Machine. An interested designer can provide feedback from those reviews. However, these user based reviews are unsystematic and based on subjective data. The Nielsen's (2005) heuristics draw a guideline to investigate the experiences of the participants at their first meeting.

As being demo, game provides neither tutorial nor help as documentation. So participants have to explore the game by themselves. However, none of the participants complained about lack of documentation. This is compatible with Nielsen's 10th heuristics that is help and documentation. Users do not need separate help or documentation. However, all the levels contain the required help within the hints, but this limited documentation does not give any information about how to start the game. This situation resulted in the delay to start testing for the users' solution offer. The design of the start button should be reconsidered. All the objects in the game are visible, but their functionalities are not convenient with real world. For example, an alligator can be used to toss the ball in the game. This contradicts with the 3rd heuristic of the Nielsen which is "user control and freedom". Another problem related to 3rd heuristic is that some of the levels can have more that one solution but only one of them is accepted as the solution in simpler levels. On the other hand, complex levels can accept to create own solutions of masters. This situation annoyed the one of the novice participants in the game till realizing that there might be another solution. The game provides sufficient control and freedom to its players. And the structure of the levels seems to be standard apart from, each level becoming harder. All of the objects that will be used for the solution of contraptions is given in one screen. But this does not mean that all of the hints or the tools are being used in that level, so there is no one-to-one correspondence in levels.

In summary, the verdict about usability of this game can be as follows: Although the game has some usability drawbacks, minor touches can be sufficient to solve these problems in terms of interface.

Current situation is addressed that research about computer games are conducted from different perspectives. One of the perspectives is designers' perspective. The aim of this perspective is to design better games to attract attention of people. Saltzman (2003) presents the designer views to games as follows: "Making computer games for a living may sound like the ultimate 'dream work' but it's an attainable (and often lucrative) reality". This perspective utilizes the up-to-date technology, information obtained from HCI guides tools and their creativity to produce new games. Another perspective might be a social one. A sociologist, anthropologist or psychologist may investigate the effects of released computer games in peer groups or families. Another group of researchers are concentrated on the relationship between games and its neighbor phenomena such as educational use of computer games, or their effects on cognition.

The use of computer is encircled by the development of the appropriate educational software. Although there are ample number of software in the market, utilization of them is being constant. Quintana, Krajcik, Soloway, and Norris (2003) pointed out the fundamental theoretical approaches about educational software. Theoretical background is essential to evaluate any educational software. These approaches are behaviorist approach, information processing approach, and social constructivist approach. None of these approaches provides definitive answers to the problems of user or learner centered perspectives. All of them have strengths and weaknesses. Every instructional technologist should take into account HCI issues for all theoretical approaches. In this manner the task of the HCI community is being cognizant about the considerations of education and to develop technology and design principles which are well suitable to education.

HCI researchers can work on many different tools which can be valuable in education. Games are one of the tools with great variety. Computer or video games, console games, mobile phone games, or the Internet games can be subject to any scientific investigation. Moreover, their production rate is greater than the studies about computer games. All of them have shared and differentiated characteristics when inspected in detail. Those characteristics are waiting to be for exploration.

5.1. RECOMMENDATIONS FOR FURTHER RESEARCH

The results of this study can be utilized by different disciplines. The results obtained by questionnaire and interviews can be used by the researchers who have social, emotional and attitudinal considerations about the effects of computer games. The results of the computer game play session can be used in cognitively oriented experimental studies. The results of interviews can be used for educational professionals who want to integrate computer games and instruction.

The aim of the present study was to provide data about how novices explore the games. The answer is that almost all of the subjects prefer try and error strategy.

This strategy make them prone to show perseverance when they faced with a problem. Although the subjects reported that the game is educative, none of them show any sign that they might play this game later on.

Popular genres of the games among participants are strategy, race action/adventure, shooter, and sport games. These results are coherent with Onay Durdu, Tüfekçi and Çağıltay's (2005) study which conducted on METU students. METU students also prefer strategy and race games. It is interesting to note that, although the most frequent reason to play games is to decrease stress, they prefer interestingly games which have high levels of adventure. On the other hand, it would be better strategy to ask directly the names of the games rather, precategorized game genres to find out their preferences for consequent studies.

In order to explain the reasons of this inconsistency or to make generalizations about this result, a more detailed questionnaire should be conducted with a greater sample. This can be done perhaps by conducting another independent survey study with a similar sample. To reach wider conclusions about game preferences, this survey might be applied with interviews.

The quantitative data revealed that free form of playing can produce eye tracking data compatible with other experiment in HCI. Eye tracking method can be used to measure attentional changes during playing at different levels. The results showed that computer game play can have different tasks, such as reading, searching or manipulating.

To investigate the varied and complex characteristics of the games more detailed studies should be designed. In this study the data can be analyzed in large groups because of synchronization problems. The more controlled studies give the chance of analyzing data step by step.

Eye tracking methods can be integrated with fMRI and ERP studies in the near future. Eye tracking methods are sensitive to preattentional and attentional processes. Moreover sensation and perceptual responses to the stimuli can be measured by ERP techniques. Integration of these to methods can produce a better picture about the unknowns of the mind.

Another encouraging application of eye tracking technology is using gaze as input device. Sibert and Jacob (2000) proposed that selection of an object on screen is faster than a mouse, so it can be assumed that using of gaze as an input device become practical as eye tracker technology matures. They added that HCI researchers should be aware of this promising possibility. If it can be achieved, humans have to find new functions for their hands.

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APPENDIX A

QUESTIONNAIRE CONDUCTED BEFORE TEST SESSION

ANKET – Ekim 2004- GYTE

1. Yaşınız: ....
2. Cinsiyetiniz

   [ ] K [ ] E
3. Bölümünüz : ____
4. Görme bozukluğunuz var mı? Varsa cinsi, gözlük veya lens kullanıyor musunuz?

   ....
5. Yakın zamanda deneydeki performansınızı etkileyeceğini düşündüğünüz bir ilaç aldınız mı?

   [ ] Evet [ ] Hayır
6. Evinizde ya da odanızda kişisel bilgisayarınız var mı?

   [ ] Evet [ ] Hayır
7. Genellikle bilgisayarları nerelerde kullanabiliyorsunuz? (Birden fazla işaretleyebilirsiniz)

   [ ] Evde [ ] Okulda
   [ ] Internet Kafede [ ] Yurtta
   [ ] İşyerinde [ ] Diğer ....
8. İlk defa kaç yaşında bilgisayar kullandınız?

   [ ] 5 yaşımdan küçükken
   [ ] 5 – 10 yaş arası
   [ ] 10 – 15 yaş arası
   [ ] 15 – 20 yaş arası
   [ ] 20 yaşımdan büyükken
9. Bulmaca ve/veya zeka oyunları çözmeye meraklı mısınız?

   [ ] Evet [ ] Hayır
10. Bilgisayar oyunlarını ne sıklıkta oynarsınız?

    [ ] Haftada .... gün, Günde .... saat
    [ ] Hiç

	SAAT				
Haftada ortalama kaç saat	< 1	1-5	5-10	10-15	>15
11. Bilgisayar kullanıyorsunuz?					
12. Televizyon seyrediyorsunuz?					
13. Kitap okuyorsunuz? (ödevleriniz dışında)					
14. Sosyal aktivitelere katılıyorsunuz? (arkadaşlarınızla, ailenizle)					

15. Bilgisayar oyunu oynamadığınızı varsayarsanız (ya da zaten hiç oynamıyorsanız), bunun en önemli nedenleri nelerdir? (1'den 5'e kadar puan veriniz)

    [ ] İlgilenmiyorum
    [ ] Vakit kaybı
    [ ] Zamanım yok
    [ ] Bilgisayarlara erişimim yok
    [ ] Nasıl oynayacağımı bilmediğim için
    [ ] Diğer ....
16. Sizce bilgisayar oyunları kişilerin eğitim hayatlarına nasıl etki ediyor? Neden?

    [ ] Olumsuz
    [ ] Olumlu

    ....
    ....

10. Soruya "hiç" diye cevap verdiyseniz diğer soruları cevaplamayınız?

17. Bilgisayar oyunları açısından kendinizi ne kadar usta görüyorsunuz?

[ ] Acemi [ ] Orta
[ ] İyi [ ] Usta

18. İlk defa kaç yaşınızda bilgisayar oyunu oynadınız?
[ ] 5 yaşımdan küçükken
[ ] 5 – 10 yaş arası
[ ] 10 – 15 yaş arası
[ ] 15 – 20 yaş arası
[ ] . 20 yaşımdan büyükken

19. Kaç yıldan beri bilgisayar oyunları oynuyorsunuz?
[ ] 1 yıldan az [ ] 2-3 yıl
[ ] 4-5 yıl [ ] 6-7 yıl
[ ] 8 yıldan fazla

20. Hangi tür oyunları tercih ediyorsunuz?
[ ] Tek kullanıcılı oyunlar
[ ] Çok kullanıcılı oyunlar (Multiplayer, Network oyunları)
[ ] Her ikiside eşit miktarda

21. Sürekli birlikte network oyunları oynadığınız bir arkadaş grubunuz var mı? Varsa kaç kişiden oluşuyor?
[ ] Evet ______ [ ] Hayır

22. Oyunlar hakkında bilgileri nereden ediniyorsunuz?
[ ] Internet sitelerinden
[ ] Arkadaşlardan
[ ] Dergilerden
[ ] E-gruplardan
[ ] Diğer ....

23. Hangi oyun türlerini genellikle tercih ediyorsunuz? (İlk 5 tercihinizi 1 den 5 e kadar numaralandırarak işaretleyiniz.)

	Oyun Türü:	**Örnek:**
[ ]	Hareket/Serüven	Resident Evil, Tomb Raider
[ ]	Atari oyunları	Pacman, Frogger, Pinball
[ ]	Oyun kağıdı/ Zar	Solitaire, Vegas Fever 2000
[ ]	Klasik oyun tahtası oyunları	Monopoly, Checkers
[ ]	FRP (Fantasy Role Playing)	Final Fantasy, The Legend of Zelda, Diablo
[ ]	Dövüş	Mortal Kombat, Tekkan
[ ]	Bulmaca	Tetris, Free Cell
[ ]	Bilgi yarışması (Quiz)	Jeopardy, Bilgi Yarışması
[ ]	Yarış	Need for Speed
[ ]	Shooter	Quake, Duke Nukem
[ ]	SIM (Simulasyon)	SimCity, Rollercoaster Tycoon
[ ]	Spor	NBA Jam
[ ]	Strateji	Command & Conquer, Civilization, Age of Empire
	Bunların Dışında (Tür ve İsim)	

24. Oyunlarda hangi temaları tercih ediyorsunuz? (Birden fazla işaretleyebilirsiniz)

[ ] Serüven [ ] Takip [ ] Kurtarma [ ] Kaçış
[ ] İntikam [ ] Keşif [ ] Sevgi [ ] Kurban
[ ] Başkalaşım(Metamorphosis) [ ] İyi – Kötü

25. Oyunları tercih etme nedeniniz ne?
[ ] Rekabet [ ] Meydan okuma
[ ] Sosyal iletişim [ ] Stres atma
[ ] Düşsel ortamlar(fantezi) [ ] Canlandırıcı etki
[ ] Zihinsel alıştırma [ ] Diğer

APPENDIX B

SCREENSHOT SAMPLES OF CONTRAPTIONS DEMO

Figure B.1. Main Menu

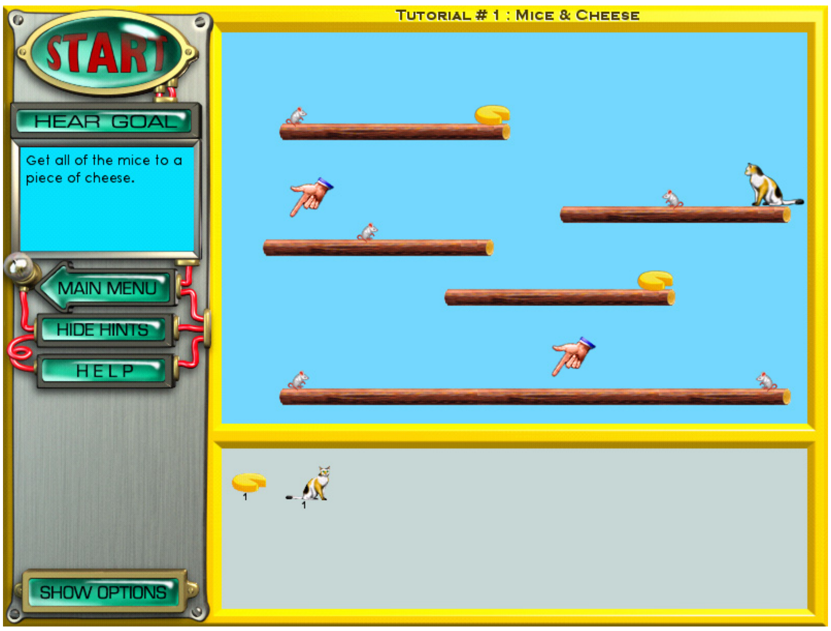

Figure B.2. Level 1

Figure B.3. Level 2

Figure B.4. Level 3

APPENDIX C

SAMPLE RAW GAZEPOINT DATA OUTPUT OF EYEGAZE

```
Gazepoint Trace Data File,  12:20:38  10/12/2004
Scene Type: bitmap 1024 768 C:\Eyegaze\LionsAndPlane.bmp
Raw Gazepoint Data (60 Hz Sampling Rate):

samp  Eye     Gazepoint   Pupil   Eyeball-Position  Focus   Fix
indx Found    X       Y    Diam     X      Y      Z   Range  Indx
     (t/f)  (pix)  (pix)  (mm)    (mm)   (mm)   (mm)   (mm)

  0     1    180     -1   2.71    -6.4 -11.8  -6.8   710.4    0
  1     1    174      1   2.70    -6.4 -11.8  -6.8   710.4    0
  2     1    173      2   2.68    -6.4 -11.8  -6.9   710.4    0
  3     1    180     16   2.69    -6.4 -11.8  -6.8   710.4    0
  4     1    178     17   2.69    -6.3 -11.8  -7.0   710.4    0
  5     1    174     18   2.70    -6.3 -11.8  -6.8   710.4    0
  6     1    171      5   2.74    -6.3 -11.8  -7.1   710.4    0
  7     1    179     11   2.68    -6.3 -11.8  -7.0   710.4    0
  8     1    184     26   2.72    -6.3 -11.7  -6.9   710.4    0
  9     1    175     14   2.73    -6.2 -11.7  -7.1   710.4    0
 10     1    175     13   2.70    -6.2 -11.7  -7.0   710.4    0
 11     1    181     34   2.69    -6.2 -11.7  -7.3   710.4    0
 12     1    264    154   2.83    -6.1 -11.7  -5.2   710.4   -1
 13     1    410    327   2.83    -6.0 -11.7  -5.8   710.4   -1
 14     1    445    365   2.79    -5.9 -11.7  -6.0   710.4    1
 15     1    431    374   2.70    -5.8 -11.8  -7.1   710.4    1
 16     1    439    384   2.76    -5.8 -11.8  -7.0   710.4    1
 17     1    448    383   2.71    -5.8 -11.8  -7.7   710.4    1
 18     1    447    402   2.69    -5.8 -11.8  -7.6   710.4    1
 19     1    434    394   2.75    -5.8 -11.8  -8.0   710.4    1
 20     1    437    384   2.75    -5.8 -11.8  -8.5   710.4    1
 21     1    438    383   2.69    -5.9 -11.8  -8.5   710.4    1
 22     1    448    385   2.68    -5.9 -11.9  -9.0   710.4    1
 23     1    446    389   2.70    -6.0 -11.9  -8.7   710.4    1
 24     1    437    382   2.71    -6.0 -11.9  -9.2   710.4    1
```

APPENDIX D

SAMPLE OF DETECTFIXATION( ) FUNCTION OUTPUT

Gazepoint Trace Data File, 12:20:38 10/12/2004
Scene Type: bitmap 1024 768 C:\Eyegaze\LionsAndPlane.bmp
Raw Gazepoint Data (60 Hz Sampling Rate):

samp indx	Eye Found (t/f)	Gazepoint X (pix)	Gazepoint Y (pix)	Pupil Diam (mm)	Eyeball-Position X (mm)	Eyeball-Position Y (mm)	Eyeball-Position Z (mm)	Focus Range (mm)	Fix Indx
0	1	180	-1	2.71	-6.4	-11.8	-6.8	710.4	0
1	1	174	1	2.70	-6.4	-11.8	-6.8	710.4	0
2	1	173	2	2.68	-6.4	-11.8	-6.9	710.4	0
…									
32291	1	347	332	2.75	-8.9	-14.8	-17.0	710.4	-1
32292	1	342	328	2.82	-8.8	-14.8	-16.9	710.4	-1
32293	1	347	333	2.75	-8.7	-14.8	-19.3	710.4	-1
32294	1	355	339	2.79	-8.7	-14.8	-18.1	710.4	-1
32295	1	354	332	2.81	-8.6	-14.8	-19.5	710.4	-1

Fixation Data: (60 Hz Sampling Rate)

fix indx	Fixation X (pix)	Fixation Y (pix)	Sac Dur (cnt)	Fix Dur (cnt)	Fix Start Samp
0	177	13	0	12	0
1	441	384	2	11	14
2	166	672	2	11	27
3	81	696	1	11	39
4	29	694	0	23	50
5	78	649	1	38	74
6	89	509	4	30	116
7	232	503	4	8	150
8	299	685	2	41	160
9	476	669	1	16	202
10	506	693	0	24	218
11	612	652	1	13	243
12	635	628	0	14	256
13	696	628	1	26	271
14	633	637	1	22	298
15	683	649	0	24	320

…

APPENDIX E

GAZETRACE DATA OF SUBJECTS ACCORDING TO LEVELS

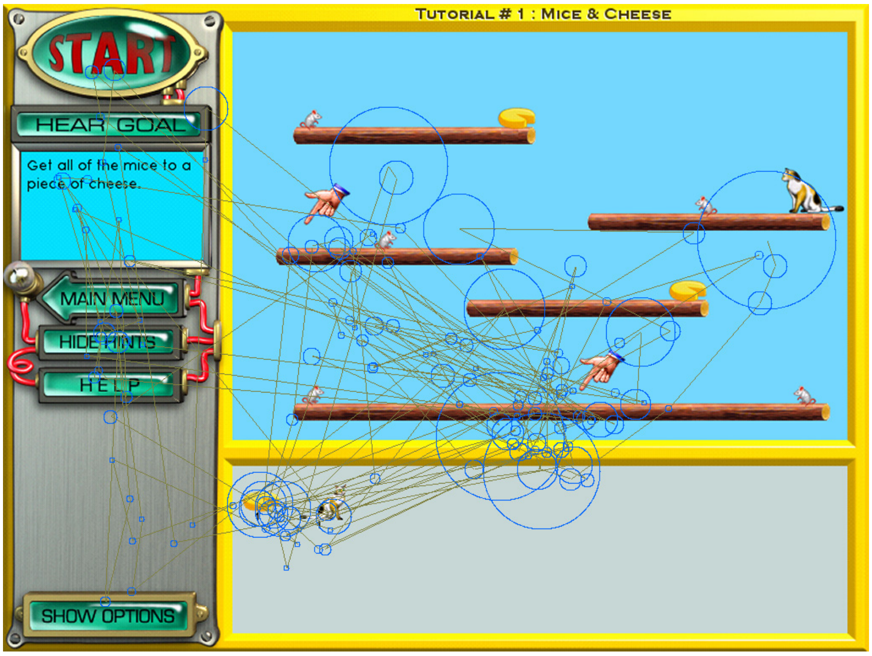

Figure E.1. Subject 1 Level 1

Figure E.2. Subject 1 Level 2

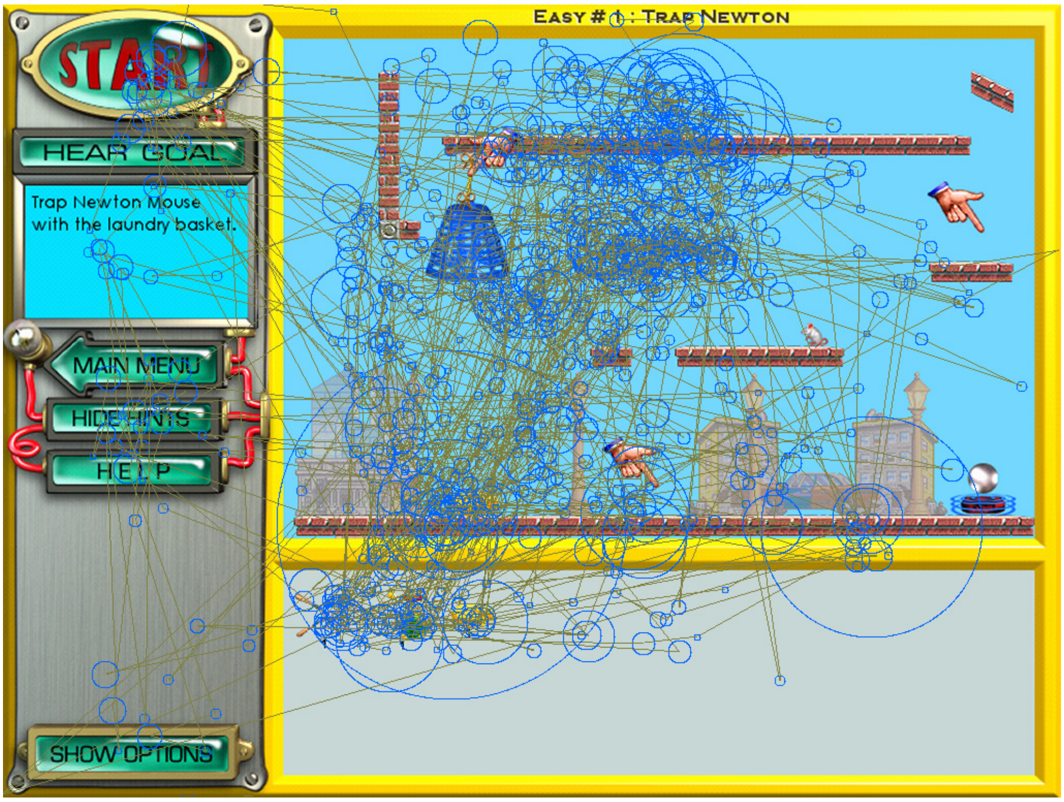

Figure E.3. Subject 1 Level 3

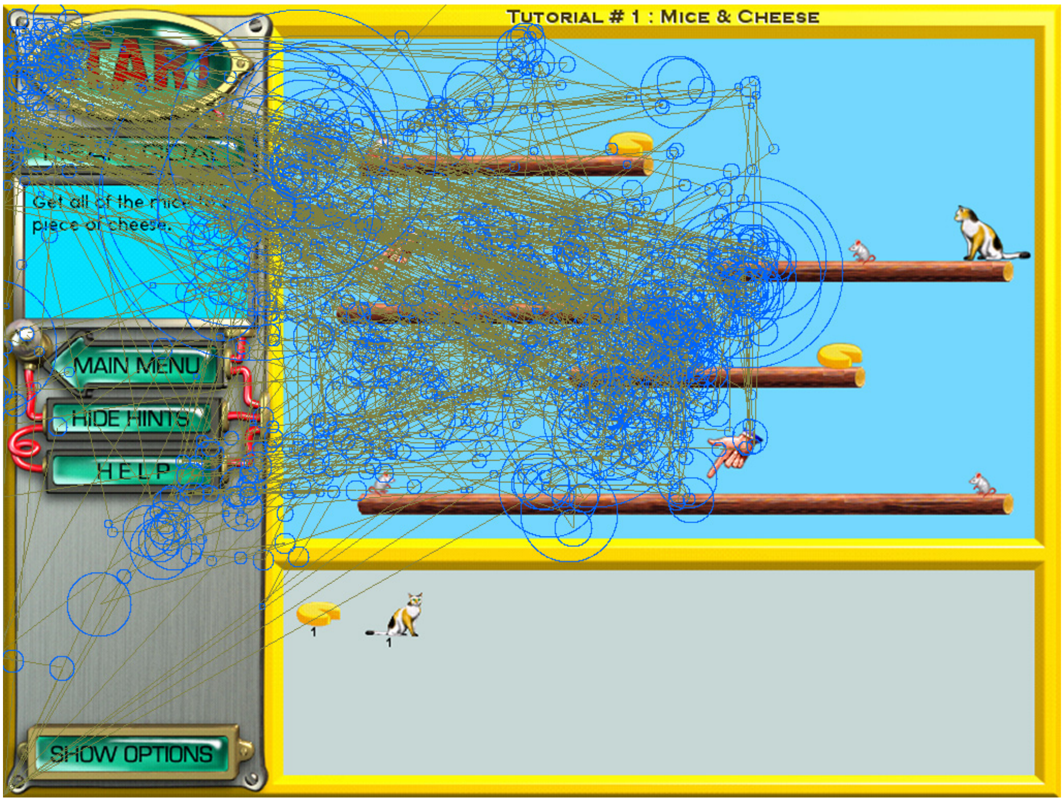

Figure E.4. Subject 2 Level 1

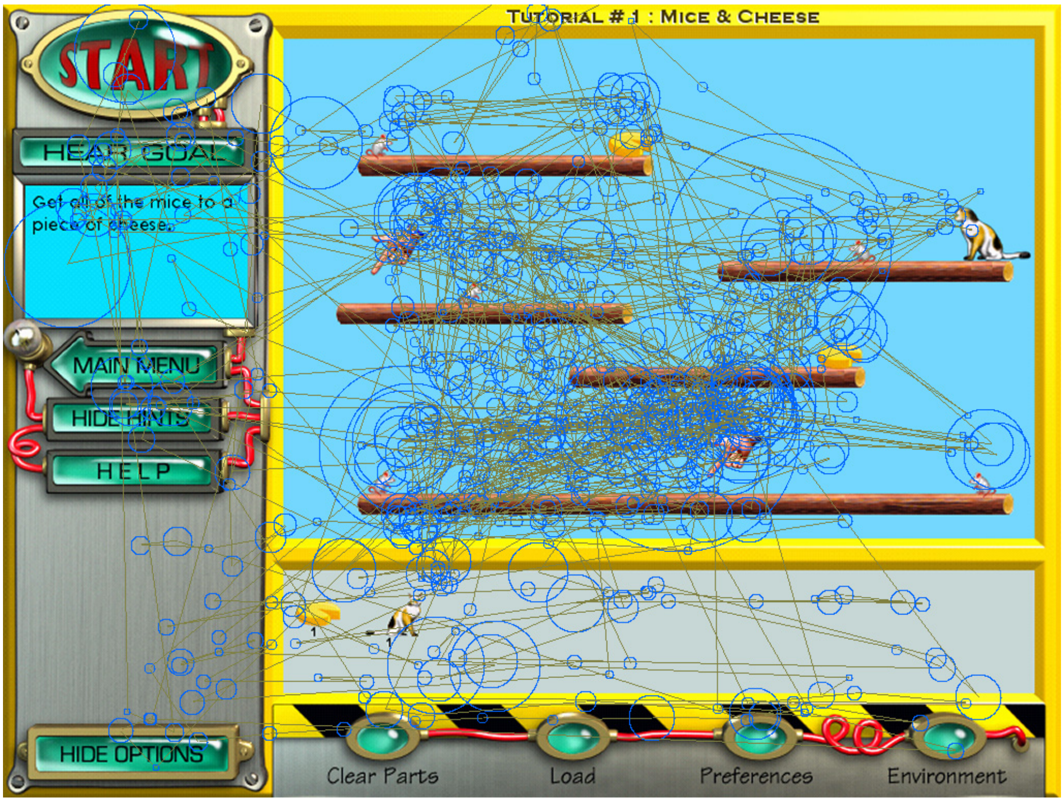

Figure E.5. Subject 3 Level 1

Figure E.6. Subject 3 Level 2

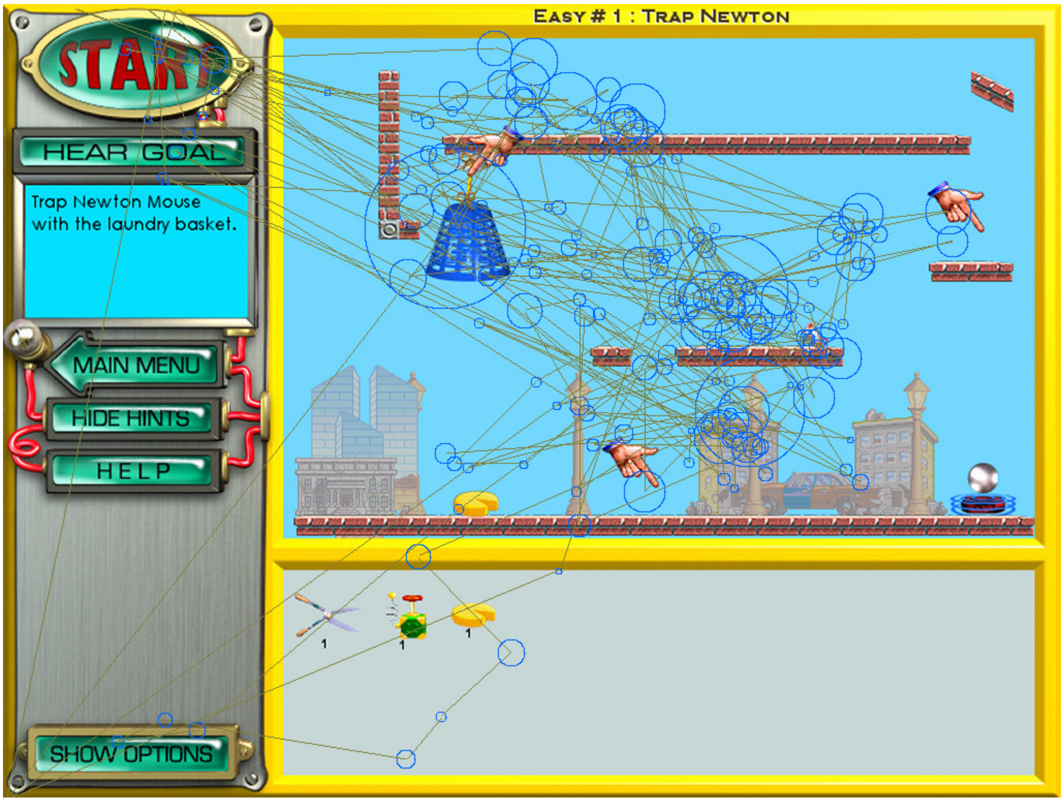

Figure E.7. Subject 3 Level 3

Figure E.8. Subject 3 Level 4

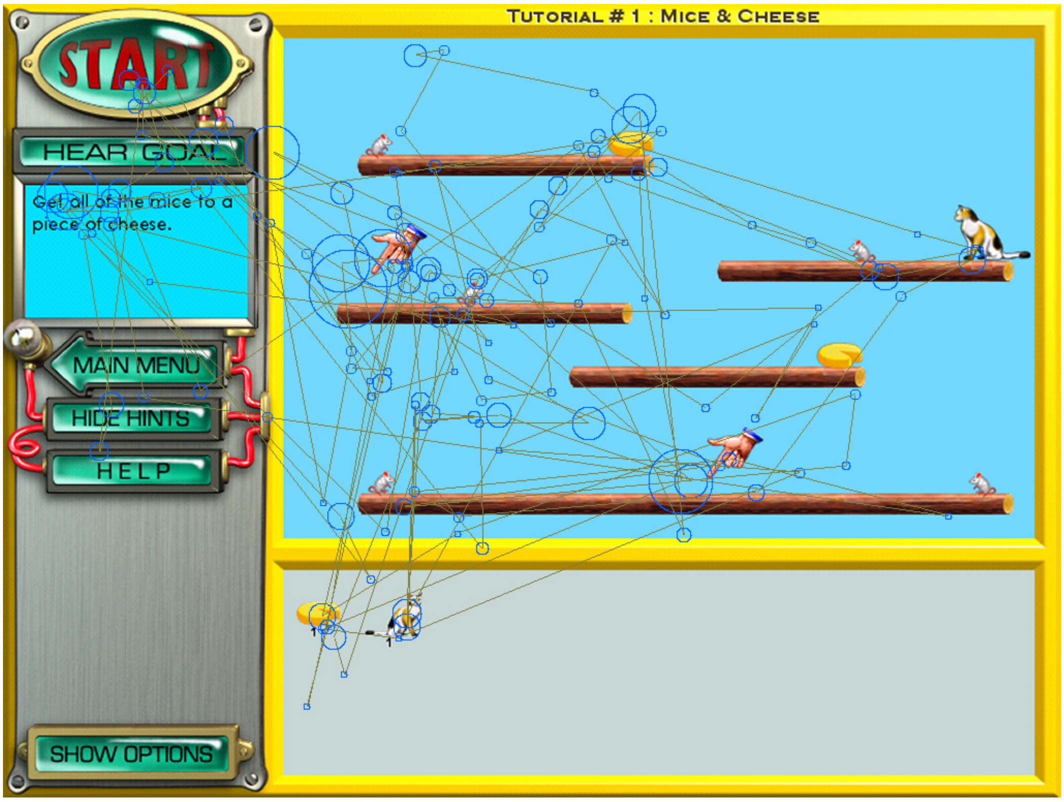

Figure E.9. Subject 4 Level 1

Figure E.10. Subject 4 Level 2

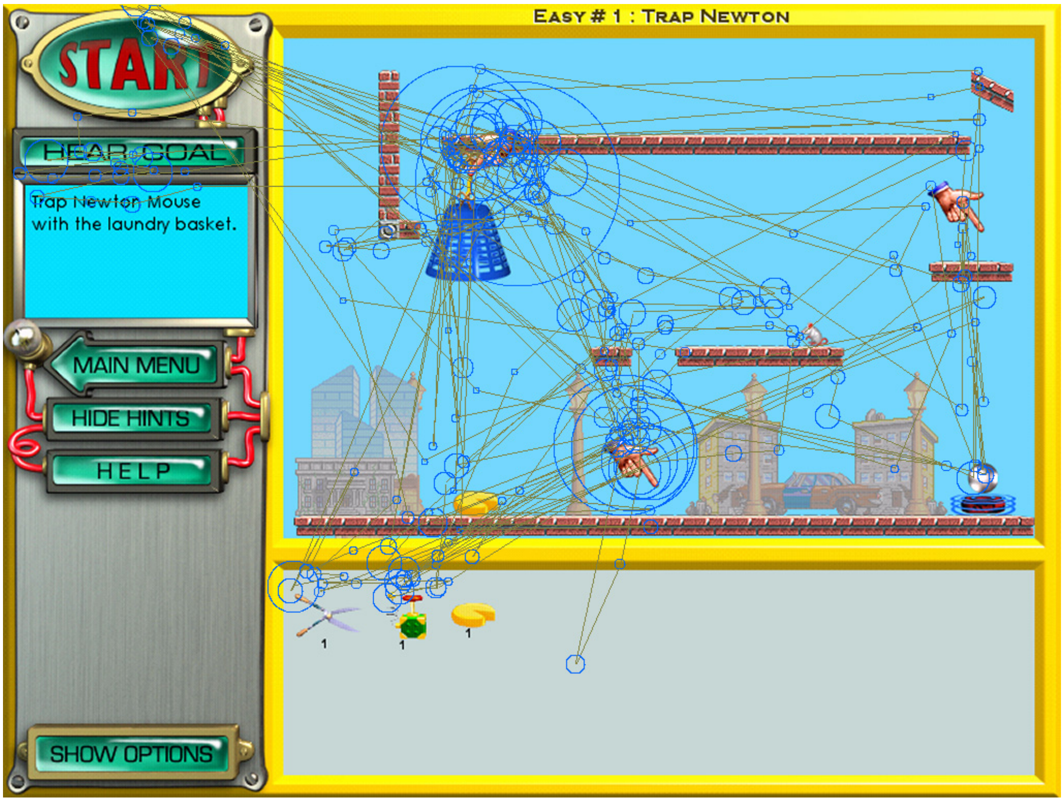

Figure E.11. Subject 4 Level 3

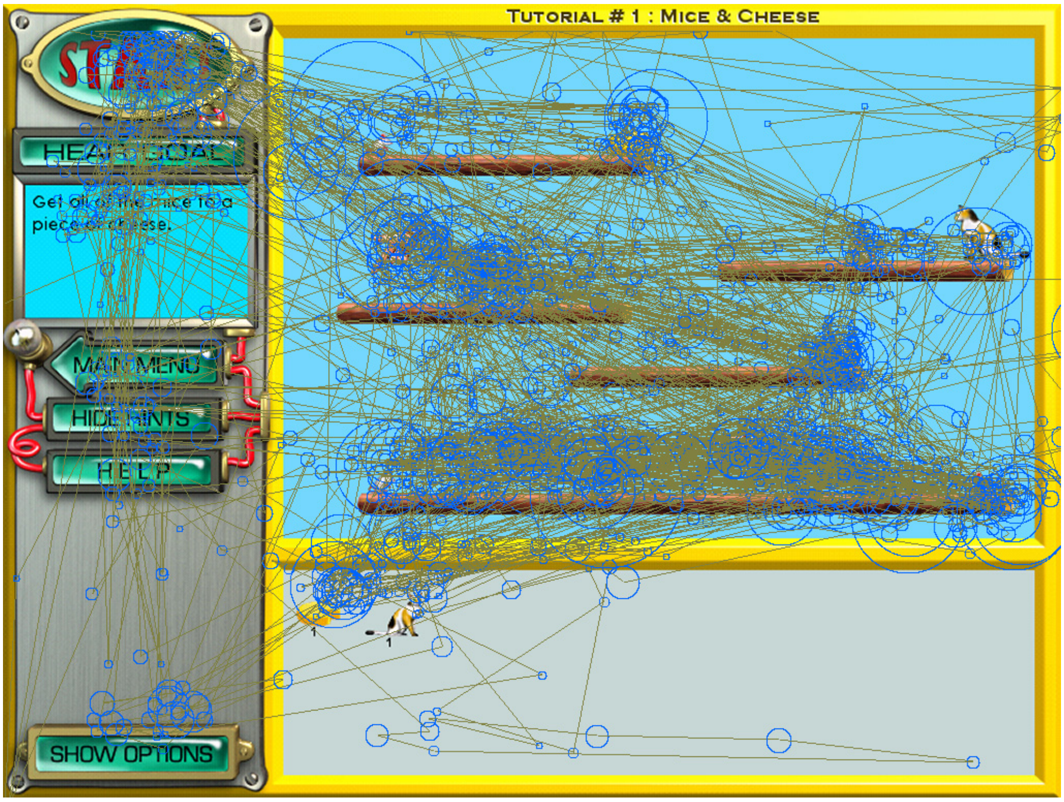

Figure E.12. Subject 5 Level 1

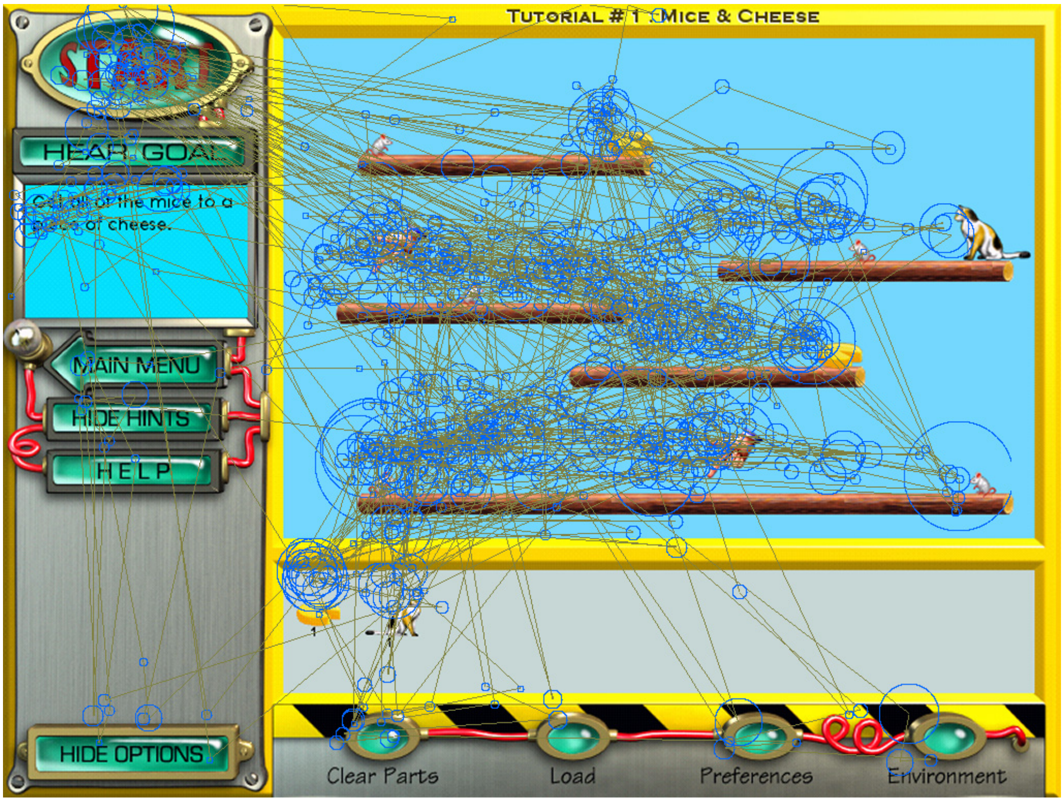

Figure E.13. Subject 6 Level 1

Figure E.14. Subject 6 Level 2

Figure E.15. Subject 6 Level 3

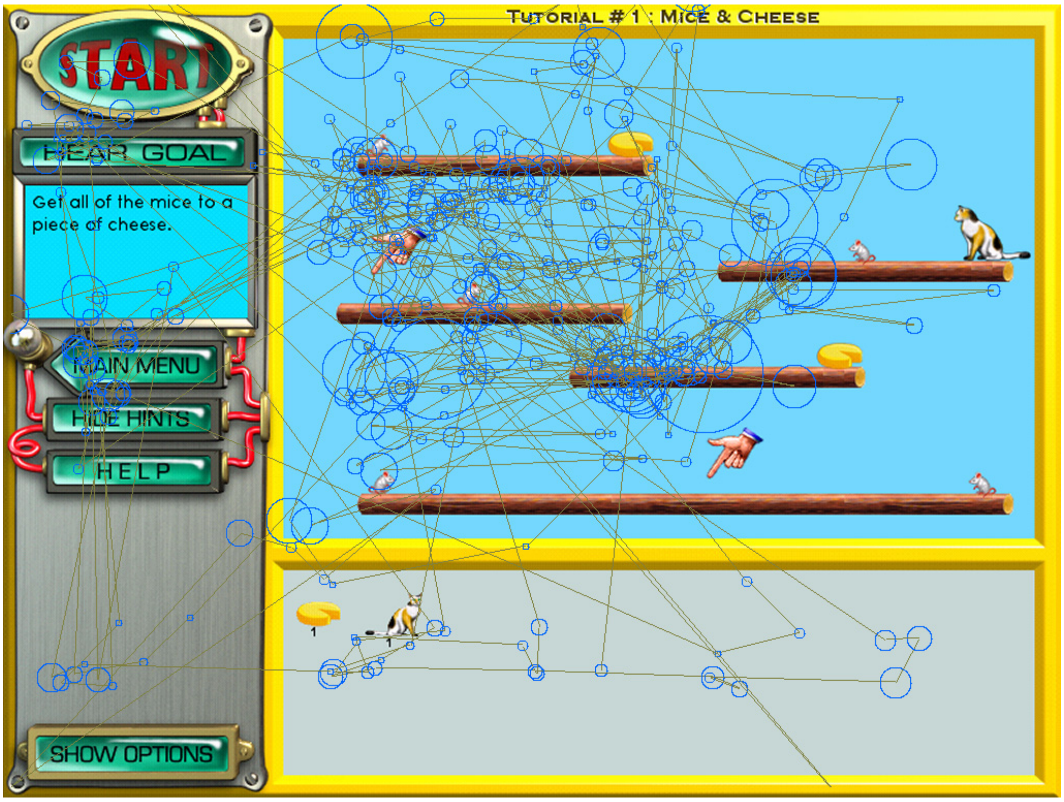

Figure E.16. Subject 8 Level 1

Figure E.17. Subject 8 Level 2

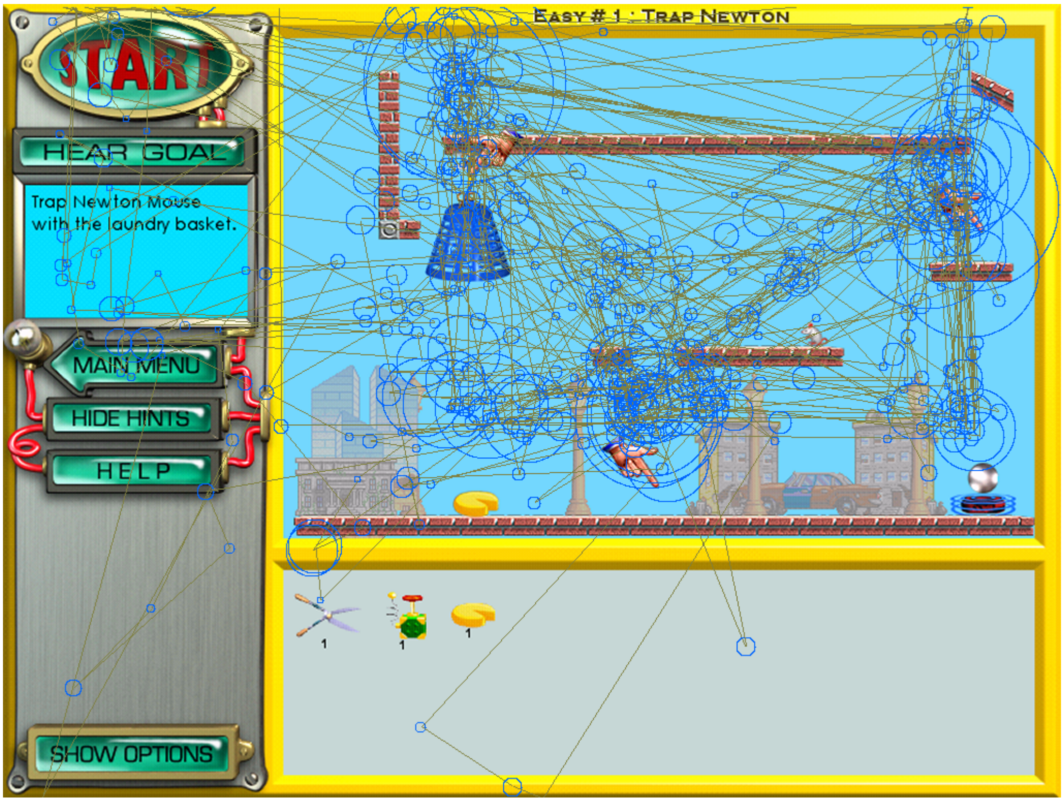

Figure E.18. Subject 8 Level 3

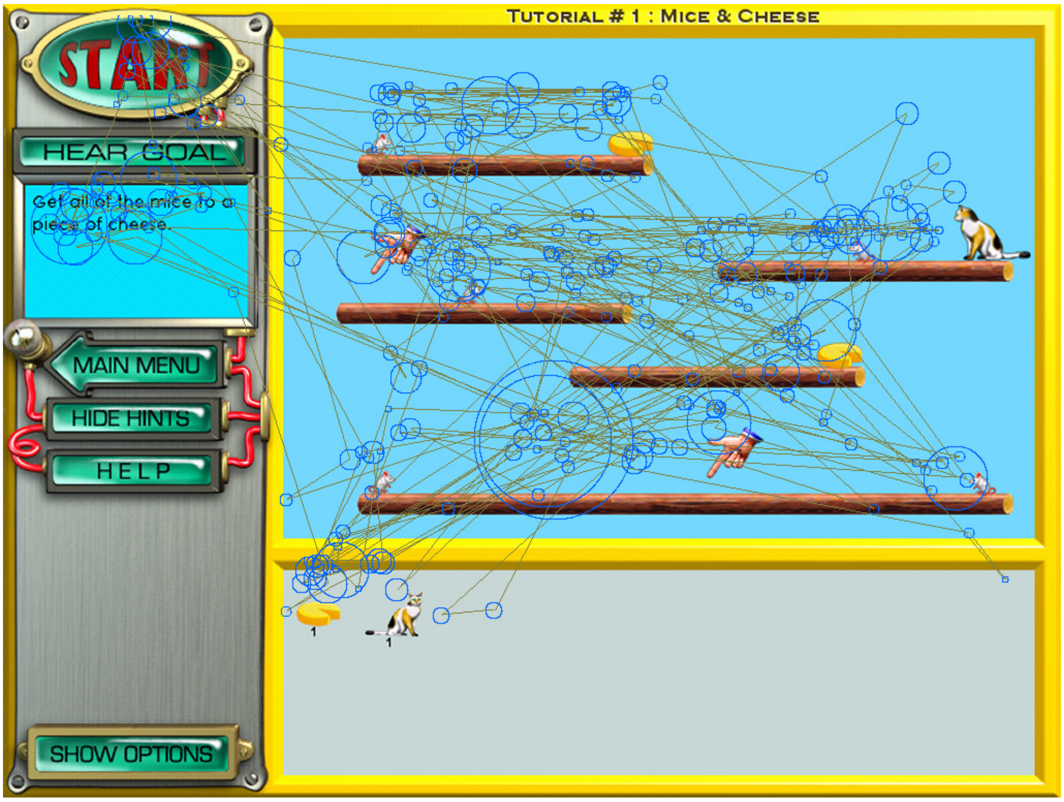

Figure E.19 Subject 9 Level 1

Figure E.20. Subject 9 Level 2

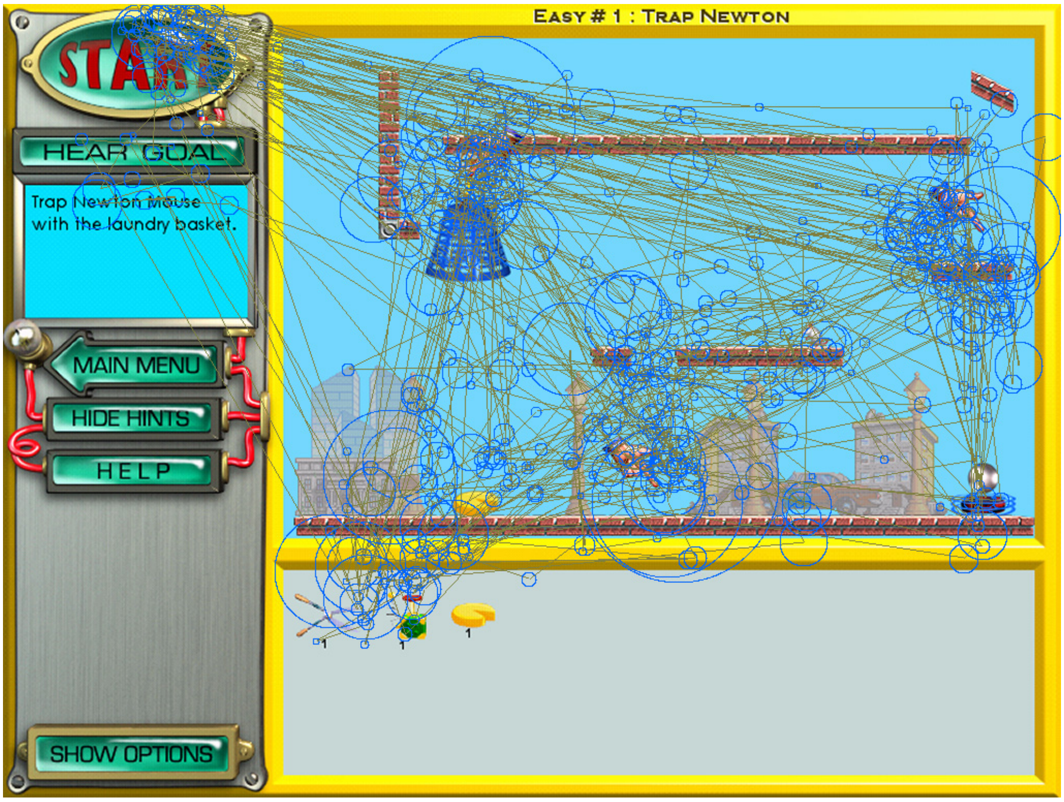

Figure E.21. Subject 9 Level 3

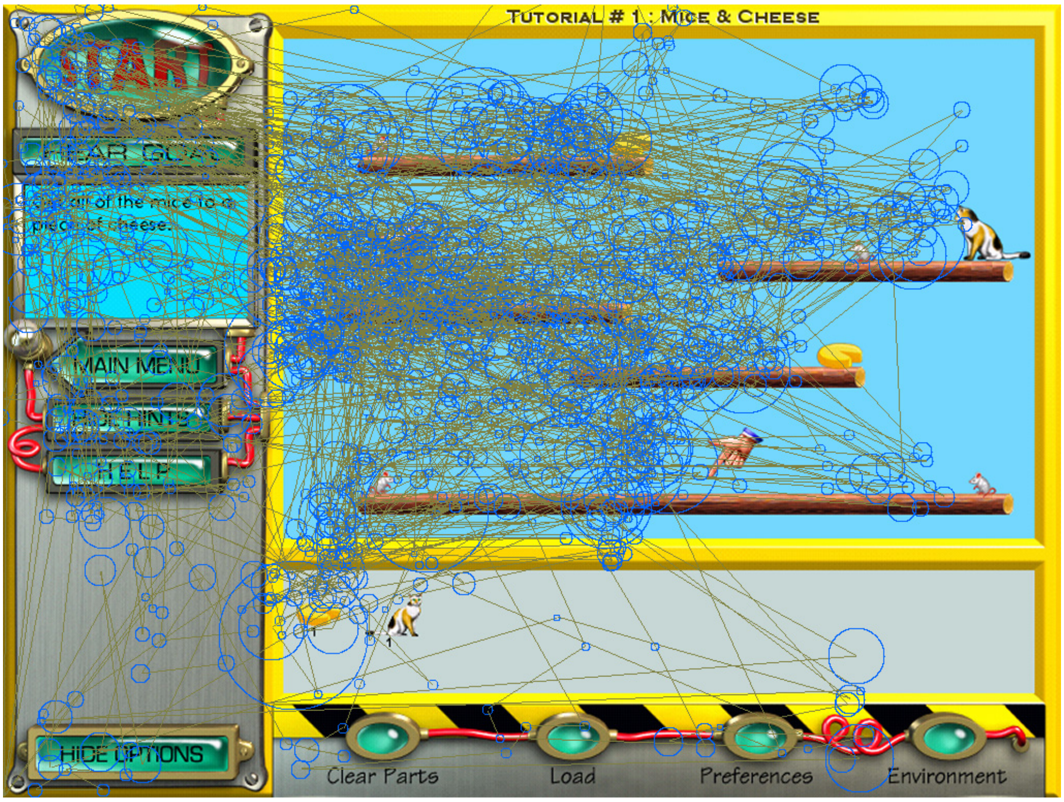

Figure E.22. Subject 10 Level 1

Figure E.23. Subject 10 Level 2

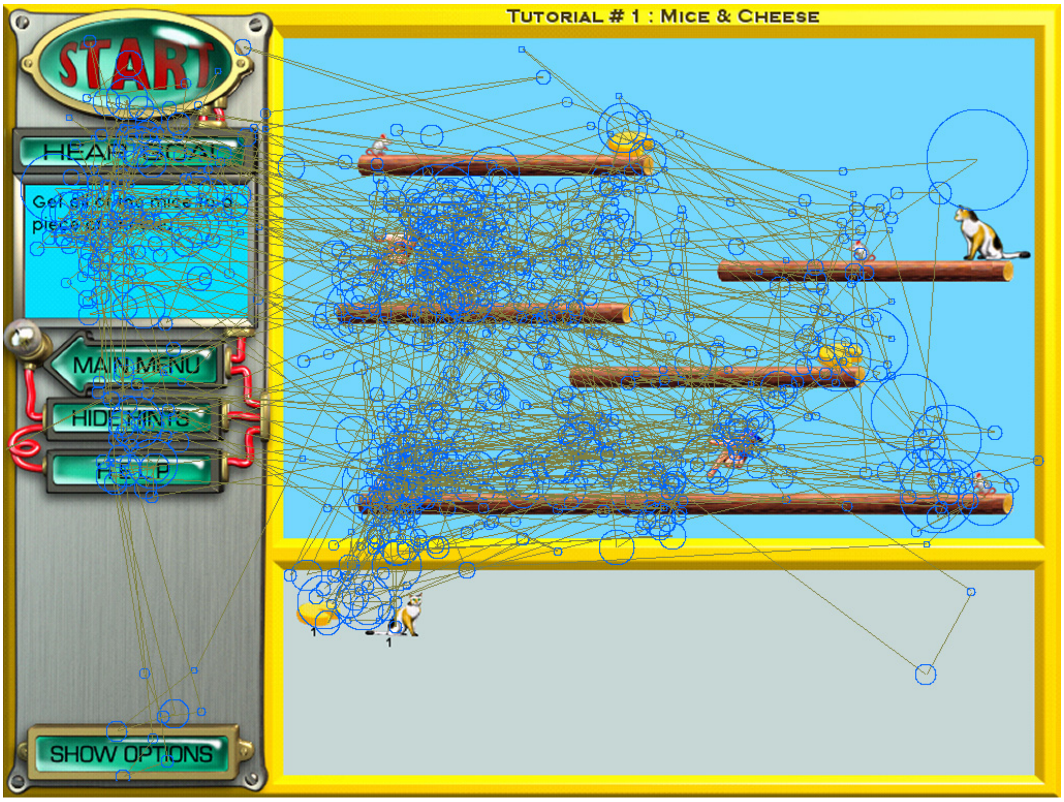

Figure E.24. Subject 11 Level 1

Figure E.25. Subject 11 Level 2

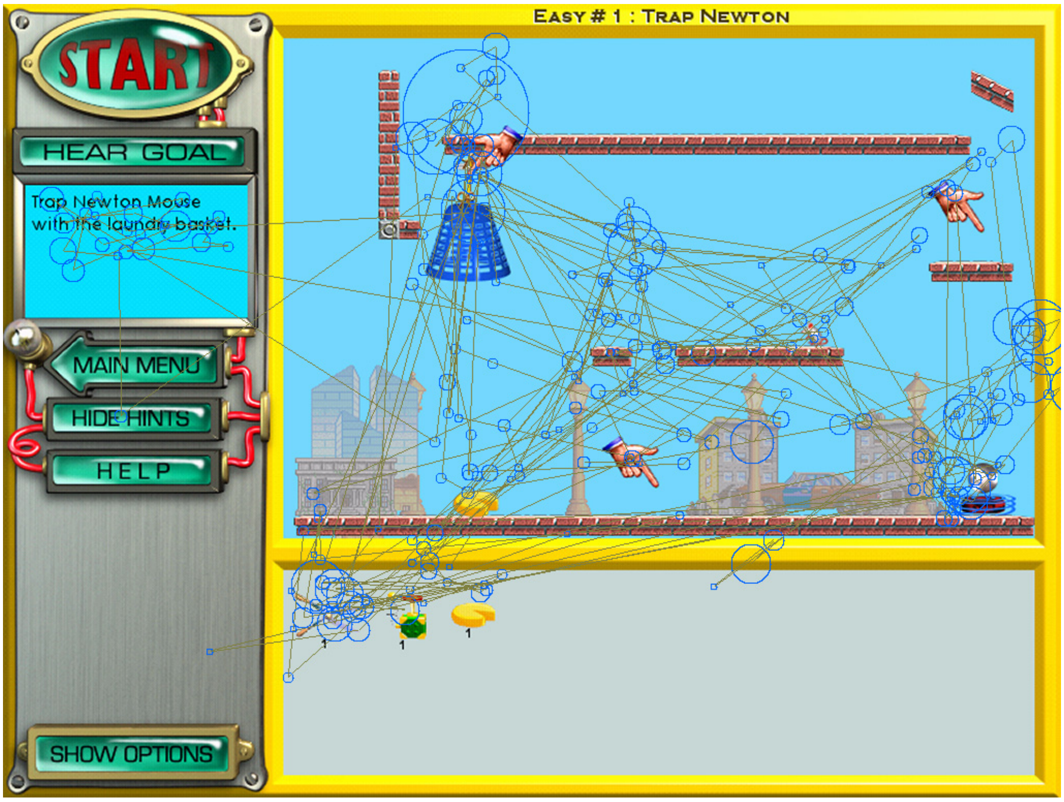

Figure E.26. Subject 11 Level 3

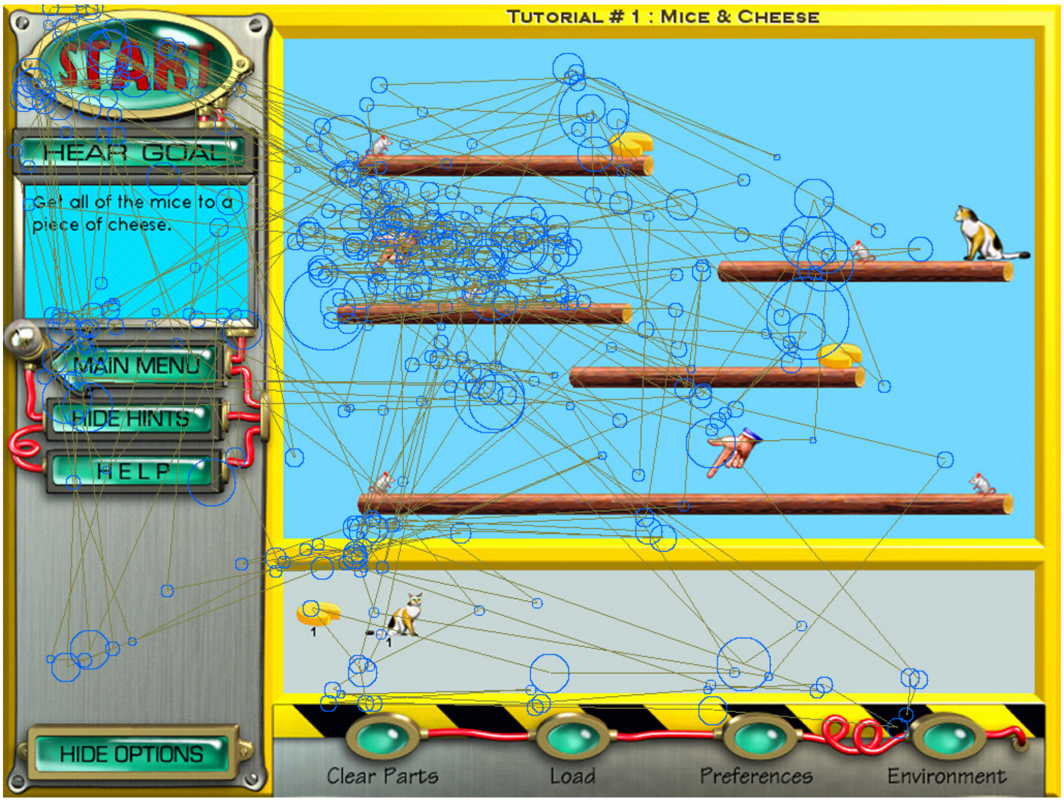

Figure E.27. Subject 12 Level 1

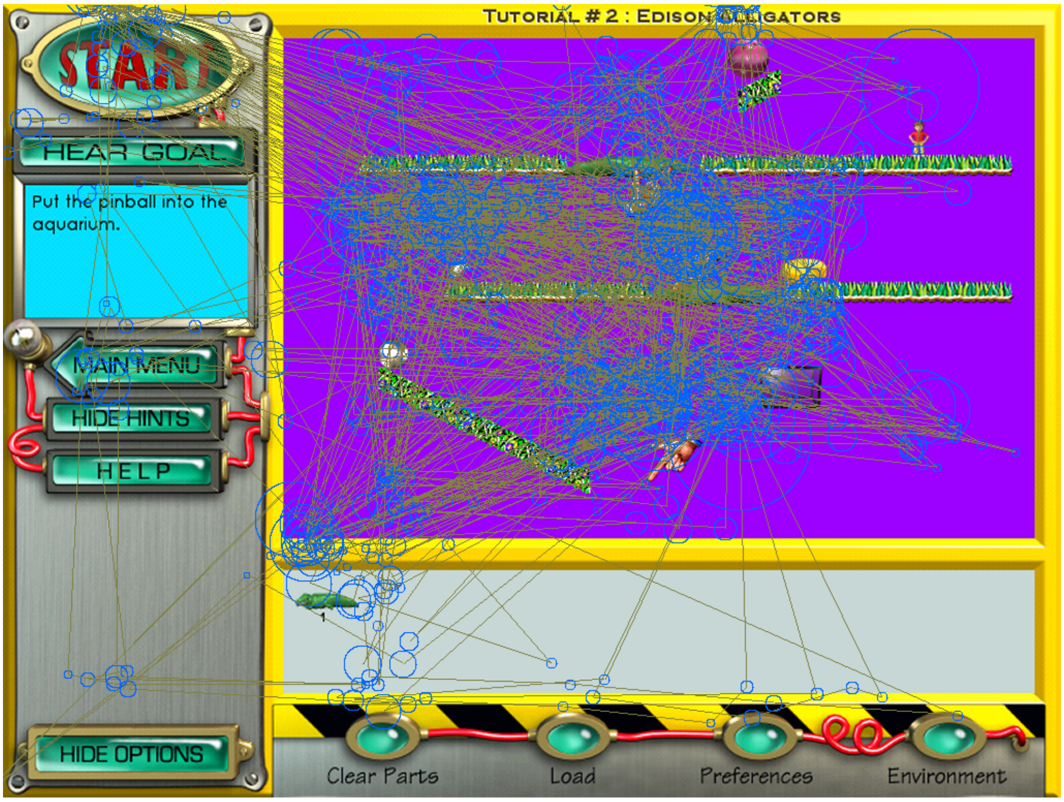

Figure E.28. Subject 12 Level 2

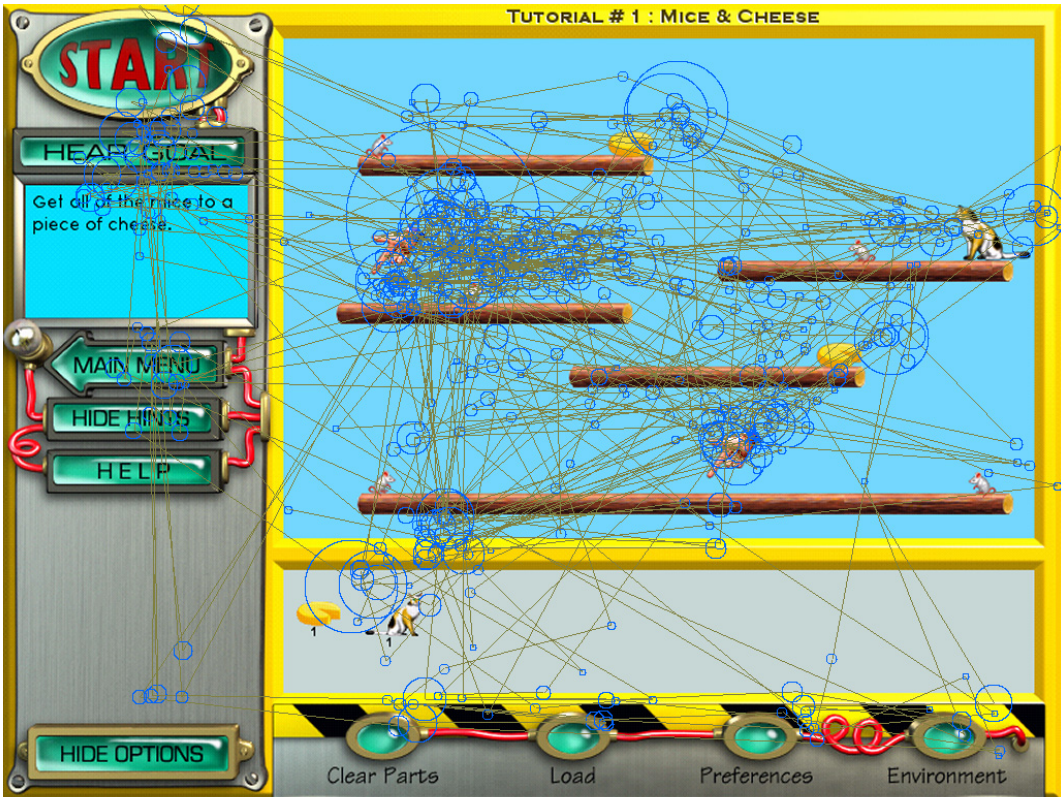

Figure E.29. Subject 14 Level 1

Figure E.30. Subject 14 Level 2

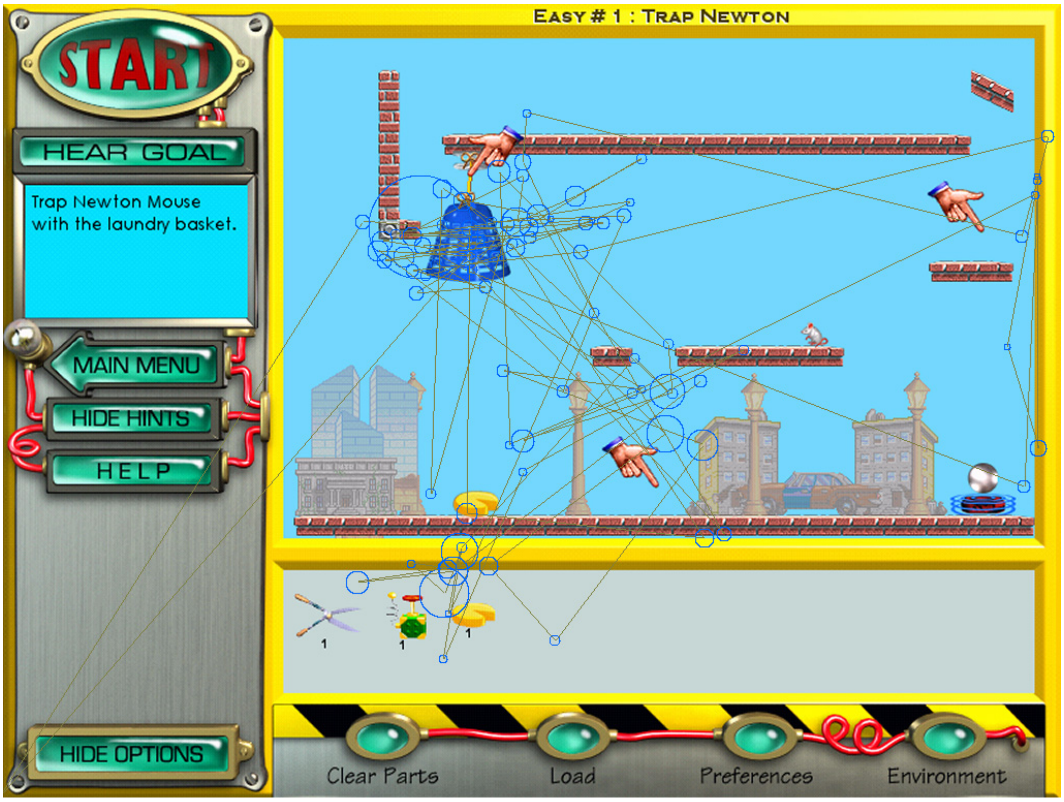

Figure E.31. Subject 14 Level 3

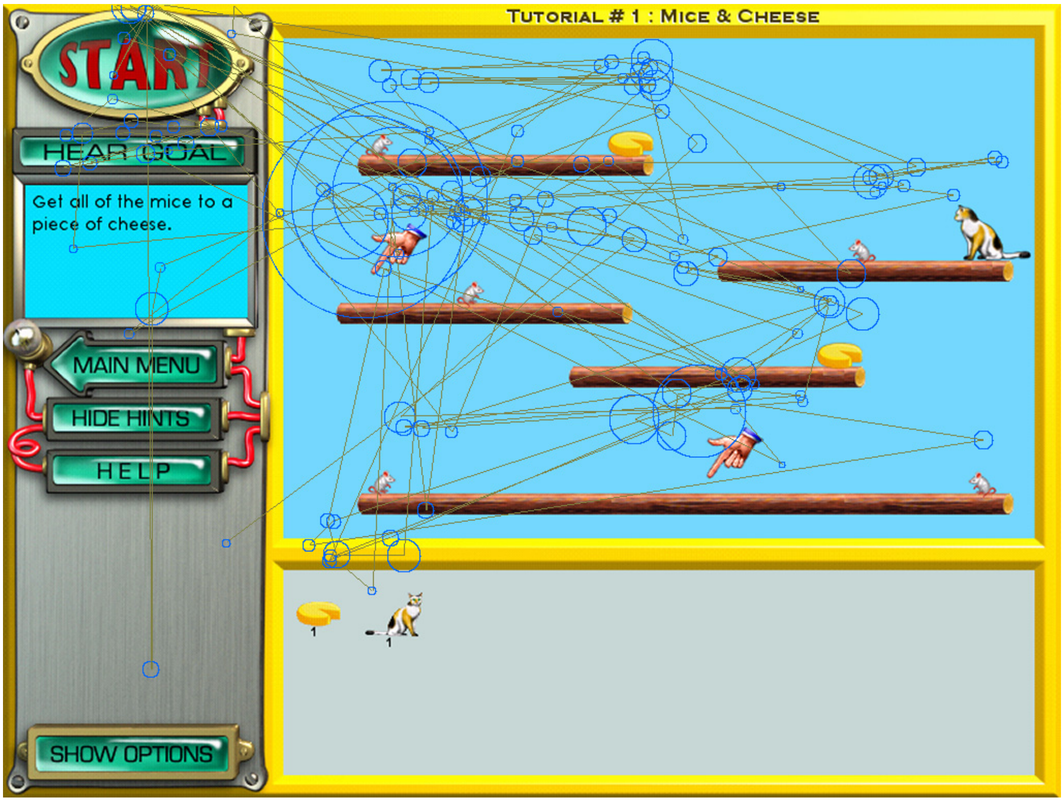

Figure E.32. Subject 15 Level 1

Figure E.33. Subject 15 Level 2

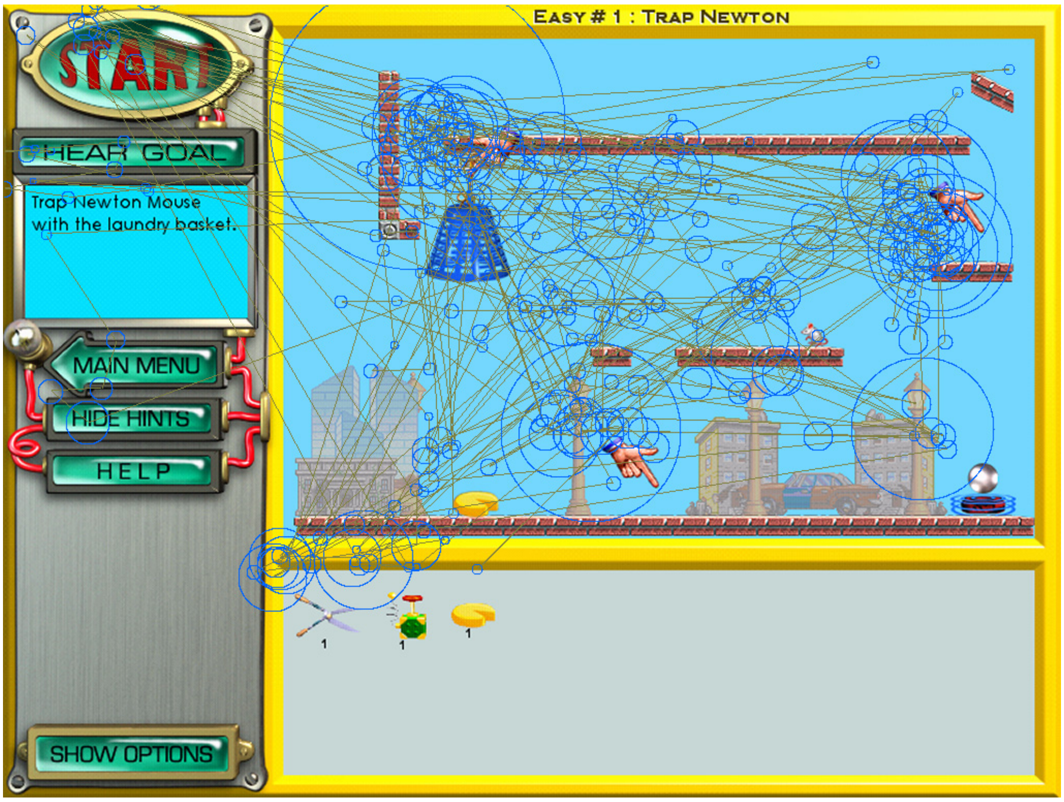

Figure E.34. Subject 15 Level 3

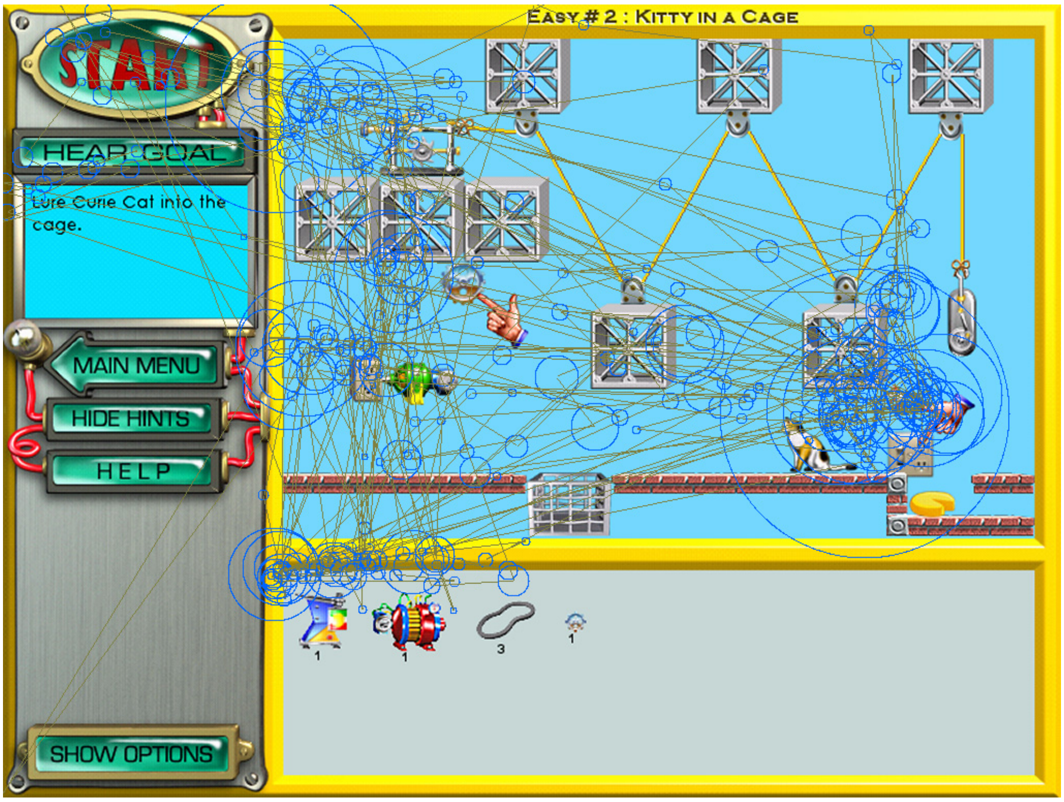

Figure E.35. Subject 15 Level 4

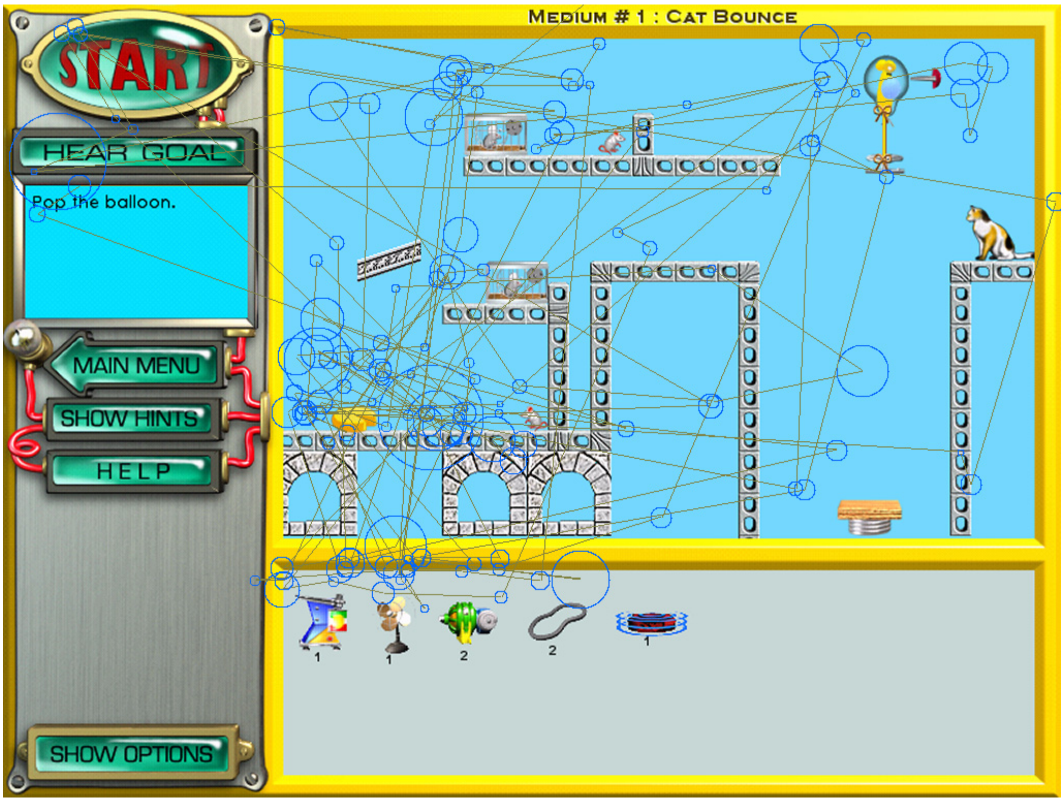

Figure E.36. Subject 15 Level 5