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Computer Games as Interactive Labels for Science Centre Exhibits

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2 INTRODUCTION

2.1 Research Aim

This thesis deals with the possibility of implementing computer games as visitor friendly and visitor-attractive information conveyors in places whose mission is to deliver, through inanimate artefacts (e.g. interactive science centre exhibits), some information (‘knowledge’) to the continuous stream of interested visitors.

The general idea is that, since playing computer games is inherently a very attractive activity – and not just for the youngest generations - the state of sensory immersiveness it is capable of inducing in the engaged player can be used to convey to the player specific information. In great majority of museums, galleries and science centres this role of conveying information about various displayed artefacts to the visitor is entrusted to traditional labels – a passive piece of paper with some text written on it. However, research has shown that visitors do not find reading the labels very lucrative, and hence the so much wanted information transfer from the artefact to the visitor is not satisfactorily achieved.

This work is a first step in exploration whether combining the appeal of computer games with the pure information delivery offered by the traditional exhibit labels can increase information transfer from the exhibit to the visitor – or in other words, increase informal learning output of a museum, a gallery or a science centre.

The aim of this work is to establish to what extent supplying a physical science centre exhibit with ‘virtual interactive label’ in form of a computer game can enhance and systematize visitor activity on that physical exhibit.

2.2 Thesis outline

The material in this thesis is organized as follows:

- **Chapter 3: Literature Review** – Three topics relevant to the main theme of the thesis are discussed through the references on the work done previously by a number of authors. This chapter fully sets the stage for the consequent more technical discussions in the **Chapter 5**.
- **Chapter 4: Research Setup** – This chapter contains a discussion of various technical and methodological issues which were necessary prerequisites for setting up and conducting this research. Some details about the methodology employed are further reviewed in the **Chapter 5**.
- **Chapter 5: Results and Discussion** – This chapter represents the heart of the whole thesis as it contains all of the research findings as well as a number of discussions about the interpretations of the obtained results.
- **Chapter 6: Conclusions and Recommendations** – The final research chapter of the thesis, discussing the implications of the obtained results and the possible future extensions of this research.
- **Chapter 7: References** – List of materials referenced in the main body of the thesis.
- **Chapter 8: Appendices** – Additional material of interest related to the thesis: raw data, ethnographic observation form

3 LITERATURE REVIEW

3.1 Informal Education in Digital Information Age

This first section of the literature review is devoted to discussion about the background on which the whole idea of 'informal' (i.e. 'out of school') education is based. The motivation for the new approach to education and in particular to the necessity of lifelong learning is argued. Also, some of the possible models for setting up and running this enterprise are briefly sketched.

3.1.1 The Quest for Lifelong Learning

In today's ever faster changing world, rapid adaptation to the new ways of doing things is becoming a prerequisite for professional survival. Thanks primarily to the immense global flow of information enabled by the modern Information and Telecommunication Technologies (ICTs), new knowledge of both natural as well as social processes is being amassed as well as adapted and converted to new applications at unprecedented pace. Only 50 years ago most of students leaving high-school were almost fully equipped for the professional life. They could pursue their career to its very end with almost no need to develop any new skills or acquire new knowledge. However, the changes brought by the digital information age enabled - and even started forcing - the perpetual modifications of most professions. Nowadays the successful worker in almost any field of human activity is required to constantly adapt to and learn to use the new technologies and procedures in her/his daily professional life.

Accompanying this change in professional requirements is the change in the role and means of education in today's society. Traditional formal education, a process that encompasses only at most the first 20 years of human life, simply cannot satisfactorily fulfil the requirements of the new era. On its own, it cannot sustain lifelong learning, so much needed by the new economy. This shift in the role of education is nicely described in **NRC CBSSE [2000]**:

> *In the early part of the twentieth century, education focused on the acquisition of literacy skills: simple reading, writing, and calculating. It was not the general rule for educational systems to train people to think and read critically, to express themselves clearly and persuasively, to solve complex problems in science and mathematics. Now, at the end of the century, these aspects of high literacy are required of almost everyone in order to successfully negotiate the complexities of contemporary life. [...] Above all, information and knowledge are growing at a far more rapid rate than ever*

before in the history of humankind. As Nobel laureate Herbert Simon wisely stated, the meaning of "knowing" has shifted from being able to remember and repeat information to being able to find and use it. More than ever, the sheer magnitude of human knowledge renders its coverage by education an impossibility; rather, the goal of education is better conceived as helping students develop the intellectual tools and learning strategies needed to acquire the knowledge that allows people to think productively about history, science and technology, social phenomena, mathematics, and the arts. Fundamental understanding about subjects, including how to frame and ask meaningful questions about various subject areas, contributes to individuals' more basic understanding of principles of learning that can assist them in becoming self-sustaining, lifelong learners.

NRC CBSSE [2000] (pp.4-5)

Reviewing various attempts to reform the formal education - and particularly formal science and technology education - in UK and USA during the past century clearly shows that a suitable solution for tackling lifelong learning problem is still far away. The problem is even further aggravated with the fact that every educational reform is regularly accompanied with a plethora of political agendas running in the background, making the whole state-run formal educational system extremely inert and making administration of any significant changes almost impossible. (**Donnelly and Jenkins [2001]**; **Shamos [1995]**)

3.1.2 Going Informal

Hence, as traditional school will not be able to support the lifelong learning for at least some time in the future, more flexible informal methods of education are emerging to fill the gap. Institutions like museums and science centres are becoming more and more important places of contemporary learning. This issue has been for some time now clearly recognized in the UK, and many activities and projects are developed to help the sites of informal learning bloom to their full potential. (**Artworks [2004]**; **the Museums, Libraries and Archives Council [2004]**)

MacDonald [2004] claims that science museums, as prime formal sites of informal education, can have a significant impact on today's education. She suggests that instead of being just a plain extension of strictly programmed education which is provided by formal education system, they have the opportunity to be much more provocative, question rising and opinion creating environments for their visitors. Unlike the formal education, which is focused on teaching a range of well known facts to the students, these facilities can aim more at teaching pure creative and critical thought, which is equally important and necessary element for the future development of science, technology and society at large. In her words:

> *'[...] the kinds of provocations provided by less tightly orchestrated exhibitions might often be more appropriate to the current age in which what is most needed is for the public to be able to engage in critical reflection.'*
>
> **MacDonald [2004]**

Going even further, the concept of *free choice learning* strives to demonstrate that learning is not an activity that happens at any particular place and time. Instead:

> *'As a society we need to recognize and support the vast, important and successful learning enterprise that takes place outside of schools and the workplace – learning from museums, libraries, the Internet, television, film, books, newspapers, radio and magazines. Collectively, these experiences encompass what is known as the "free-choice learning" sector. "Free-choice learning" is the most common type of learning that people engage in. It is self-directed, voluntary, and guided by an individual's needs and interests. Free-choice learning is so common that we have taken it for granted, despite its being as vital as learning in school and the workplace. Free-choice learning is amazingly efficient and effective learning. This is because people have control over what and how they learn, and because they can choose to learn in appropriate and supportive contexts. For example, if they want to learn about art, they can go to an art museum or borrow a book on art from the library. If they want to learn about nature, they can go to a state, regional or national park.'*
>
> **Institute for Learning Innovation [2002]**

3.1.3 The Promise of Computers and ICTs

So, slowly but surely attempts to find the suitable mechanisms to support and develop tools for the lifelong learning are finding their way into the social practice. One of the many interesting approaches to this problem harvests the power and the appeal of new information technologies:

'Computers and other aspects of Information and Communication Technologies (ICTs) allow children and young people a wide variety of activities and experiences that can support learning, yet many of these may not be considered "educational" according to our conventional understanding of that term. For most of us, discussion about learning is inextricably related to formal education systems (how schools should be organised, managed and run). However, any interest in the role of ICTs in children's learning forces the recognition that many children are immersed in ICT-related activities in their homes and with their friends. This recognition requires us to acknowledge a wider "ecology" of education where schools, homes, playtime, the library ant the museum all play their part.'

Sefton-Green [2004] p.2

But, young students are not the only ones that could potentially benefit from seemingly playful activities related to the use of ICTs in acquiring new and very important professional skills:

'Several years ago, a small sales organization implemented a simple email system in order to improve internal communications. Employees sat through a 30-minute training session on the rudiments of the system, including sending, reading, and replying to messages. Following this introduction, employees were encouraged to experiment with the system. [...] Management made no attempt to monitor or curtail this activity. [...] During this period of free play, an interesting phenomenon occurred. Employees not only started using email for a variety of work-related communication, they also greatly expanded their knowledge of the system's capabilities without any additional formal training. [...] Soon, they began to use email for myriad work-related communications, not limiting their use to requesting technical staff assistance. In a relatively short period, email became ingrained into the fabric of the organization.'

Belanger and Van Slyke [2002]

Finally, it is worthwhile mentioning that along with this idea that ICTs and computers in particular could have a great impact on informal education, the idea of using computers to refocus and modernize formal education as well is even older, almost as old as the computers themselves. (**Ahl [1976-I]**; **Ahl [1976-II]**)

3.2 Science Centre Environment

In this second section of this literature review I shall explore several elements of hands-on science centre's environment. The ideas developed in this section shall form the basis for the next and final section, devoted to the concept of hybrid exhibits.

3.2.1 Learning through Play

Anyone who has ever visited a hands-on science centre will undoubtedly agree that the venue can easily be perceived as huge playground. The 'exhibition floor' of such an institution is packed with huge number of curious-looking colourful objects, inviting the visitor to take a closer look at what they are all about. And indeed, the very behaviour of the great majority of the young visitors confronted with such an environment confirms this assertion. (**Bonacci [2004-II]**)

This should not come as a surprise as - although it is too often forgotten or even negated in formal education settings - the relation between the play and the learning is well established one. This relation is well documented in the literature. **Crawford [1982]** states:

> *'Games are thus the most ancient and time-honoured vehicle for education. They are the original educational technology, the natural one, having received the seal of approval of natural selection. We don't see mother lions lecturing cubs at the chalkboard; we don't see senior lions writing their memoirs for posterity. In light of this, the question, "Can games have educational value?" becomes absurd. It is not games but schools that are the newfangled notion, the untested fad, the violator of tradition. Game-playing is a vital educational function for any creature capable of learning.'*
>
> **Crawford [1982] chapter 2**

Further, in his seminal work, Roger Caillois, one of the most influential scholars of games and play as an important integral element of human culture says:

'Games discipline instincts and institutionalize them. For the time that they afford formal and limited satisfaction, they educate, enrich, and immunise the mind against their virulence. At thesame time, they are made fit to contribute usefully to the enrichment and the establishment of various patterns of culture.'

Caillois [1956] p.55

In this light, the fact that science centres do have an 'aura' of playfulness integrated into their very fabric receives the full justification. Moreover, what I am interested in exploring through this thesis is how this relation between the playing and learning can efficiently be extended into the virtual world of computer games. To this topic I shall return in one of the subsequent sections.

3.2.2 Exhibit Labels

In traditional non-interactive museums and galleries, both the role and the layout of exhibit labels are fairly clear:

'Labels provide a means for visitors to connect with objects in a museum. They may provide only the most basic identifying information for an object, or they may provide additional levels of interpretation, tying together numerous objects, facts and ideas into a thematic exhibition. [...] In all cases, labels should be easily visible, readable and enhance the viewing experience. Effective labels go hand-in-hand with clearly conceived ideas about how exhibits are organized and presented. Ideally, they should be an integral part of your exhibit design, rather than added to an exhibit after the fact.'

DeRoux [1982]

Some more unconventional 'affectionate' views of the concept of exhibit label can also be found:

'...since the beginning of museums, exhibit labels have been used as instruments for torture on helpless visitors [...] Labels can be designed so that they have a high probability of being read, meet the educational objectives of an exhibit, and create visitor satisfaction.'

Bitgood [1991] p.115

In this traditional museum setting, where all of the interaction the visitor is allowed to have with the exhibits is through reading labels, these same labels do act as an integral element of the exhibit which provides an added value to the visitor's experience.

However in a contemporary museum setting, which more and more often includes interactive 'hands-on' exhibits, the role of labels is somewhat dimmed. The basic philosophy behind the hands-on approach is simple:

> *'There is really only one way to learn how to do something and that is to do it. If you want to learn to throw a football, drive a car, build a mousetrap, design a building, cook a stir-fry, or be a management consultant, you must have a go at doing it. Throughout history, youths have been apprenticed to masters in order to learn a trade. We understand that learning a skill means eventually trying your hand at the skill.'*
>
> **Schank and Cleary [1995] p.74**

Although the work of **McManus [1989]** argues that the apparent lack of use of labels by the visitors is partly caused by the inappropriate methods of research into how visitors interact with those labels, the more up-to-date research presented in **Hein [1998]** indicates that in this new museum environment visitors seldom read labels and are more likely to use trial and error methods rather than written instructions (i.e. labels) when engaging with interactive exhibits.

With the pervasiveness of the ICT in the today's society, it was only a matter of time when traditional labels will be refurbished and upgraded using the new technologies. However, these technologically advanced versions of traditional exhibit labels still do not revolutionize the concept of exhibit labels. They simply add some flexibility to the traditional tasks of informing the visitor about the exhibit by supplying her/him with the visitor-tailored factual information about the exhibit. One typical example of this type of 'intelligent' label is presented in **Oberlander et al. [1998]**.

It is my strong belief that the new type of exhibit - such as interactive hands-on exhibit - requires completely new approach to the role and formatting of exhibit labelling. In this respect, the possibilities offered by the ICT - particularly information storage and retrieval, multimedial output and interactivity - should be more thoroughly and liberally explored. The concept of 'virtual part of hybrid exhibit' which I shall thoroughly discuss in the following section aims to do precisely that.

3.2.3 Computer Exhibits

The second common use for the ICTs in the contemporary museums is in form of standalone computer exhibits. These exhibits are basically various computer programs run on computers placed in more or less arcade-style computer cabinets. As it is thoroughly discussed in **Flagg [1994]** and in references therein, this type of exhibit is nowadays well established and visitor-appealing elements of museum exhibitions.

Internet has enabled a further step in interactive museology, as it enabled real-time information transfer between any two points on the globe. A number of online museums and galleries can be found and their collections and exhibitions browsed by a single click of the mouse. (**Online museums and galleries (a selection) [2004]**)

Standalone computer exhibits and exhibits in online museums and galleries have one thing in common: they are completely *virtual*! In other words, they are constructed out of pure information, and as such have no strong physical reliance on actual concepts they are presenting. In some cases this is quite all right, as many things presented to the audience through such virtual exhibits could not be presented in any other way. For example, whereas it is a simple matter to make a computer animation of a day in a life of a pre-historical animal, it would be quite impossible to face the visitor with real specimen of the animal itself.

However, in hands-on science centres, such situation is somewhat contradictory. As the exhibits in such centres tend to stick to 'hands-on' philosophy, which stresses that whatever you want to learn about, you should do so by actually trying to do it with your own hands. Now, if the phenomenon a visitor wants to inquire into is locked behind the computer code, and her/his only access to it is through the computer interface (buttons, trackball, joystick...) then it is obviously not a real hands-on exhibit! I believe that the concept of hybrid exhibit, explored in the following section, can resolve this issue and significantly enhance both the real physical hands-on exhibits as well as the completely virtual computer exhibit by merging them in a coherent whole.

3.3 Hybridizing the Physical Exhibit

The following sections of this literature review shall focus on a discussion of elements that should constitute the new 'virtual' learning environment built around currently existing physical hands-on exhibits. The fundamental idea is to join the powers of hands-on philosophy and the information manipulation power of the ICTs.

The complete layout of the concept of hybrid exhibit is presented in Bonacci [2004-I]. Hybrid exhibits can be considered as a step towards combining the motivational and educational output of science centre visit, as they provide not just the hands-on demonstration of particular concepts, but also much broader contextual 'playground' for free and individual visitor research on - and engagement with - the topic.

3.3.1 Advantages and Disadvantages of Physical Hands-on Exhibits

Physical interactive exhibits are the type of interactive exhibits that can be found in most today's hands-on science centres like Techniquest, Explore@Bristol or Launch-Pad in Science Museum in London (to name only a few of the UK examples - there are many more both in the UK and around the world!). These are actual physical artefacts through which a certain scientific concept or natural phenomenon is directly demonstrated to the visitor.

The greatest value of the physical exhibit lies in the immediacy that they provide between the visitor and the actual phenomenon. They truly demonstrate the phenomenon 'as it happens in the real world'. Hence, to visitor they have a value of clearly demonstrating that on whatever involved theoretical scientific construct it might be based on, the phenomenon presented indeed is something that actually happens in the nature.

The problem with the physical exhibits is that they are still too often designed using some templates from the days of 'glass-case' exhibits. One of such templates is the usage of labels, which (as I have already discussed earlier) in their traditional form simply do not make a good fit with the hands-on philosophy. Also, the finding by **Beer [1987]** that visitors average encounter time with an exhibit is only between 10 to 40 seconds is still equally valid in a science centre setting (**Bonacci [2004-II]**), and this is by far too short time period to yield any significant learning output. It should, however, be kept in mind that such brief interaction nevertheless can have a significant impact on the motivational aspects of visitor's experience, which is indeed an element just as important as (if not even more important than) the educational output of a visit to the science centre. (A very good discussion of the psychological and motivational aspects of interactive exhibits can be found in **Hayes [1998]** and **Hayes [1999]**).

3.3.2 Virtual Part of Hybrid Exhibit

The virtual part of the hybrid exhibit is not an exhibit by itself, but is rather an advanced version of traditional exhibit label which employs the full power of the technology. Its primary aim is to add a new dimension to visitor's total (educational and motivational) experience with the physical interactive hands-on exhibit in science centre. It is composed of three separate elements with different but complementary functions: 'The Arena', 'The Gallery', 'The Workshop'.

3.3.2.1 'The Arena' - Providing Motivation for Learning

The process of learning is inherently voluntary process. Knowledge simply cannot be poured into the learners mind without the learner's willing and active participation in the whole process. Hence, the motivation that the learner has for learning is crucial element of any educational effort.

In today's world, entertainment industry is prospering on inherent appeal of its products to its customers, and the strong link between entertainment and learning has existed throughout the history (Bender [1996]). According to **Zillmann and Vorderer [2000]**:

> *'In prosperous industrial societies, the citizens' pursuit of happiness seems to entail an entitlement to being well-entertained [...]'*
>
> **Zillmann and Vorderer [2000] p. vii**

The novelty in this respect is the means of entertainment delivery that have sprouted from the new computer technologies. Especially among the youngest generations - but not just among them - computer games are rapidly becoming the preferred entertainment. Hence, incorporated as an element into the new 'interactive' label of a physical exhibit, a computer game could provide an increase in the appeal of the whole exhibit. In fact, in discussing the elements that make an intrinsically motivating museum exhibit, **Perry [1994]** relied on the research inquiring into what makes computer games so appealing (**Malone [1980]**; **Malone [1982]**).

As its role in the virtual part of the hybrid exhibit is to provide the playground for visitors' adventurous free-spirits, the computer game incorporated into the virtual part of the hybrid exhibit is called 'The Arena'.

3.3.2.2 'The Gallery' - navigating the informational jungle

The new knowledge generation today is so fast that no single person can follow everything that is going on or contain in her/his own head all of the information available. However, the advance of technology and establishment of Internet has enabled mass archiving and convenient real time access to information. Information has become highly delocalised, but at the same time highly accessible.

To utilize this free global library, learner must first learn how to efficiently use the tools for information mining. Hence, one of the elements of the new 'lifelong learning curriculum' has to be concerned with navigating the information jungle and looking for information. Today one of the most powerful research tools in any scientific discipline is a web search engine. In the future, learning to use the search engine efficiently will become an absolute cultural necessity, not just in academic circles. The second element of the virtual exhibit - 'The Gallery' - contains small searchable database of concepts and objects related to the physical part of the exhibit.

Also, going back to the work of **McManus [1989]**, it is clear that some basic factual information about the exhibit - which is precisely the role that traditional exhibit labels have - is a very useful element of the exhibit, even though it is clearly insufficient in fulfilling all the needs of hands-on interactive exhibits. Hence, The Gallery can also be considered as the direct descendant of the old concept of exhibit label.

3.3.2.3 'The Workshop' - environment for hazard-free experimentation

The final element of the virtual part of the exhibit provides the visitor with the 'tools' and 'materials' for free virtual exploration of the concepts and phenomena demonstrated by the physical exhibit. Namely, some tasks of a kind may be hazardous, time or space consuming or expensive to be exercised in science centre setting. In such situations, the fundamental tool in learning - the method of trial and error - is completely inappropriate.

However, today’s technology enables us to very realistically recreate the necessary environment in form of computer simulation. Such a virtual simulated environment then provides a very realistic yet risk free 'workshop' where the beginner-learner can safely exercise the skills needed to successfully control the actual real environment. Indeed, the potential of simulations as an educational tool has been clearly recognized and as can be seen from examples like **Aldrich [2004]** or **BBC [2004]** it is already being employed. Hence, the final element of virtual part of hybrid exhibit - 'The Workshop' - is interactive computer simulation which provides virtual free exploration research area for interested visitor.

4 RESEARCH SETUP

4.1 Technical Aspects of Exhibit Design

4.1.1 Original Exhibit: Techniquest Fish Tank

The starting point of this thesis was the fish tank displayed as an exhibit on the Techniquest exhibition floor. Unlike all the other Techniquest exhibits, this fish tank is not the least interactive and the only way a visitor can engage with it was to simply take a look at it.

By ‘hybridizing’ the fish tank – i.e. supplementing it with an interactive computer label – I hoped to broaden this rather poor range of possible visitor interaction with the exhibit.

The fish tank is located in the Techniquest ‘wet area’ which contains several water-related exhibits. The whole wet area is located in one corner of the Techniquest exhibition floor and the fish tank is located on the very interface of the wet area with the rest of the exhibition floor so that most of the visitors that come to the wet area pass by it.

Fish tank is roughly 200 cm * 150 cm * 40 cm in size. It contains the habitat of the Amazon river (fresh water at temperature of 27 C) with four different cohabiting species of fish: cardinal tetras (about 20 specimens), penguin tetras (about 5 specimens), rummynose tetras (about 5 specimens) and bushynose catfish (4 specimens).

4.1.2 Software Development

The software for the computer game, titled ‘Todd the Cod’s Great Techniquest Fishtank Adventure’, was developed in Macromedia Flash. The game itself is made as a web (html) page with a flash game embedded into it.

4.1.2.1 Game type

Two slightly different versions of the game were developed to enable comparison between the various game parameters. They are available online at following addresses:

- **version 1** – http://mozak.znanost.org/~duje/portfolio/radiona/globalgame1.swf
- **version 2** - http://mozak.znanost.org/~duje/portfolio/radiona/globalgame2.swf

Both versions are quiz-type games in which the visitor is asked to answer as many questions as possible within a given time limit. Games contain a total of 12 different questions (which are the same for both versions) classified in 3 categories: questions about the fish tank environment; questions about the geography related to the fish tank habitat; and questions about the fish in the fish tank.

4.1.2.2 Time limits

Time limits were slightly different between the two versions.

In version 1 of the game visitor was given 60 second limit to answer all (or as many as possible) questions. In version 2 of the game 30 second limit was given to answer each of the questions. After the time limit is reached, the game automatically ended.

In fact, all of the interactive scenes in both versions of the game have some time limit, so the game is automatically reset to the initial scene after some period of inactivity. This enabled each consecutive visitor to start from the same point in the game (default initial scene) and greatly simplified and systematized the data gathering.

4.1.2.3 Instructions

After pressing the ‘Play the Game’ button on the initial scene, visitor is given brief instructions explaining how to play the game and the scoring. Time limit of 20 seconds is given for reading the instructions, after which the game automatically resets back to the initial scene.

4.1.2.4 Scoring

For each correctly answered question player is awarded points which contribute to the total final score. Scoring is slightly different for the two versions of the game.

In version 1, 10 points are awarded for each correct answer and 5 negative points are awarded for each wrong answer. No constraints exist on the total number of wrong answers, so visitor can freely pursue trial-and-error method throughout the game. If the visitor answers all of the questions correctly, the bonus points are given for the remaining time available.

In version 2, 10 points are awarded for each correct answer, but no negative points are awarded for the wrong answer. However, visitor had 3 ‘lives’ and by answering wrongly one life was lost. After the third wrong answer the game was over. If the visitor answers all of the questions, the bonus points are awarded for the time remaining in answering the last question.

4.1.2.5 ‘Hall of Fame’

The 20 of the current highest scores are displayed in the ‘Hall of Fame’ on the default initial scene of the game. After finishing the game, visitor who achieved one of the high scores is offered to enter her/his name in the ‘Hall of Fame’.

The name is entered through the separate ‘Enter your Name’ scene containing the complete alphabet. Time limit of 20 seconds is set for entering the name.

4.1.3 Hardware and On-the-Floor Installation

Game was hosted by one of the standard computer cabinets used in Techniquest (**Figure 4.1**).

Figure 4.1 *– Standard computer cabinet on which the game was hosted.*

4.1.3.1 Cabinet positioning

Two things were taken into account when deciding on the location of the computer cabinet.

The first was that the player sitting down before the cabinet has to be able to thoroughly see the fish tank while playing, as number of the questions were directly related to observing the fish tank and its contents. Hence, the cabinet was placed immediately besides the fish-tank.

The second requirement was the one related to research data gathering. Namely, to gather the ethnographic observation data, I had to be able to follow as closely as possible the visitor's in-game activity. As I did not want to interfere with the players during the game in any manner, the cabinet was slightly angled with respect to the fish tank so that I could clearly observe the visitor activity behind their back from a distance of about 5 metres.

The exact positioning of the cabinet with respect to the fish tank can be seen in **Figure 4.2**.

Figure 4.2 *– The location of the cabinet with respect to the fish tank. Fish tank is behind the glass surface on the right side of the image.*

4.1.3.2 User interface

The game is controlled using the trackball and a button. This is the standard user interface employed in most of the Techniquest computer exhibits. It works excellent as it is very familiar to great majority of the visitors. Indeed, great majority of visitors had no problem using it.

4.2 Research Methodology

As I was not aware of any previous research on this type of science centre exhibits, the first step in my research was to decide on the research methodology.

4.2.1 Formative Evaluation and Variable Selection

The introductory formative research period spanned one week. It started as soon as the exhibit was put on the exhibition floor. During this period several things were done simultaneously.

4.2.1.1 Tweaking the game details

The first task in the formative evaluation period was to fine-tune the details of the game design in response to the observed visitor interaction with the game. Several game elements were adjusted as a result of these observations.

- Hall of Fame was incorporated in the initial scene. In the beta version of the game, Hall of Fame was a separate scene which could be opened from the initial scene.
- The Help/Hint button was experimented with, changing its size, position on the screen, colour and the content of Help/Hint text. For the reasons which will be discussed in the Results and Conclusions section of this thesis, all the introduced changes had no impact whatsoever on changing the visitors' urge to use this button.
- Animated element – Todd the Cod swimming on the bottom of the initial scene – was introduced to capture the visitors' initial attention more efficiently.

4.2.1.2 Establishing the coding for visitor behaviour

As I did not have available any previous work akin to this research, I needed to establish the strongest among the patterns of visitor interaction with the whole hybrid exhibit (fish tank + computer game) whose occurrence could be firmly quantized by simple observing whether particular visitor displayed them or not.

Based on these observations, the data collection form was developed into which behaviour of each particular visitor was entered in terms of several observable codes. The detailed discussion of the finally adopted coding can be found in the Results and Discussion section.

4.2.2 Summative Evaluation and Data Collection

The second phase of the research was summative evaluation period during which the data set to be fully analysed was gathered. The research methods selected were the amalgam of qualitative and quantitative approaches, which enabled me to capture the visitor interaction with the hybridized fish tank in full detail.

4.2.2.1 Quantitative methods

Two different types of the quantitative data were gathered during the data collection phase of this research.

The first type of quantitative data was computer logs of visitor interaction with the game. The game software included a simple data collecting routine which collated the precise sequence and times of each button pressed during the game, as well as all the consequences of these actions (correct/wrong answer, visitor score, visitor name entered in Hall of Fame,...). This data enabled me to fully reconstruct each the games played. This data was collected automatically, for all the games played.

The second, complementary, quantitative data set were counts of coded visitor behaviours on the exhibit. Computer logs could not decipher e.g. whether the consecutive games were played by the same visitor, whether only a single player of a group of them were engaged in a particular game or whether the player interacted in some manner with the physical part of the hybrid exhibit (i.e. the fish tank). On the other hand, this ethnographic data gathered through direct observation of visitor on the exhibit enabled me to link the gameplay with the actual visitor behaviour and hence to find out why and how some game fully logged by the automatic data gathering system was started, played and ended by the particular visitor.

More details about the quantitative data collected can be found in the Results and Discussion section of the thesis.

4.2.2.2 Qualitative methods

As every visitor that interacted with a hybrid exhibit is a distinct individual, quantitative data could not capture the full richness of the total behaviour displayed. Hence, along with the coded behaviour ‘counters’, each entry in the ethnographic data gathering form contained a plain text-box into which additional comments and observations could be entered. Also, additional qualitative data amassed in these text-boxes greatly facilitated the process of linking the two quantitative data sets into a coherent whole. Sample ethnographic observation form can be found in **Appendix** 1.

5 RESULTS AND DISCUSSION

5.1 Data Set Robustness and Completeness

This first section of this chapter is devoted to the quick overview of the quality of the gathered data. The role of the following discussion is twofold: first, it should help interested reader find their own way through the vast quantity of raw data which can be found collated in the **Appendix 2**; second, it should reassure the reader of the breadth and depth of the collected data and hence demonstrate the consequent reliability and limitations of the conclusions based on it and drawn in the **Section 5.2** and **Section 5.3**.

5.1.1 Total Raw Data Set and Coding

For each of the two versions of the game, data were gathered on five different weekdays, all of them during the school term. Data for the first version of the game were accumulated on the Thursday 17/06, Friday 18/06, Monday 21/06, Thursday 01/07 and Monday 05/07. Data for the second version of the game were taken on the Tuesday 22/06, Friday 25/06, Monday 28/06, Tuesday 29/06 and Wednesday 30/06.

5.1.1.1 Excluding weekends

The reason for not incorporating weekends into this research is the following. In order to produce a statistically sound data set, data had to be collected during a prolonged period of time. During the formative evaluation phase, I have established that daily number of computer logs was about 100 whereas the number of ethnographic data logs was between 40 and 60. To achieve statistical significance of both of the data sets on each of the selected codes I needed at least 200 – 300 individual entries with the same type of visitors. This meant at least 5 days of data collection for each version of the game.

However, the sociological structure of the visitor groups is very different on the week days, when the great majority of visitors come as large school groups, and on the weekends, when the majority of visitors are small family groups. Hence, to make the conclusions of this research firm, I would need to analyse separately the weekdays and weekend data, totalling 20 daily data sets. In terms of data collection time this would mean that collecting week days data would require just about a week for each version. However, to collect enough data for the weekends, it would take at least five weeks.

There is a further element that would make weekend data gathering even a lengthier task. Namely, all of the school groups come to Techniquest according to pre-booked schedule so that the daily number of visitors on the weekdays is relatively constant throughout the school term and ranges between roughly 500 and 800. The details on the total visitor numbers for the observed days can be found in **Table 5.1**.

version 1	Thursday 17/06	Friday 18/06	Monday 21/06	Thursday 01/07	Monday 05/07
	627	579	592	740	575
version 2	Tuesday 22/06	Friday 25/06	Monday 28/06	Tuesday 29/06	Wednesday 30/06
	518	494	678	602	653

Table 5.1 *– Total visitor numbers in Techniquest for the observed days*

On the other hand, the number of family visitors that come on the weekends is quite unpredictable (from 200 to over 1000) as most weekend visitors come without any advance booking arrangement. There is also well established and quite strong correlation between the weekend visitor number and the weather in Cardiff on a particular weekend day: if the weather is nice, the visitor numbers are low; if however the weather is unpleasant, visitor numbers are very high. Hence, to get the good daily weekend data, I would need to observe on 10 different bad-weather days. As I could not rely on the weather being bad absolutely each weekend during a five-week period in June and July (which was the time I had available for data collection), I decided to abandon the whole weekend and family group analysis and focus only on the week days and school groups.

5.1.1.2 Ethnographic data set

Ethnographic data for this research was collected using the structured observing log sheet. The following elements (along with the respective coding) were observed:

- precise start time of interaction;
- sex and estimated age of visitor(s) at the exhibit;
- number of visitors engaged simultaneously: individual, group with group size and group type (peer, family, other – e.g. teacher and students);

- in case of group engagement, whether there was some notable social interaction elicited by and focused on the game;
- whether during the game there was some notable attention shift from virtual exhibit (computer game) to physical exhibit (Techniquest fish tank): none, just a quick glance, thorough examination of the fish tank; and
- whether visitor(s) abandoned game or finished it fully and how many times in a row they played it.

To add some even fuller qualitative content to observations (e.g. various uncoded distinctive characteristics of individual visitor(s) behaviour), some space for additional comments was provided with each single log template.

The total number of interactions with the exhibit directly observed during the mentioned period is displayed in **Table 5.2**.

version 1	Thursday 17/06	Friday 18/06	Monday 21/06	Thursday 01/07	Monday 05/07
	83	38*	63	83	69
version 2	Tuesday 22/06	Friday 25/06	Monday 28/06	Tuesday 29/06	Wednesday 30/06
	58	49	53	55	73

Table 2 *– Total ethnographically observed interactions for the observed days. On Friday, 18/06 more data was collected than indicated, but due to the temporary failure of the automatic computer logging system not all of the collected ethnographic data had a corresponding computer log counterpart, and hence were not used in the analysis.*

5.1.1.3 Computer log data set

Computer log data set was collected automatically. The computer game code automatically collated the detailed data about all the events occurring during the game (*play the game*, *start game*, *quit*, *select question - which*, *select answer - which*, *hint/help*) due to visitor activity in the game along with precise respective times when they occurred. Each time the game returned to the initial scene, software automatically sent me an e-mail with all the data gathered during the previous game.

Ethnographic data was collected by looking at the visitor at the computer cabinet from behind their back and a distance of about 5 metres. Hence it was impossible to make out all the details of the interaction. However, when that data is supplemented with the computer log data – to which it is unanimously linked by the times noted in both logs – the full detail of visitor engagement with the game can be recreated.

The total number of interactions loged through computer logs for each day of the observation period is given in **Table 5.3**. Each daily data subset corresponds to all of the interactions that have occurred on the exhibit that day during the Techniquest working hours.

version 1	Thursday 17/06	Friday 18/06	Monday 21/06	Thursday 01/07	Monday 05/07
	102*	61*	127	193	153
version 2	Tuesday 22/06	Friday 25/06	Monday 28/06	Tuesday 29/06	Wednesday 30/06
	87	92	109	101	131

Table 5.3 – Total number of automatic computer logs of interactions for the observed days. On Thursday 17/06 some data is missing as the computer game was switched off between 12:30 and 13:30. On Friday 18/08 some data is missing due to the temporary failure of computer loging system between 11:45 and 14:00.

The complete set of coded data (both ethnographical and computer loged) can be found in the **Appendix 2**.

5.1.2 Data set representativeness

Before drawing any conclusions from the collected data, the matter of the representativeness of the complete data set must be thoroughly discussed.

5.1.2.1 Representativeness of ethnographic data

Computer loged data represents the complete set of visitor interactions with the exhibit and are therefore fully representative of the visitor engagements. On the other hand, ethnographical data represents only a partial contribution to the total visitor interaction data set, as I spent only the busiest half of the Techniquest working hours (i.e. from about 9:30 – 13:00) observing on the exhibition floor.

By comparing the data in **Table 5.2** and **Table 5.3** it can be seen that for the version 1 of the game ethnographically observed data encompasses just under a half of the total visitor interactions with the exhibit. This number is slightly greater in the case of the version 2, where it amounts to just over a half. Both these numbers have no other significance but to show that ethnographic data can be expected to be sufficiently representative as it contains about half of the total interactions that have daily occurred on the exhibit.

Certainly, given enough time and (primarily) more researchers, all of the daily interaction data could be ethnographically observed and loged. However, as this research was done by a single person the amount of ethnographical data collected can be claimed fully satisfactory.

5.1.2.2 Total visitor number representativeness

Comparing total number of interactions (given by data in **Table 5.1**) and total number of visitors on each particular day (given in **Table 5.3**) it can be estimated that roughly about 20% of the visitors engaged with the game. Compared with the number of ethnographically observed interactions (**Table 5.2**) it can be estimated that about 10% of all the visitors were observed directly interacting with the exhibit.

It could be argued that this mentioned percentage should be even lower since some visitors played the game more than once. However, as it will be thoroughly shown in section 5.3, ethnographic data can be used to show that the total (and daily consistent) number of distinct players was about 2/3 for version 1 of the game and about ¾ for version 2 of the game, both respective to the total number of game engagements. This means that about 13% and 15% of all the visitors to Techniquest engaged with versions 1 and 2 respectively.

Hence, although it cannot be concluded that the data are representative of complete Techniquest school group visitor population, I could nevertheless suggest that the data does fairly represent that part of the Techniquest visitor population which is attracted by the computer exhibits and in particular computer games. Namely, the default initial scene of the game clearly indicated that it is a computer game, and I have observed quite a few visitors who actually engaged with it after either shouting out loud to their friends '*Look - a computer game!*' or clearly talking to themselves '*What's this? Oh – a computer game!*'.

Finally, I must admit that this last claim might be founded on shaky grounds, as I am not aware of any research findings that have actually measured how large share of the school group population in Britain has an affinity for computer games. It might be an interesting line of future research. On the other hand, considering the great flux and diversity of school age children through Techniquest which can be considered fairly representative of the whole UK school age population, the findings mentioned here might also be considered a contribution towards the conclusion that at least about 13-15% of school age children in the UK are keen on engaging with computer games, and hence computer games could be used as an educational tool with that share of the population.

5.2 Data analysis

This section of the thesis contains the quantitative analysis of various visitor - exhibit interaction elements. Speaking about these analyses, the first important caveat is that in all of them all of the different variables were considered completely independent. This greatly simplifies the analysis as with that assumption each of the variables can be analysed on its own, assuming that the variations in all the others normally distribute (and hence cancel, on average) through the total set of data.

This, certainly, cannot be fully justified and the more detailed and serious approach should incorporate factor analysis (see e.g. **Darlington [??]** or **StatSoft [2003]**). The only plausible justification for not doing so in this work is that there are simply too many variables for the amount of data available – fully fledged factor analysis would require an order of magnitude more data, and such a research effort would certainly be well beyond the scope of this thesis.

5.2.1 Elementary quantitative analysis

Having in mind previously mentioned limitations of this research, in this section I start with the simplest of the statistical inquiries into the collected data.

5.2.1.1 Engagement with the game

The first element of visitor – exhibit interaction that I shall focus on is the analysis of how intensively the players engaged with the game. **Table 5.4** displays the ethnographical data based statistics on how many games were started and how they were played.

version 1		
total games opened	342	**%**
games not started	37	*11*
games abandoned	56	*16*
games quit	117	*34*
games finished	132	*39*
for time out	125	*95*
all done	7	*5*

version 2		
total games opened	285	**%**
games not started	39	*14*
games abandoned	59	*21*
games quit	77	*26*
games finished	110	*39*
for time out	21	*19*
for lives	77	*70*
all done	12	*11*

Table 5.4 –Data for the analysis of how the games were played.

The precise meanings of the data codes are the following:

- **total games opened** represents the total number of times button *play the game* on the default initial scene of the game was pressed and *instructions* scene of the game was activated;
- **games not started** is the number of times *play the game* button was pressed on the default screen, but then button *start game* wasn’t pressed to actually start the game;
- **games abandoned** is the number of games that visitors transparently walked away from before they actually ran out of time (in version 1 and version 2) or time/lives (in version 2);
- **games quit** is the number of games in which *quit game* button was pressed during the game hence ending it prematurely; and
- **games finished** is the number of games played throughout, with subcategories displaying how many games ended in any particular way: whether it was due to the fact that time limit was achieved (‘for time out’ - in both versions), whether it was because all 12 questions were answered before the time limit was achieved (‘all done’ - in both versions), or whether it was because player lost all three lives (‘for lives’ – only in version 2).

The numbers in the second column are the total event counts obtained from the ethnographic observations. The numbers in the last column are the corresponding percentages of the events – the first row (**total games opened**) is 100%. For the last few rows, representing the breakdown of various ways in which a completely finished games ended, the numbers in the last row represent percentage with respect to the total number of games fully finished.

First note that the version 1 of the game has slightly lower percentage of games not started. Since one of the reasons for not starting the game after opening the *instructions* scene is that automatic 20 second timeout is reached before the visitor finishes reading the instructions, this might suggest that the instructions for the version 2 of the game were somewhat more involved than for the version 1. They did actually contain slightly more information, but as will be shown later, great majority of visitors did not spend more than 2 seconds on the *instructions* scene anyway, so that this conclusion might be somewhat suspicious and more down to chance than to the real effect. However, an independent indicator of the same conclusion will be presented in **Section 5.2.2.3**, which somewhat reinforces such conclusion.

Further, note that although the total number of games started but not finished (either abandoned or quit) is fairly similar, 50% and 47% respectively for version 1 and version 2. Now, if the previously discussed difference of 3% in the number of games not started is indeed due to the difference in the amount of information on the *instructions* scene, it might be argued that this difference between the two versions in the games not finished could be exactly compensated. Certainly, some of the players who did not manage to read the instructions in one go but then opened, started and did in eventually finish the game should have a share of those 3% games not started as well. However, if that difference is distributed between the games started but not finished and the games finished, the remaining difference of 1%-2% could well be down to the statistical error bars due to the size of the data set for both cases.

What sticks out much more decisively is the difference in the breakdown between **quit/abandon** not-ended– in version 1, 5% more games were quit and 7% less were abandoned than in version 2. One rather trivial explanation for this could be the fact that **quit game** button in the two games was located in different position on the scene and was hence more 'visible' to the player in version 1 than in version 2. However, with the available data such assertion cannot be seriously discussed. The other – parallel - reason could be that since the version 2 allowed more playing time, more visitors simply walked away from it after 'having enough of it' without bothering to quit. This issue will be further discussed in the following **Section 5.2.1.2**.

The last row - total number of games finished - is practically the same, which would indicate that both versions of the game were equally appealing to the players. However, the breakdown of the ways in which games were finished in version 2 is quite interesting: whereas 70% of the games that did not end with all of the questions answered ended due to three wrong answers, only 19% ended due to the 30 second timeout on a particular question. It can thus be argued that most players did not hesitate just giving their best (maybe even random) shot and getting wrong answer. Even with plenty of time available to look for the right answer, they seemingly preferred guessing instead of trying too hard in getting it right. In **Section 5.5.5.6** I will further discuss the issue of validity of trial and error method as a legitimate learning tool.

5.2.1.2 The name of the game: 'Hall of Fame'

I consider the *Hall of Fame* to be one of the most interesting and valuable elements of both versions of the game and the one which - education-wise - deserves the most detailed inquiry and development in the future work in this field.

Table 5.5 contains the quantitative details about the visitor's interaction with *Hall of Fame*. The first row in these tables (**total high scores achieved**) gives the total number of games that ended with a high score. The second row (**abandoned before end**) is the games that players abandoned without finishing them. The third row (**high scores unsigned**) is the number of games that players ended, and ended with a high score, but that were not signed. The next row (**high scores signed**) refers to the games that players completed and signed their names. Finally, the last row gives the lower limit of the number of signed games which resulted from the single player or a group playing multiple times - they can be isolated from the data set by looking for similar or the same signatures in consecutive games. I should mention that there might well be more of them, but it is hard to pinpoint them as due to some problems with the signature scene design and implementation, signing the name was not made as simple as possible. Namely, the time limit of 20 seconds was given for entering the signature and many players took more than that to figure out how to do it. In any future adaptation of the software, this should be taken care of. The second column gives the absolute numbers, whereas the third column gives the respective percentages compared to the total number of games in which high score was registered.

version 1		
total high scores achieved	113	**%**
abandoned before end	9	*8*
high scores unsigned	22	*19*
high scores signed	82	*73*
multiple signatures	>43	*>38*

version 2		
total high scores achieved	101	**%**
abandoned before end	16	*16*
high scores unsigned	17	*17*
high scores signed	67	*67*
multiple signatures	>31	*>31*

Table 5.5 *–Hall of Fame entries data.*

First observe that the percentage of the games that made it among the high scores but were abandoned before end is fairly low. Hence, I would argue that most visitors who engaged with the game in the first place and had some initial interest in actually playing it were quite drawn to pursue it all the way to the end. In other words, even though it was fairly simple, visitors seemingly found the game (both versions) interesting enough in the setting in which they encountered it (i.e. on the science centre exhibition floor).

Let's now return back to the discussion from the end of previous section. The difference in fraction of abandoned games between the two versions here seems very indicative. Namely, version 2 of the game was designed with intention of making it somewhat less challenging but at the same time somewhat more contemplative than the version 1, as it allowed more time to play through – whereas version 1 allowed a total of 60 seconds for the whole game (all 12 questions), version 2 allowed 30 seconds for each individual question.

Hence, from the data in **Table 5.5** it could be suggested that shorter game is more likely to be pursued to the end by the player then the longer one as many more games in version 2 were abandoned before end than in version 1. However, there is one very important caveat that should be added before jumping to the conclusion that data in **Table 5.5** clearly indicate that indeed is so. Namely, the players who achieved high-score sometime during the game, but who also abandoned the game before it was fully finished (either for lives of for timeout) were not even offered to enter their name into the hall of fame and hence could not possibly make it among the registered high-scores. At the same time, the data from **Table 5.4** clearly show that version 1 of the game had in total many more games quit than version 2. It is hence straightforward to conclude that the number of games 'effectively' abandoned before end (but for quitting rather then for just walking away) for version 1 given in **Table 5.5** would be much closer to those of version 2 if this is accounted for. Also, the percentage of games abandoned before end would be somewhat higher for both versions. Nevertheless, as the majority of the players who achieved a high-score sometimes during the game did in fact finish the game – or rather most of the players who did not finish the game did not even engage with it seriously enough to obtain a high score (it did take some effort...) – the total number of games with high scores achieved (and displayed in **Table 5.5** for each version of the game) would not be significantly different. Although the data available in this research cannot clearly resolve this, further more focused research could easily do so e.g. by analysing a range of games with design similar to version 1 but varying the playtime (e.g. by setting 40– ,50-, 60-, 70-, 80- and 90-seconds limits).

Finally, the numbers of the signed and unsigned finished high score games (third and fourth rows in the **Table 5.5**) are quite decisive: over 2/3 of players that got the high score were willing to sign their result. I believe this percentage would be even somewhat greater if the signature scene came out a bit sooner after finishing the game. This conclusion is founded on two observations. First, in both versions of the game, the time between the game end and signature scene was 5 seconds, and I have noted that during this period of game inactivity some players left the game without waiting to see what will happen next. Second, I have also seen players make few steps away from the computer cabinet and come back to sign their name once they discovered that they are asked to do so. In fact, on several occasions it happened that after signing their name and seeing themselves in the hall of fame, they decided to have another go at the game to improve on their score. This suggestion is reinforced by the fraction of about 30-40% given in the last row of the **Table 5.5** and representing the total number of players who signed their name – and consecutively played the game - more than once.

Once signed – especially (but not exclusively) if their score was high on the list - many players invited their peers or/and teachers to show them that ‘they have made it’, demonstrating clearly that they are proud of their achievement. On several occasions I also observed that players who ranked themselves high in the hall of fame ‘tutor’ their peers who came to play after them.

Final comment on the figures given in **Table 5.5** regards the total number of high-scored games, which for both versions of the game amounts roughly to the 1/3 of the total games opened. It should be stressed that this number could have been even higher. The problem, which was unfortunately noticed rather late during the data collection phase, was that due to the commonly observed ‘high-score hunting’ by the keenest players the results on the high score list saturated within about three hours from the time the game was switched on at the beginning of the Techniquest operating hours. It was hence almost impossible for the novice players that engaged with the game after this period to get high enough score to reach the hall of fame. For this reason, last few days of the data collection period the software was adapted to automatically reset the high-score list every three hours, but it was a rather late save and it could not significantly correct the previously ‘skewed’ statistics. I would suggest that for all but the hardest latecomer ‘high score hunters’ this situation was so frustrating that it caused them to lose any willingness to play the game more than once.

Based on the presented quantitative data and on mentioned observations I believe it would be just to conclude that even such a simple feedback on and ‘appraisal’ of their demonstrated skills – as is the one of finding their name in the hall of fame – serves to a visitor as a very efficient incentive to engage with and to profess in what is basically a learning activity – getting the right answers! Seemingly it also serves as some sort of ‘certificate of merit’ that boosts the players’ confidence of their skills and gives them confidence to help others develop their own respective skills. I must add that such ‘tutoring’ behaviour can also be noted with number of other Techniquest exhibits.

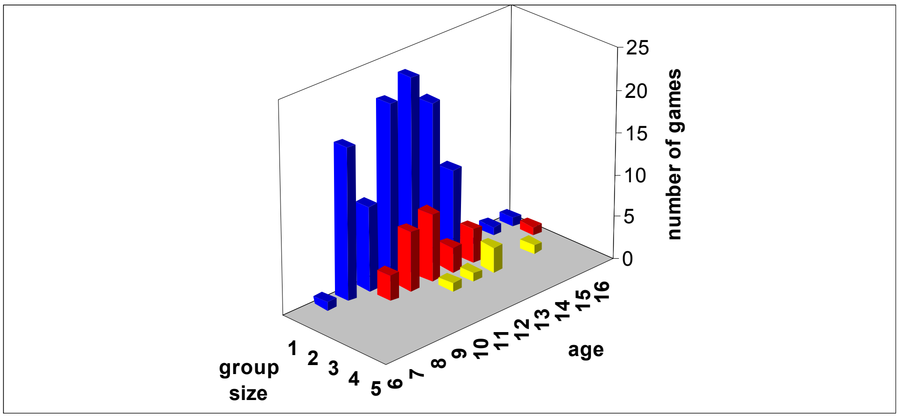
5.2.1.3 Age and sex group play patterns

As it was stressed earlier, the focus of the research was on the school-age visitors. Hence, the results shown in this section are based on the reduced ethnographic data set: among the excluded data were those involving adult visitors (indicated with *a* in the *age* section of the **visitor group data**), Techniquest helpers (indicated with *g* – for 'greenshirts' - in the *age* section of the **visitor group data**), family groups (indicated with *f* in the *group type* section of the **visitor group data**). Also, I have eliminated from the analysis the mixed sex groups of school-age visitors as they were impossible to fit in the used classification and were also so rare that no statistical analysis whatsoever can be done exclusively for them in parallel to single sex groups. For version 1 and version 2 of the game this reduced set contains respectively 80% and 90% of the total ethnographic data, so its statistical representativeness is not significantly disturbed.

Figures 5.6-5.9 present the distribution of number of games opened by the female and male groups of players of different sizes (1-5 players) for both versions of the game. The ages are not exact – they were merely estimated by the looks of the visitors. Nevertheless, the error could reasonably be estimated to 1 year plus or minus.

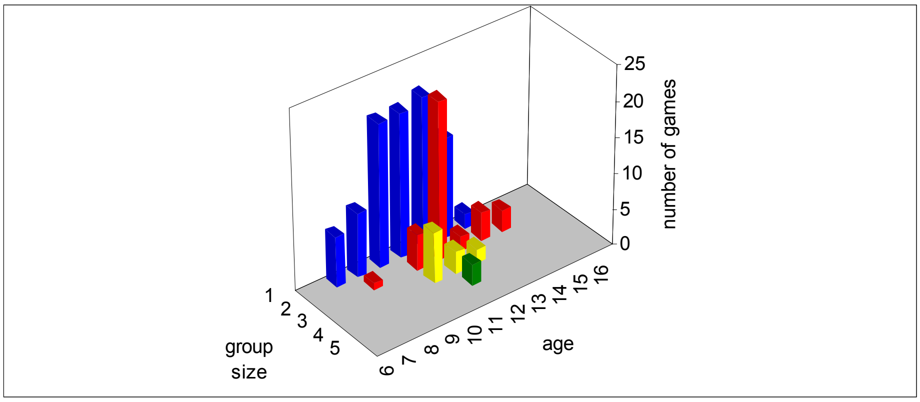
The data in the adjoined tables are self explanatory, apart from the bottom row (***total (%)***) which is obtained as sum of products of number of games for particular age with the group size and hence represents the total number of players of that age given as percentage of the total number of players.

Although the data set is insufficient to subject it to a deep quantitative analysis like the ones that will be presented in the **Section 5.2.2**, it nevertheless provides some interesting hints on the age and sex differences in visitor engagement with the exhibit. The data does span the whole range of Tehcniquest school-group visitors, and during the observation period all age groups were represented in representable proportions.



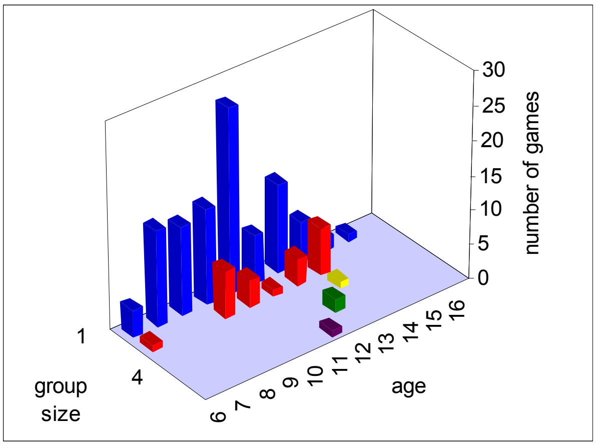
version 1 **male**		**estimated age** 6	7	8	9	10	11	12	13	14	15	16	***total (%)***
group size	**1**		1	18	10	21	23	19	10	0	1	1	*76*
	2				3	7	8	3	4			1	*19*
	3						1	1	3		1		*4*
	4												*0*
	5												*0*
total (%)		*0*	*1*	*10*	*9*	*20*	*24*	*16*	*16*	*0*	*2*	*2*	

Figure 6 *– Age and group size distribution of number of games opened by male school group visitors for version 1.*



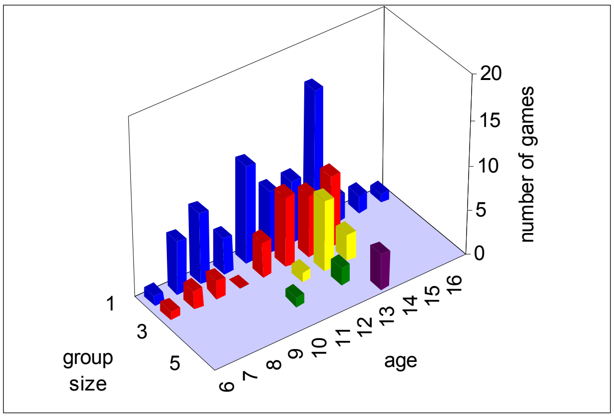
version 1 **female**		**estimated age** 6	7	8	9	10	11	12	13	14	15	16	***total(%)***
group size	**1**		7	9	20	20	21	14	2				*64*
	2			1		5	22	2	4	3			*26*
	3					7	3	2					*8*
	4						3						*2*
	5												*0*
total (%)		*0*	*3*	*5*	*9*	*24*	*40*	*11*	*5*	*3*	*0*	*0*	

Figure 7 *– Age and group size distribution of number of games opened by female school group visitors for version 1.*



version 2 male		estimated age											
		6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	***total (%)***
group size	**1**	4	14	13	14	27	7	13	6	2	1		*78*
	2	1			7	4	1	4	7				*19*
	3								1				*1*
	4							2					*2*
	5						1						*1*
total (%)		*4*	*8*	*8*	*17*	*21*	*8*	*18*	*14*	*1*	*1*	*0*	

Figure 8 *– Age and group size distribution of number of games opened by male school group visitors for version 2.*



version 2 female		estimated age											
		6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	***total (%)***
group size	**1**	1	6	8	4	11	7	7	16	3	2	1	*56*
	2	1	2	2	0	4	8	7	8				*27*
	3						1	8	3				*10*
	4					1		2					*3*
	5								4				*3*
total (%)		*2*	*5*	*6*	*2*	*12*	*13*	*27*	*31*	*2*	*1*	*1*	

Figure 9 *– Age and group size distribution of number of games opened by female school group visitors for version 2.*

The first notable difference in game engagement of boys and girls is that girls are somewhat more likely to engage in joint activity on the computer cabinet. This can be qualitatively seen from the graphs, but a better and fully quantitative indicator is the percentage of games played by groups of different sizes - the data in the last column of the tables in **Figures 5.6–5.9**. Indeed, I have observed many groups of girls - and several, but relatively fewer, groups of boys – ‘split the tasks’ while playing the game together: one member of the group would sit at the console and operate the interface (choosing questions and selecting answers) while others would engage in discussion about which answer to choose and search the fish tank for the answers on the fish-related questions (which actually required looking into the fish tank). In this respect, one interesting extension to this research would be to create the real multiplayer game as the ‘arena’ part of virtual exhibit, and to see whether stronger social interaction would result then the one observed in the presented case.

Further, observe the total number of visitors of different ages displayed in the last row of the tables in **Figures 5.6–5.9**. Although the data hints so, it would be wrong to conclude that the peak in the age distribution of visitor numbers indicates the varying level of interest in the exhibit for children of different ages. Rather, it is an artefact of overall Techniquest visitor age distribution during the time of data collection. Namely, it can easily be discovered from the internal Techniquest daily booking reports that during the data gathering period great majority of school group visitors were between the ages 11 and 13. Taking into account the age estimated error margin I mentioned earlier, this span stretches to 10 - 14, which is precisely what is observed in **Figures 5.6–5.9**.

Finally, one technically very useful conclusion that can be drawn from the pure observing data is that the selected user interface (trackball) presented a good choice, as great majority of players had no problem whatsoever in figuring out how to use it, and this was so regardless of the players’ age.

5.2.1.4 Attention manipulation through virtual exhibit

The most important question that this research was set to answer was how efficient the computer game can be in systematically focusing the visitors’ attention to the specific activities at the physical exhibit? In other words, is there any solid evidence that the concept of hybrid exhibit, described in **Section 3.3**, can fulfil the role it is intended for?

To get an answer to this question, during the ethnographic data collection I have observed whether - and if so, to what extent – the visitor looks away from the computer game and into the fish tank. One of the three sets of questions – the one about the fish in the fish tank – was created with this task in mind: possible prior general knowledge that visitor had was of no use in answering these questions correctly. Rather, all the correct answers could be obtained by thoroughly looking into the fish tank, e.g. comparing the fish and seeing which of the species was the largest or most numerous. In fact, to make the task absolutely transparent to the player, the introductory line to all of the questions in this category was: '*Look into the fish tank and find out!*'.

Data on the player this programmed attention shifting is presented in **Table 5.10**.

version 1		
fish questions opened	**176**	*%*
not looking into tank	41	*23*
glancing into tank	49	*28*
looking thoroughly into tank	53	*30*
already knows the answer	33	*19*

version 2		
fish questions opened	**172**	*%*
not looking into tank	41	*24*
glancing into tank	36	*21*
looking thoroughly into tank	79	*46*
already knows the answer	16	*9*

***Table 5.10** –Data on programmed attention shifting from the virtual part of hybrid exhibit (computer game) to the physical part of the hybrid exhibit (fish tank).*

The data codes have the following meaning:

- **fish questions opened** – the total number of games in which a question about the fish in the fish tank was opened and hence the attention shift from the virtual to the physical part of the hybrid exhibit was required;
- **not looking into the fish tank** – number of games in which player, after opening the question about the fish, did not even take a glance at the fish tank (no attention shift);
- **glancing into the fish tank** – number of games in which the player, upon opening the question about the fish, briefly glanced at the fish tank, acknowledging its relatedness to the game but not making an effort to thoroughly search it for an answer to the question asked (some attention shift, but not complete);
- **looking thoroughly into the fish tank** – number of games in which the player clearly invested notable amount of time and effort into exploring the fish tank and its inhabitants in search for the answer to the related question (complete attention shift);

- **already knows the answer** – players who played the game several times in the row learned – either by trial-and-error or by previous inspection of the fish tank - the answers to the questions about the fish they have encountered in the previous games, and hence had no need to look again into the fish tank (no attention shift, but knowledge about the fish already acquired through previous play).

The first notable thing is that in both versions of the game, slightly less than a quarter of the games involved no attention shift from the virtual to the physical part of the hybrid exhibit. In some – but admittedly rare – cases, I have observed that this was due to the simple reason that visitor did not even figure out there was an actual fish tank somewhere by the computer cabinet! Anyway, the majority of players in this category engaged with the game quite casually, and abandoned it after only randomly picking out few questions and answers. I believe that if the game could be in some way made more interesting even for such players, this fraction would be reduced.

Second, from this data the difference in the design between the two versions of the game clearly stands out. The first element to observe is the percentage of the games in which the players thoroughly inspected the fish tank. Whereas for version 1 this fraction amounts 30%, for version 2 it is much larger, 46%. This can undoubtedly be attributed to the fact that in version 2 players simply could – and on average did - concentrate more on the task as they were given more time for the completion of the whole game than in version 1 (60 seconds in the version 1 and up to 6 minutes - 30 seconds per question - in version 2). Also, the smaller percentage of the games in which visitors just glanced at the fish tank nicely ties in to the previous conclusions: in version 1 of the game, some visitors who might have otherwise (i.e. given enough time) be tempted to take a thorough look into the fish tank, decided just to quickly glance at the tank in hope of immediately capturing the necessary information and if that fails to rely on good fortune. They preferred to try to improve on their score by trying to answer more questions, rather than by spending too much time on a single one and being sure of getting that one correct. I believe this clearly indicates the difference in general gaming strategies for the two versions of the game. This finding can be very useful in future development of games as virtual parts of science centre hybrid interactive exhibits.

Further, the number of players that played the game more than once – directly related to the percentage of players who already knew the answer – is significantly greater for the version 1 of the game (19%)

than for the version 2 (9%). This could indicate that version 2 – being shorter – attracts repeat play even from less 'patient' and 'dedicated' visitors with somewhat shorter attention span. Such conclusion can be reinforced by the data on number of multiple signatures given in **Section 5.2.1.2** (last row in **Table 5.5**) which shows that version 1 also had more high-scoring repeat players than version 2. On the other hand, it could also simply mean that the number players who decided to get their name into the hall of fame at all cost is roughly equal for both versions, but as in version 2 that can be achieved in a single go whereas in version 1 it takes some 'practice', these players had to - and did - play through more games to do it in version 1 than in version 2 and that version 2 was simply less challenging in this respect than version 1.

To conclude, the results presented in this section undoubtedly indicate that the concept of hybrid exhibit has a huge potential for systematizing and improving visitor engagement with the exhibits and hence the total informal education output of interactive science centre exhibition floor. However, technical details on how to optimize various elements in the design of virtual parts of such hybrid exhibits – in this case just a computer game – to make the attention focusing impact as full as possible have yet to be thoroughly examined in future work.

5.2.1.5 Use of *hint/help* button

The last topic I would like to discuss in this elementary quantitative analysis section concerns the usage of *hint/help* button.

Namely, in both versions of the game, during the game the player was offered help with the questions in form of the large, easily notable *hint/help* button. By pressing this button, a hint or even the complete answer to the selected question was offered to the player.

The use of the *hint/help* button was almost nonexistent. As I started gathering data first for version 1, I thought that the lack of usage of *hint/*help button was due to the shortage of time available. The share of games in which the button was used with respect to all of the games played was under 9%. In version 2, where I expected that due to the longer time given player would be prepared to spend more time looking for the correct answer and would hence be happy to use *hint/help* button more often, this share 'increased' to meagre 10%.

Also, during the formative evaluation phase that preceded data collection, I experimented with placing the *hint/help* button on different locations on the scene, increasing its overall size, changing its colour etc. – anything to make it stick out more clearly from the rest of the on-screen game elements. Absolutely nothing worked... Finally, later during the data gathering I actually asked a few visitors whether they have noticed the button as I thought that the main reason for not using it was that they did not see it. Their answers were interesting and strikingly similar: ‘Yes, I have seen it but I didn’t want any help – I’d rather solve it myself!’. This attitude, I believe is the one to take into account very seriously when devising any educational programmes.

5.2.2 Distributions and Mathematical Regularities

Unlike the previous section, which was moderately quantitative but fairly conclusive, this final section of the ***results and discussion*** chapter will be extremely quantitative, but somewhat more speculative regarding the actual findings. It should hence be observed primarily as a very careful step on the road towards the curious realm of experimental mathematical psychology. Time and (more importantly) funding provided, I believe that in the future the methods sketched here could be developed into very powerful quantitative tools of both general as well as educational psychology.

5.2.2.1 Game start to next game start period distribution

The first of the distributions to be discussed is the one regarding the duration of periods between the starts of two consecutive games.

This distribution basically encapsulates data about only two parameters: visitor density distribution on the Techniquest exhibition floor and the game duration distribution. Since both of these quantities are fairly constant from day to day (although they do vary quite a bit during a single day and hence taking their average value doesn’t make much sense), the total distribution should clearly yield both of these regularities. The plot of this distribution is given in **Figure 5.11**.

As both data sets contain statistically abundant data (629 and 517 respectively) both graphs have y-axis expressed as a percentage of this number. The x-axis contains the different time categories.

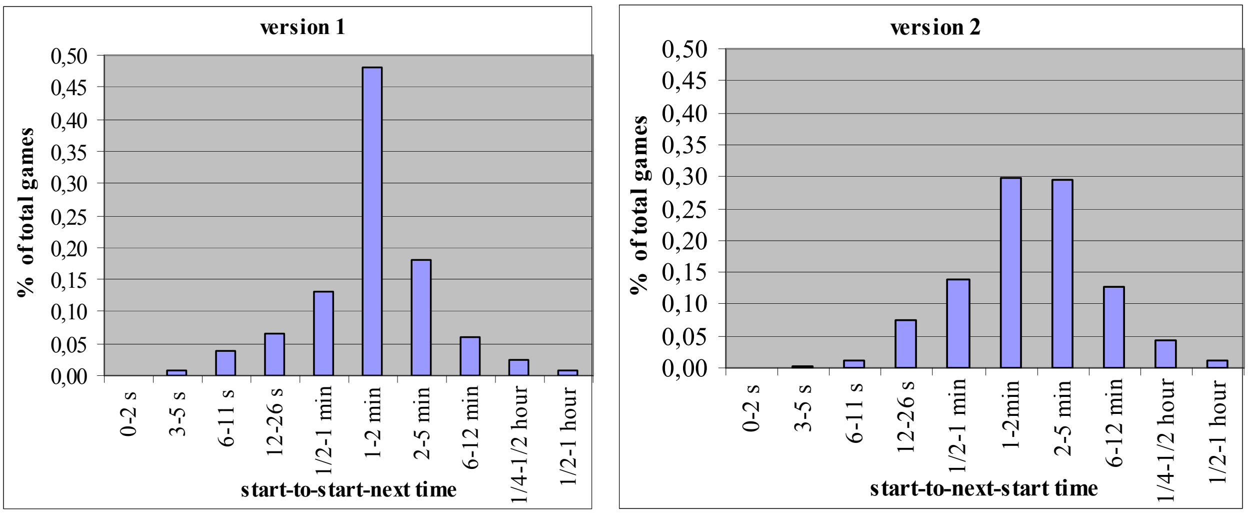


***Figure 5.11** – Distribution of periods between two consecutive openings of the game.*

First thing that immediately strikes the eye is that both distributions are fairly Gaussian. However, the next important thing to notice is that the x-axis is not linear, but rather logarithmic. The displayed categories were obtained in the following manner: the total list of periods between two consecutive game openings (expressed in seconds) was ordered in an increasing series; then each entry was divided by the number of seconds in an hour (60*60=3600); then the logarithm was taken from each entry in this 'hour normalized' series; finally, displayed distributions were obtained by grouping this new 'log hour normalized' series data into 10 equally spaced categories (0.00-0.99, 1.00-1.99, ... , 9.00-9.99). From the looks of the distributions in Figure 11, such categorization is very convenient.

From the graphs in **Figure 5.11** two things can be observed. First, from both of them it is clear that the inactivity ('visitorlessness') of the spot on the Techniquest exhibition floor where the computer cabinet with the game was located is less then an hour. In other words, the probability that there will be no visitor at the cabinet for a period longer than an hour is exceedingly low. This finding tells more about Techniquest exhibition floor, than about the computer game itself.

The second finding, related directly to the game design, is that the most probable period between the two consecutive game openings is 1-2 minutes for version 1 of the game and 1-5 minutes for version 2. This difference clearly corresponds to the different game designs (60 seconds limit per game vs. 30 seconds limit per question), and indicates that on average visitors spent more time per game playing version 2.

5.2.2.2 Game end to next game start period distribution

The next interesting distribution related to the previously discussed one is the one of the periods between the end of one and the opening of the next game. By the end of a game is understood the moment at which the game resets to the default initial scene.

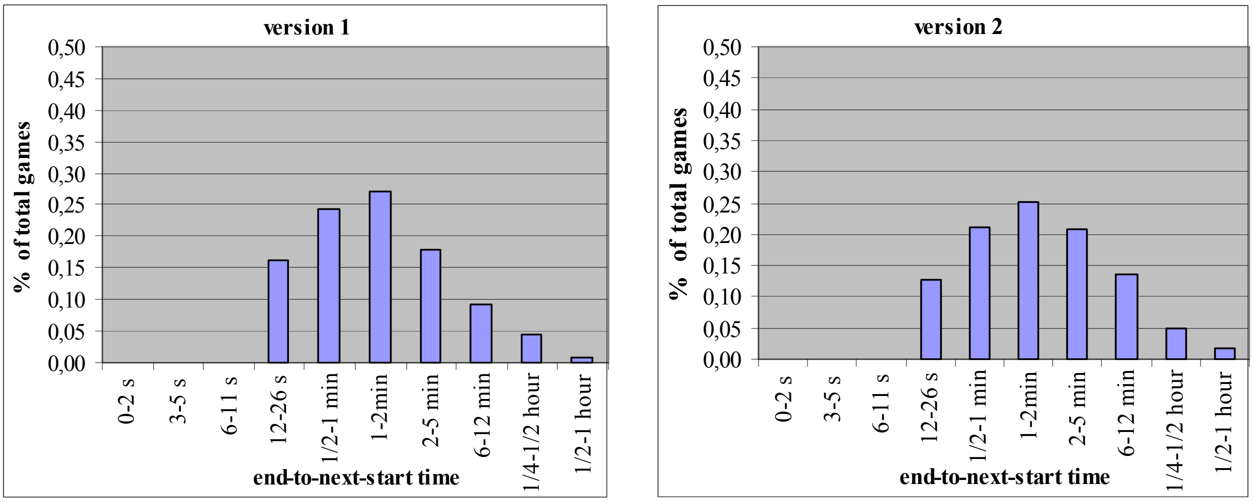


***Figure 5.12** – Long term part of the game end to next game open period distribution. The graphs are equivalent to the ones in Figure 5.11 apart from the fact that they are slightly shifted to the lower values.*

This distribution is composed of the two very distinct contributions. The first - long term one - is strongly related to the previously discussed distribution as it describes the engagement of consecutive *different* players with the game. Compared with previous one it is merely slightly shifted to the smaller values due to the deduction of the duration of the previous game itself. It is displayed in the **Figure 5.12**.

In both cases, the data on the lower end of the time scale is missing as it was used to reconstruct the more interesting, short term distributions, displayed in **Figure 5.13**: x–axis is the time in seconds; y–axis is the percentage of the total number of games opened. Along with the raw data, graphs in this figure contain the least-square best fit curve, the corresponding equation as well as correlation coefficient (R^2).

All of this data must be attributed to the repeat players rather than the first-time players, as these games were started almost immediately after the end of previous game. The mathematical relations that emerged from regression analysis of this data with such robust correlation coefficients (90%)

undoubtedly indicate the workings of some strong yet simple psychological mechanism in the background. That the mechanism is simple stems from the mathematical simplicity of the discovered mathematical law – logarithmic decay of the probability of 'repeat play delay' in this case.

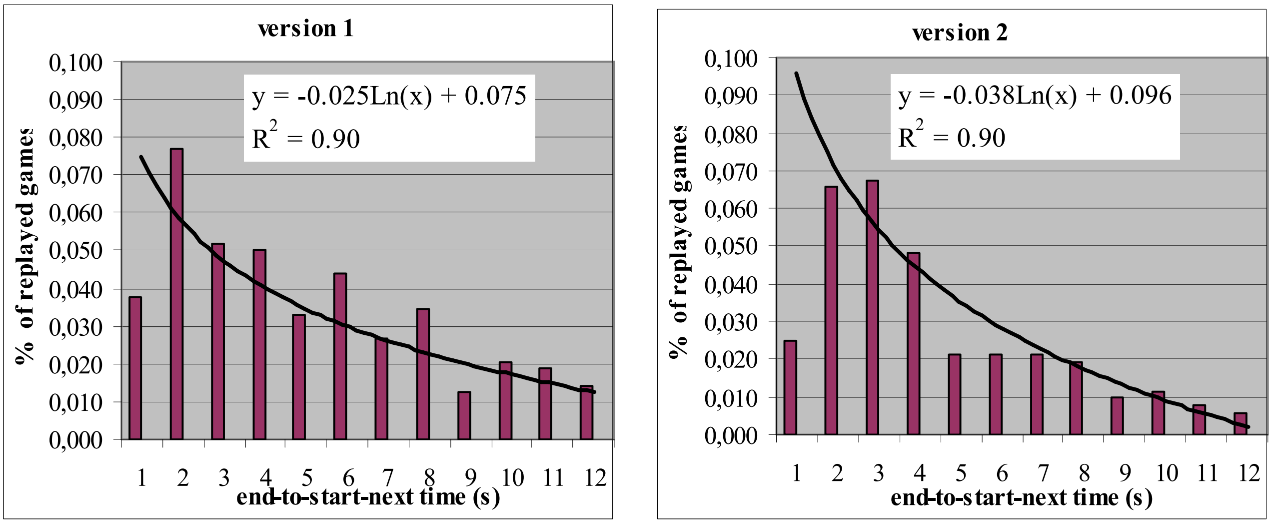


Figure 5.13 *– Short term part of the game end to next game open period distribution, along with the fitted curves and the data on those curves and correlation factors.*

It should be stressed that the regression line was fitted using only data from the times between 2 and 12 seconds, excluding the data for the first second, as it obviously doesn't fit this trend. This is not surprising, as deciding on starting a new game certainly is a mental process that requires some processing time to which there is a lower limit – in this case it can be estimated to about one second.

What can be read out from the data available is that the relative contribution of the immediate repeat plays to the total number of games opened was somewhat smaller in the case of the version 2 (3.2%) than in the case of version 1 (4.2%). This can again be interpreted using the same arguments as in penultimate paragraph of **Section 5.2.1.4**.

Also, the greater slope of the fitted curve in the version 2 hints that – although more serious and conclusive analysis should include more data as well as the error calculation for the fitted curve parameters – in version 2 of the game repeat players tended to start their consecutive games more quickly than in the case of version 1. This might indicate that version 2 was more often replayed by the visitors who were more decisive about playing and finishing the game in the first place.

With more data available and better knowledge of psychology than mine (at least at present), I believe that the psychological mechanism behind these findings could be unravelled. The difference in the two best fit curves for version 1 and version 2 could supposedly indicate the qualitatively different ‘state of mind’ induced by the game-play in visitors in the two cases. It might be interesting to add that researchers in the field of mathematical psychology did actually develop some binary logic based mental models that could accommodate for the encountered mathematical regularities (e.g. Figure 5C in **Dzhafarov, Schweickert and Sung [2004]**)

5.2.2.3 Instruction reading time distribution

The next interesting distribution is the one related to the how much time visitors spend reading the instruction scene before starting the game proper.

Instruction scene pops up immediately upon releasing the ‘*play the game*’ button on the initial default scene of the game. If the button ‘*start game*’ is not pressed within 21 seconds after entering the instructions scene, the game automatically resets back to the initial scene. Hence, visitors are given 21 seconds to read the instructions and decide whether they want to play the game or not. The distribution of visitor ‘instruction reading times’ is given in **Figure 5.14**. x–axis contains time in seconds, y–axis contains the relative number of games that were started during the corresponding period. The solid line on both graphs is the best fit curve, whose parameters and correlation coefficient are given in the boxes on the graphs. Regression is again calculated by excluding the data for the first second.

The correlation in both cases is quite impressive. Again, I believe it indicates the working of some simple but yet to be explored psychological mechanism. From the exponents of the two obtained power laws (-2.2 for version 1 and -1.9 for version 2) it could be concluded that visitors on average spend more time reading the instructions in the version 2 of the game – the decay of the corresponding distribution is slower than the one for the version 1 of the game. This conclusion reinforces the similar one mentioned previously in **Section 5.2.1.1**, but to be absolutely certain about its validity, the error calculation for the regression curve parameters should be made – a rather simple task but which I shall not pursue here.

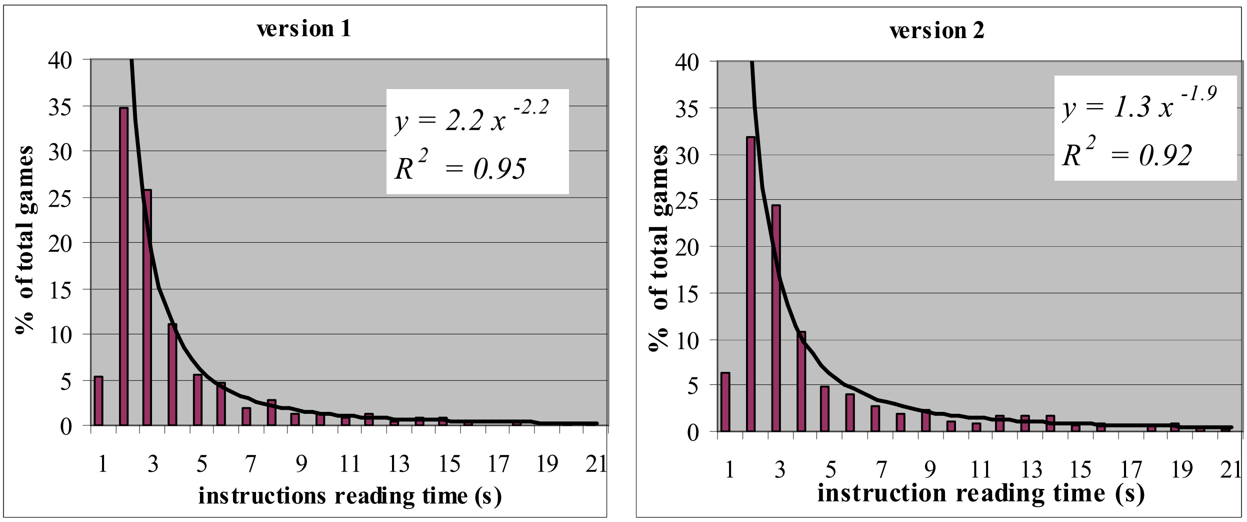


***Figure 5.14** – Instruction reading time distribution.*

As the probability of long times (>10 s) is in both cases exceedingly low, it means that great majority of players did not need more time than was provided to read the instructions. In fact, to make the whole game a bit quicker, the total duration of instructions scene could be cut down to 15 seconds.

5.2.2.4 Repeat play distribution – the appeal of doing it well vs. the appeal of doing it at all

As I thoroughly discussed earlier, the major drive for the repeat play by the same visitor was to achieve the higher score and to get as high as possible on the *Hall of Fame* list. The distribution on the number of players who actually finished the game at leas once versus the number of consecutive times they played the game is given in **Figure 5.15**.

Whereas the previously discussed distribution (**Section 5.2.2.3**) might in some way have been reasonably expected to yield a mathematical regularity as it is mostly related to a fairly simple cognitive reaction mechanism, I was quite surprised to discover statistically even stronger mathematical rule for the present distribution, as I would argue that the psychological mechanism involved here (after playing game N times, whether I want to play again or not) is much more involved. However, the data undoubtedly indicates that such mechanism does exist.

Comparison of the power law exponents in the two versions of the game (-2.3 vs. -2.7 for versions 1 and 2 respectively) again leads to the conclusion that the probability of the repeat play was lower for the version 2 due to the inherent difference in game designs between the two versions.

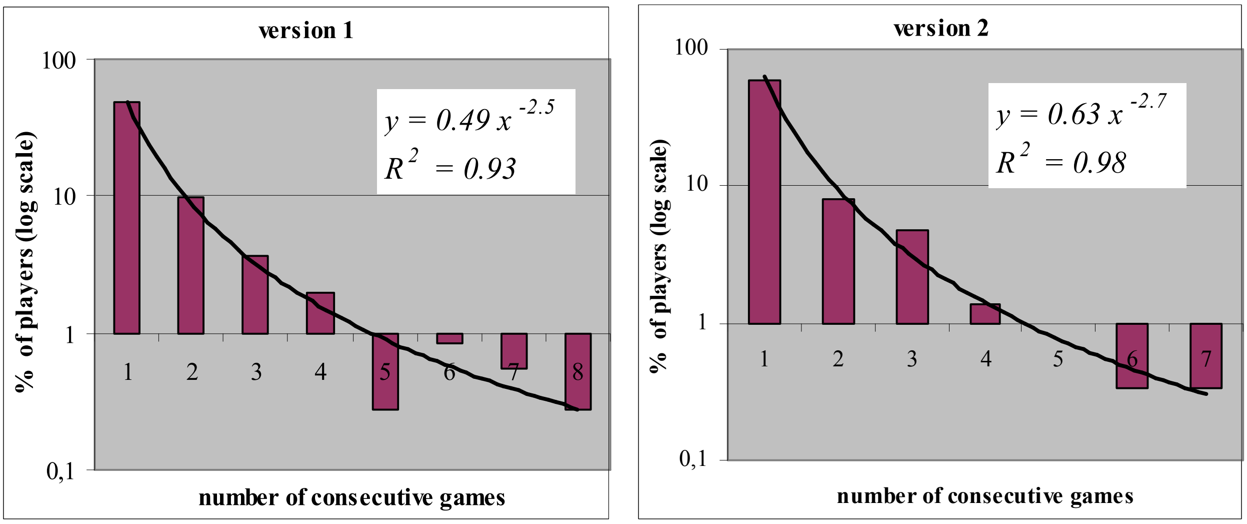


***Figure 5.15** – Repeat play distribution.*

Quantitatively examining each of the two curves, the overall appeal of the high score hunting – directly related to the number of consecutive repeat plays – can be quantified. Then, by experimenting with various game scoring protocols or various designs of the *Hall of Fame* scene, the game code can be optimized in such a way as to yield the highest repeat play appeal. As repeat play actually means going through the range of same or similar tasks (whether purely intellectual, as in this case of fish tank as an exhibit, or intellectual-sensory-motor ones that could be devised for the ‘real’ interactive exhibit) over and over again until they are professed to a certain level, it can be directly considered as an act of actual learning. I would argue that by increasing the visitors’ willingness to repeated several times in a row a specific pre-designed task on the physical exhibit – which is in the present science centre setting very challenging venture – the actual educational output of that particular exhibit is effectively and quantifiably increased.

5.2.2.5 No. of questions answered distribution – the holding power of the game

The next distribution can be related to – and actually firmly quantify the concept of - the ‘holding power’ of the hybrid interactive science centre exhibit. (**Miles and Tout [1994]**). This quantity effectively measures how much time (or, rather, effort in this care) visitors are likely to invest into the particular exhibit. The data is presented in **Figure 5.16**: x – axis contains the number of questions asked; y – axis the relative frequency of each particular number of questions asked.

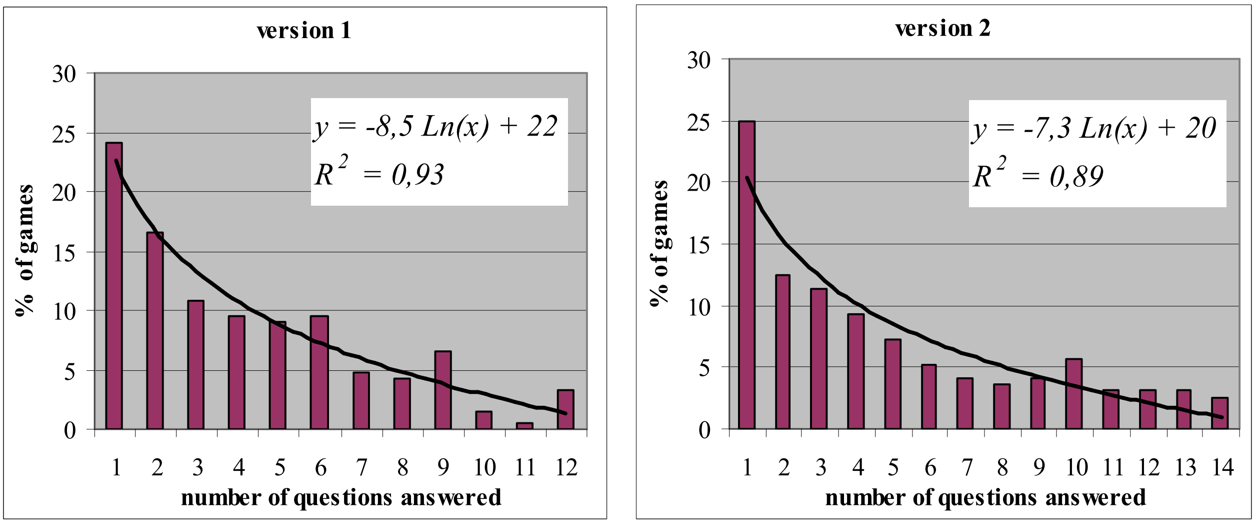


Figure 5.16 – Number of questions answered distribution.

The first assumption I am making in this analysis is that only the players who answered at least one question can be considered to have decided to engage with the game. The ones that just started the game and left without playing it, or opened one question and did not even bother to answer it are not considered to be 'real' players and are neglected.

Again, as in the previous distributions, the regression curve is fitted to the data and its parameters are displayed in the boxes on the graphs. The first notable difference between the two versions of the game regards the maximum total questions answered - 12 in the case of version 1 and 14 in the case of version 2. This difference is the consequence of different game designs, just as is the observation that the relative contribution of high number games (with respect to questions asked) is much higher in the version 2. Indeed, version 2 allowed much more (roughly 6 times as much) time to answer each question than the version 1. Also it is simple matter to demonstrate that whereas version 2 allowed for maximum of 14 questions to be answered (12 correct + 2 wrong), version 1 did not really allow enough time to answer more than 12 questions: only the players who professed in the game had enough time to maybe answer more questions (get one or two of them wrong), but as they professed in the game, they simply knew all the right answers and 12 was the most they did! The others didn't even come close to this number...

Because of all this it should be noted that in both cases – and especially for version 2 - obtained regression curves are somewhat skewed by the data on the upper end of the asked question number. Although the regression coefficients indicate that version 2 had more holding power, as the probability of player engaging with more questions falls of slower than in the version 2 than in version 1 (log(x) multipliers -0.073 vs. -0.085 respectively) this conclusion should be re-examined for the reasons just explained. If it was indeed so, then it could be concluded that players pursued the version 2 of the game with more engagement than version 1, i.e. that the holding power of a single engagement with version 2 was greater.

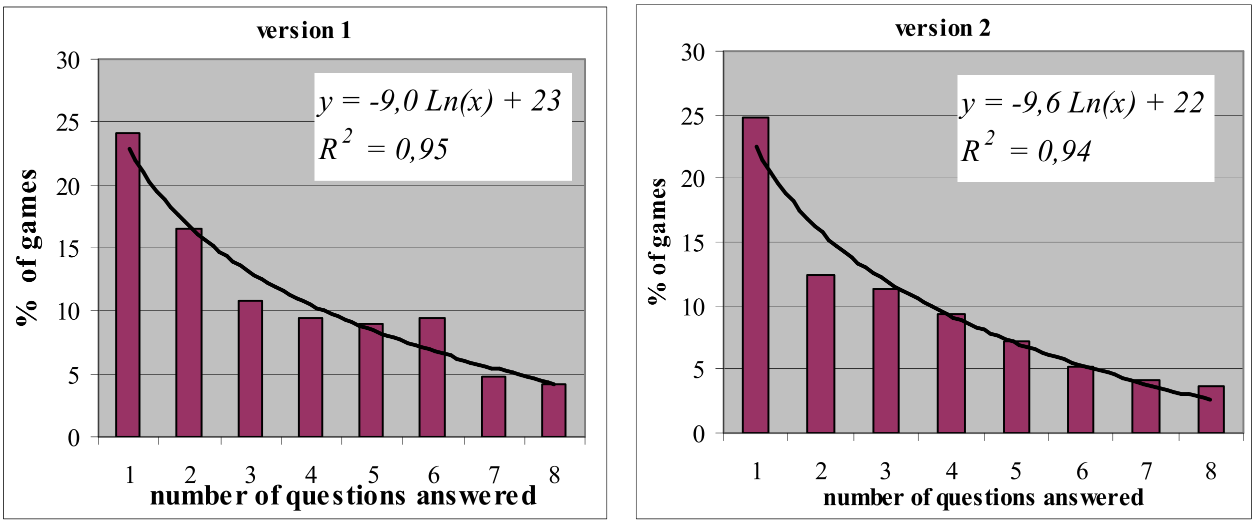


Figure 5.17 – Number of questions answered - modified data set.

However, to re-examine this, I have administered another regression analysis, but this time including only data up to 8 asked questions. The rationale is that the average player in version 1 can never reach as many as 10 or more questions within just one or two games – the ones that had all-time highest scores were actually the members of Techniquest staff (‘helpers’) who spend their whole day on the exhibition floor helping visitors around. When the crowd on the exhibition floor was low, helpers often came to play ‘Todd the Cod’s Great Techniquest Adventure’, and since they played it quite a few times day in day out, they knew all of the answers and regularly scored the highest. Very few regular visitor I observed ever came close to 10 questions in either version of the game! Hence, the average visitor might have played at most about 6-8 questions. Further, playing around with regression analysis, I have found that 8 questions yields the highest correlation coefficient for both versions of the game – this might be considered as a rather shaky argument, but as I stated on the beginning of **Section 5.2.2**, the conclusions in this section are to be considered highly speculative anyway.

The new regression curves, along with the data included, are displayed in **Figure 5.17**. Two things are clear: first the correlation is much higher than in the previous case so that this data can be considered more trustful than that previously considered; second, now the log multipliers clearly indicate that the interest for asking the next question falls of more rapidly in the case of the version 2 of the game then in the version 1. Hence, this data indicates that the holding power of the version 1 of the game outscores that of the version 2 – the conclusion quite opposite to the one discussed earlier.

5.2.2.6 No. of correctly answered questions distribution – visitor knowledge quantified

The last distribution to analyse is the one of the number of correctly answered questions per game, displayed in **Figure 5.18**.

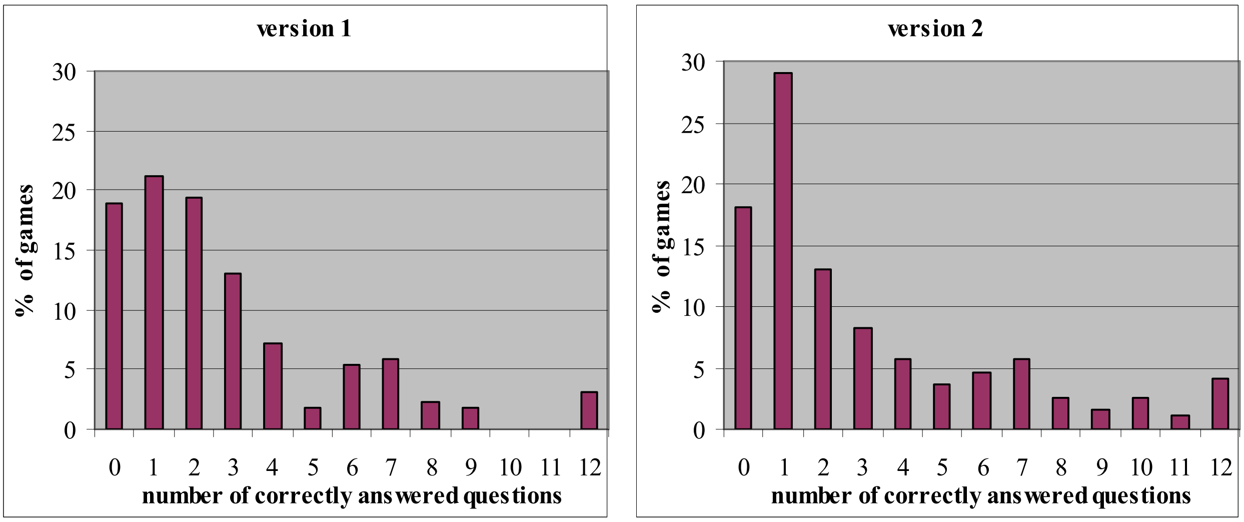


***Figure 5.18** – Distribution of the number of correctly answered questions.*

As correct answer to the question indicates some level of knowledge of the visitor, this data can be related to the knowledge about the physical exhibit demonstrated by the players. However, it should not be forgotten that some of the questions were correctly answered by a systematic application of a simple trial-and-error method, so the knowledge 'demonstrated' is actually somewhat inferior to the actual knowledge. On the other hand, as the probability of guessing the right answer in a single try was 25% (of 4 answers offered, only one was correct), this might also be interpreted that by repeatedly guessing the answer and finally getting the correct one, player actually learned what the correct answer is, and – maybe equally important – what it is not. So trial-and-error method actually should not be declared the worst educational method ever – after all, great deal (if not most) of contemporary science is actually based on it, as no professional researcher knows the final results of her/his research until he examines the available data thoroughly, and in many cases this means first eliminating many wrong hypotheses before pinpointing the correct one. Anyway, it should be appreciated that the number of correct answers per game is on average certainly lower than the total number of questions answered.

Even a quick glance at the data in **Table 5.18** shows that the mathematical regularities in this case are not as strong as the ones found in previous analyses. In fact, the correlation in the full set of data is just about 80%, so I did not even bother to discuss the possibility of some underlying model that could explain it.

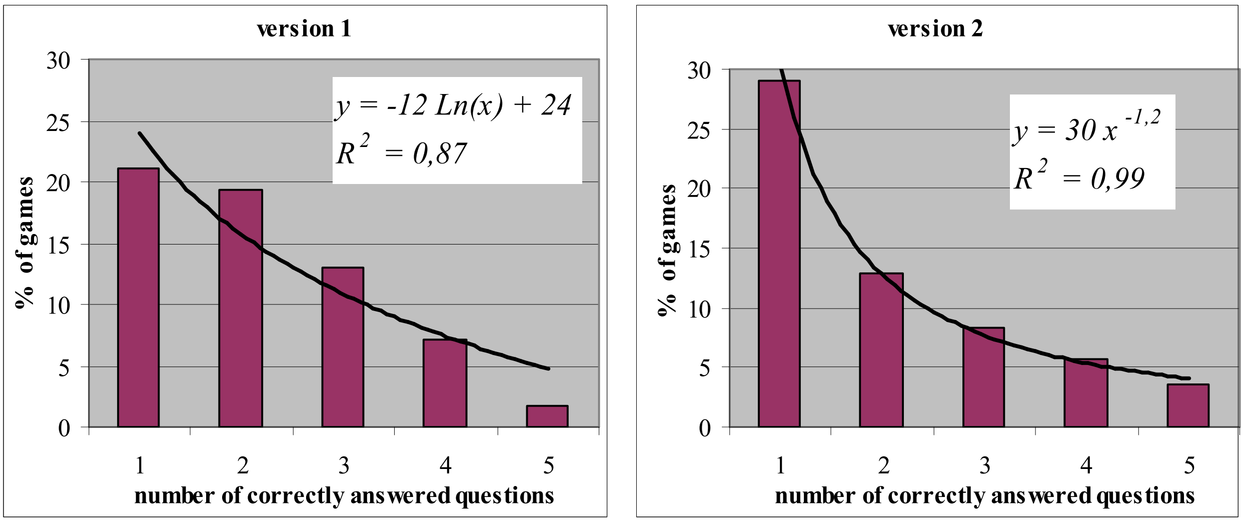


Figure 5.19 *– Distribution of the number of correctly answered question – modified data set.*

Instead - and again stressing that the whole distributions analysis should be regarded more of a mathematical exercise rather then a firmly conclusive approach - I have administered some modifications to the total data set in order to try to pick out a firmer correlation. The rationale to do so is that the analysis of the total number of questions asked from the previous section demonstrated the greatest correlation for case of 8 questions. As the average number of correctly answered questions must be lower than this, and as most games in version 2 ended with 3 wrong answers, I have decided to use the reduced data set including only up to 5 correctly answered questions. With such reduced data set, presented in **Figure 5.19**, the correlation is much higher than the one obtained from the full set of data – and, particularly for version 2, it is a fair one!

It is worth noting that there is a significant difference between distributions in both **Figure 5.18** and **Figure 5.19**. First observe that the best-fit regression curves are now of different types: for version 1 of the game, better fit is achieved with logarithmic curve, whereas for version 2 power law yields the better correlation. This might indicate that, since power-law curve generally decays much more slowly than the logarithmic curve, in playing version 2 of the game players were more knowledgeable. However, as the questions were the same in both versions, such conclusion cannot be justified. Rather, it could be argued that by playing version 2, players learned more than by playing version 1. This enhanced learning might be attributed to the more relaxed time-restrictions in version 2. Also, the difference in the type of regression curves might indicate that the demonstrated knowledge in the two versions is of qualitatively different nature. However, to fully confirm this, a separate more detailed study should be conducted.

5.2.2.7 Quantifying the total interactive hybrid exhibit learning output

As a final point to this chapter, I briefly want to discuss the possibility of quantifying the learning output that is achieved in an average visitor through the engagement with the interactive exhibit on the science centre exhibition floor.

The total learning output of the visit to a single interactive exhibit on the science centre exhibition floor depends on two parameters. The first parameter is the total number of visitors that fully engage with that exhibit – the greater this number is, the greater is the possible learning output. The second parameter is the learning output of the exhibit per individual visitor. As all the visitors are different, the interaction – and the corresponding learning output – per visitor differ greatly from case to case. However, what this whole previous discussion has shown is that, although the average value is a very vague concept, the use of distributions of various measurable visitor-exhibit interaction parameters can clearly indicate which exhibit visitors want to engage with more, and it can also precisely quantify the extent of this willingness to engage.

The analysis presented in **Section 5.2.2.6** can be considered more like a ‘still photography’ of the visitors’ knowledge, and does not say much about the actual increase of that knowledge (i.e. ‘learning’). What should be analysed to quantify the ‘learning output’ – and hence produce the actual ‘movie clip’ of the cognitive process of learning - is the data on correctly answered questions in repeat plays by single players. By varying the game design parameters the inquiry into optimizing the product of the number of players that engage with the exhibit and this parameter measuring the ‘learning output per visitor’ can then be made. I believe that such an effort towards standardization and firm quantification of the otherwise volatile concept of ‘learning output’ would be a very worthwhile enterprise. However, in the present research such data is not available and such analysis is impossible to perform.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Research Findings – A Review

This first section of the concluding chapter is devoted to the discussion of several aspects of research methodology employed in this research.

6.1.1 Reaching the Research Goal

Frequency analysis, the most basic of the statistical tools used in this research (particularly in **Section 5.2.1**) has proven to be quite a suitable one for the case at hands. Since, as was thoroughly argued in **Section 5.1**, the collected data set can be considered statistically significant and satisfactorily representative, the conclusions that arose from that analysis may be considered acceptable.

However, if this research is to be repeated of extended it would certainly be very useful to increase in volume the raw data set. One interesting thing that was not done in this research would be to gather sufficient weekend data and to compare the findings that would emerge from them with the week days data results. Such an analysis would greatly generalize findings to the second of the two most important categories of Techniquest visitors – family groups. From such a comparison, some generation gaps in appeal of computer games as interactive labels could emerge.

Hence, I consider this part of methodology fully justified in any further research on this and the like topic.

6.1.1.1 Research aim accomplished

In this respect, findings of **Sections 5.2.1.1**, **5.2.1.2** and **5.2.1.4** have the greatest merit for the final conclusions of this research.

Findings of **Section 5.2.1.1** clearly show that computer game can serve as a very efficient beacon for attracting visitor attention. At the same time, results presented in **Section 5.2.1.2** indicate where the appeal of the repeated and prolonged engagement with the game – seen as virtual part of a hybrid exhibit – lies.

Finally, **Section 5.2.1.4** shows that once the visitor’s attention is captured and kept by the virtual part of the hybrid exhibit, visitor’s attention can be efficiently manipulated – using clever game design – towards conducting specific predefined tasks on the physical part of the exhibit.

Also, I would argue that the efficiency in systematizing and enhancing the visitor's engagement with particular physical science centre exhibit could be even more efficient than the results of this research show. Namely, the actual physical exhibit used in this research – Techniquest fish tank – is the least interactive of all the exhibits on the Techniquest exhibition floor. As such, on its own it regularly receives much less visitor's attention than any other Techniquest exhibit. Notable thing about the visitor's engagement with the exhibits is that the more interactive they are – the more possibilities for trying out various physical engagements and the more possible outcomes of these engagements it offers – the more time and effort visitor invests in 'figuring them out'. As the hybridization of the fish tank greatly increased the visitor's engagement with the actual physical exhibit, I would argue that hybridizing another physical exhibit which is more interactive by itself would yield even more intensive – but still highly focused – visitor engagement, and hence would result in much higher learning output. Certainly, it would then be the matter of suitable game design to make both the engagement as well as the learning output as great as possible. This is one of the research directions that I would certainly suggest for the future.

6.1.2 Towards Experimental Mathematical Psychology

Whereas the previously mentioned mathematical tool could certainly be somewhat improved by refining the codings, I personally believe that the second tool – distributions analysis – holds much greater potential that can be just barely glanced from the findings presented in this thesis.

Strong mathematical regularities indicate the existence of mathematically describable cognitive models in the background. Mathematical models are the foundation of all well established theoretical sciences capable reaching deep below the surface of the natural phenomena, encapsulating their very roots and building our understanding of them through firmly anchored bottom-up process. Regarding human behaviour as a natural phenomenon – which it undoubtedly is – the results discussed in Section 5.2.2 can be looked upon as the fragments of psychology's 'Rosetta stone'. This is a topic I will briefly dwell on here.

6.1.2.1 Science centres as test-beds for experimental mathematical psychology

Due to their relative simplicity and a rather small range of possible (whether predicted or otherwise) activities, all of the science centre exhibits quickly elicit 'immersion' in the activity. Certainly, in a great majority of cases, this immersion lasts for a very brief period of time, roughly estimated below 10 seconds. However, on the scale of psychological processes this can nevertheless be considered significant duration.

On the other hand, the observed uniformity in the visitor behaviour during such rather superficial immersion suggests that that behaviour is governed by rather simple psychological processes, which are a necessary first step towards deeper immersion that needs to be achieved for a fully fledged conscious and willing learning effort. Hence, the exploration of how to manipulate these simple processes can certainly be employed in developing the teaching tools and strategies.

For example, the difference between the distributions of time lags between the repeat plays and instruction reading times (**Section 5.2.2.2** and **Section 5.2.2.3**) could indicate that the relevant cognitive processes for each case are governed by different psychological drives. Also, the observed mathematical regularities of both processes indicates that:

- the processes themselves can be described by a suitable underlying mathematical model, and
- analysed activities elicit a fairly uniform response from the ‘experimental’ visitor population, i.e. the activities cleanly target very small number – or even a single - human internal psychological variables.

All this indicates that science centres, with their immense daily flow of visitors which enables fairly rapid amassing of such data, could be used as excellent test-beds for experimental mathematical psychology.

6.2 Game Design

6.2.1 Suggestions For Future research

This research yielded some interesting results. However, with more data and further research targeting each particular game design issue touched in the present paper, I believe that a number of additional much more reliable and much more generalizable findings would emerge. Hence, I would suggest the following issues to be scrutinized in more details by future research:

- **Single game duration** - What is the maximal and optimal time that visitor is prepared to invest (visitor time investment - VTI) in continuous engagement with the single uninterrupted game?
- **Hall of fame effect** – What is the impact of Hall of Fame in eliciting the repeat play? Is there a difference in the maximal and optimal VTI if the visitor's achievement, tracked by the position in the hall of fame, is provided continuously throughout the game vs. only once the game ends?
- **Impact of the repeat play** – What is the impact of repeat play (RP) on the increase and retention of visitor knowledge about the physical exhibit and the phenomenon that it describes?
- **Element of surprise** – How can the surprise element, in form of 'easter eggs' (hard to elicit events 'reserved' for the most engaged and persistent players) be incorporated into the virtual part of hybrid exhibit? How does it influence the VTI and RP?
- **Multiplayer gaming** – The influence of peer group in learning is well established factor in educational psychology. How can simultaneous multiplayer gaming, both collaborative and competitive, be implemented into the virtual exhibit design? How does it impact the gameplay and learning in informal education setting?

6.2.2 Game Design Recommendations

In this section I will try to present some rough technical guidelines for the design of games that are to be used as elements in virtual parts of hybrid exhibits. Before giving the guidelines, however, I am obliged to present the ideas on which these guidelines are developed.

6.2.2.1 The aim of the game

The end goal of engagement with the game – and through it with the physical exhibit – is to make the visitor demonstrate as much factual and conceptual knowledge as possible.

If they are already acquainted with the matter concerned, there is not much that the engagement with the exhibit can teach them, but at least their knowledge can be firmly quantified through proficiency of playing the game. Such information is certainly of importance, as it enables the designer to map out the average ‘knowns’ and the ‘unknowns’ of a particular topic.

On the other hand, if the visitors do not know the ‘correct answers’ beforehand, their learning is demonstrated by playing the game several times and each time getting the higher score (not regarding trial and error method, as it is considered a legitimate learning tool). Assuming that majority of visitors are not knowledgeable about the matter beforehand, this means that the efficient and enjoyable learning would be demonstrated by numerous repeat plays in which the score is increasing in every consecutive game.

So the goal of the game design should be to achieve as many repeat plays as possible, repeat play has to be made appealing. From the findings in **Section 5.2.1.2**, the major drive of the repeat play behaviour is the 'well done' effect produced by visitors seeing their name in the hall of fame. So, to produce more repeat plays, it would be wise to design the game in such a way as to enable as many visitors as possible to enter the hall of fame in their very first game. This would provide them with the incentive to play again and try to do better and, consecutively, to learn more.

Further, if time for the game is made too short, it cannot contain too many different tasks/questions. Neglecting this could result in the visitor being overwhelmed by the challenge of the task and lose the motivation to play again. Also, as is demonstrated in section 5.2.1.4, the desired thorough interaction with the physical part of the exhibit sharply declines with the shortening of time available for 'thinking' on any particular task/question. So, to produce good attention transfer between the virtual and physical part of the exhibit, a suitable lower limit of time you need on every single question/task.

At the same time, the game should not last too long, as in an exciting environment such as science centre; great majority of visitors are not willing to spend too much time at any single exhibit. Also, if one exhibit monopolizes their attention, the learning that they could gain from engaging with the other exhibits is reduced, and the overall learning output from the visit to the science centre diminishes. Finally, if one exhibit is so attractive as to monopolize the single visitor's attention, other visitors will get less chance to engage with it themselves. All in all, there is also an upper limit of the total duration of the game which has to be taken into consideration.

As **Section 5.2.2.4** indicates – albeit not conclusively – visitors are more likely to engage with the more challenging task - they will try out more questions in version 1 than in version 2, so the sense of urgency – and hence challenge – should not be eliminated from the game, but should rather be suitably balanced with the 'thinking time' allowed for solving each particular tasks/question.

6.2.2.2 Game design guidelines

Based on these premises, I propose the following guidelines for game design:

- **Game levels** – To increase the possible learning outcome and keep the prolonged play of a single game interesting, different levels with progressively harder tasks/questions should be introduced. Each new level presents new challenge and provides the player with new information, keeping the repeat play interesting and at the same time not overloading any single level.
- **Level duration and number of tasks** – A single uninterrupted set of tasks/questions in the game (i.e. game level) should last between 40-60 seconds and it should contain at most 6 questions (or tasks). Between different sets, player should be given a short break
- **Countdown timer** – A countdown timer should be included to provide the player with a tangible indicator of challenge.
- **Wrong answers** – The number of wrong answers should not be limited, but rather trial and error method should be considered a legitimate learning tool. As discussed in **Section 5.2.2.6**, visitors are keen on trying out and failing – strongly sanctioning the wrong answers just disables them from trying out more possibilities. What should instead be done is either to award negative points for the wrong answer, or not even that, as the time lost in answering wrongly - and hence not increasing the score - is some sort of punishment by itself. Even better solution would be to give bonus points for finishing each level before the total time available for it is out.

- **Hall of Fame design** – The Hall of Fame should be incorporated into the game, and it might be useful to continuously display the player’s status with respect to the results that are already entered in the hall of fame. Name entering interface should be as simple as possible and plenty of time should be allowed for entering the name. To prevent Hall of Fame saturation, the scores should be reset from time to time, depending on the current number of very high scores.

Finally, I should stress that the conclusions presented in this section certainly deserve more extensive and much more focused inquiry into each of the mentioned game design elements. I would strongly recommend further research along these lines, particularly on issues addressed in previous **Section 6.2.2.1**.

6.3 A Final Word

The findings of this research have an absolute, rather than a relative value. Namely, as I am not aware of the previous research along the same lines, the results presented here cannot unfortunately be compared to the other similar ones. This is, quite understandably, unfortunate state of affairs as it reduces their actual overall impact.

Nevertheless, I am hopeful that the future research that might be developed from the basis set herein will be capable of correcting this and that in the years to come more clear ideas of the role of interactive computer labels and hybrid exhibits as an educational complement and/or supplement to the hands-on informal education provided by the science centre exhibition floor setting will eventually emerge.

Finally, although the research presented here deals only with the science centre setting, I believe the conclusions could be extended and applied to traditional non-interactive museums, galleries and any other institution whose task is to deliver information and knowledge through inanimate artefacts. All that is needed is to find a suitable spot for the computer cabinet, supplied with the power plug. On this thought I end the presented thesis.

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8 APPENDICES

8.1 Appendix 1 – Ethnographic Observation Form

8.2 Appendix 2 – Raw data set

8.2.1 Version 1

8.2.1.1 Coding legend for version 1

- ***link***
  - **time mark:** computer loged time of data acquisition, it was used in conjunction with the time *observation time* noted on the ethnographic observation form to link each ethnographic observation log with the corresponding computer log data.
- ***ethnographic data***
  - *observed?*: whether the game was ethnographically observed (‘1’) or not (space, i.e. no mark)
  - **visitor group data:**
    - *no. m* - number of male players instantaneously engaged with the game;
    - *no. f* - number of female players instantaneously engaged with the game;
    - *group type* – peer group (‘p’) or family group (‘f’);
    - *age* – player’s age (‘a’ - adult, ‘g’ - Techniquest helpers a.k.a. ‘greenshirts’)
    - *soc. int.* – social interaction during the game induced by the game itself (‘1’ - yes, empty space – no)
  - **play type:**
    - *starts* – how many different game starts happened during the single run of the game: one group of visitors played the game (‘1’) or first group abandoned the game before the end and the other group picked up from where the previous group left (‘2’);
    - *replay no.* – which consecutive game in a row by the same player it was;
    - *finished* – how many groups pursued to the end of the ones that independently engaged with that single game (related to *starts*)

- **answering:**
  - *fishtank* – how did the player answer the questions about the fish tank: did not look at the fish tank at all ('n'); glanced at the fish tank before answering ('g'); thoroughly inspecting the fish tank before answering ('t'); knew the answer from the previously played game ('k').
  - *geo/envi* – how did the player answer to the geography and environment questions: random guessing ('r'); group discussion ('d'); asking for assistance from non-players ('a'); knew the answer from the previously played game ('k').
  - *hint/help* – how many times a hint/help button was used in the game;

- ***computer log data***
  - **timing info:**
    - *visitor start time* – computer loged time when the button 'play the game' was pressed, expressed in standard time format, hh:mm:ss;
    - *to play* – time elapsed between the end of the previous game and the pressing 'play the game' in the current game (end-to-start-next time), expressed in seconds;
    - *to start* – time elapsed between the pressing of the 'play the game' button and 'start game' button (instructions reading time), expressed in seconds;
  - **questions answered:**
    - *q. answered* – how many questions were answered in the game, both correctly and incorrectly;
    - *ans**. correct**.* – number of correct answers;
    - *ans. wrong* – number of incorrect answers;
    - *score* – final score achieved, registered only for games that were finished, final scores of the games that were quit were not registered.

- **quit?:** was the game quit and in what way: it wasn’t quit, but finished due to the timeout (empty space); quit without even trying to answer any questions (‘1’); quit after asking fish, environment or geography question (‘f’, ‘e’, ‘g’); quit after correct or wrong answer to the last question (‘c’, ‘w’).
- **name:** the name player entered into the hall of fame.

8.2.1.2 Raw data set for version 1

8.2.2 Version 2

8.2.2.1 Coding legend for version 2

Everything is the same as for the version 1 of the game, apart from:

- ***computer log data***
  - **game end:**
    - *quit* - was the game quit and in what way: it wasn't quit, but finished due to the timeout (empty space); quit without even trying to answer any questions ('1'); quit after asking fish, environment or geography question ('f', 'e', 'g'); quit after correct or wrong answer to the last question ('c', 'w').
    - *time out* – did game end due to a timeout: no (empty space); timeout occurred without even trying to answer any questions ('1'); timeout occurred after asking fish, environment or geography question ('f', 'e', 'g'); timeout occurred after correct or wrong answer to the last question ('c', 'w').
    - *lives out.* – game ended due to three wrong answers ('1').

8.2.2.2 Raw data set for version 2