Assessing Usability of Products in the Low Vision Field

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A dissertation submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg,

In fulfillment of the requirements for the degree of Master of Science in Engineering.

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Declaration

I declare that this research report is my own, unaided work, except where otherwise acknowledged. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

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Craig Jason Tam Wing

Signed this ___ day of ___ 20___

Abstract

This paper presents the implementation of usability engineering into a device to meet the requirements of a Visually Impaired Person (VIP). Users of such a device may suffer from conditions such as Macular Degeneration, Diabetes and HIV/AID's related disorders. Since these disorders affect a person's vision, the device enlarges the desired text to reduce the effects of loss of vision. Other functionality may include image manipulation and colour modification.

A usability engineering framework is incorporated into the design as well as accommodating user requirements in the design process. Usability principles are implemented, hence meeting the aims of effectiveness, efficiency, learnability, satisfaction and context of use. The device is examined via heuristic evaluation and usability testing from specialists and end users, with comments, ratings and times recorded. Research indicates that this device successfully implements usability engineering techniques and provides a cost effective, highly functional device for the VIP.

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Table of Contents

Foreword

The format of this Masters Dissertation differs from conventional dissertation formats, in that it contains a short body and multiple appendices. The main documents of the body consist of a project overview, technical paper, conclusion and a reference section. The technical paper provides an overview of the work done and highlights all the important knowledge gained, whereas the documents presented in the appendices, serve as a reference to the reader that may be interested in gaining additional understanding into the engineering methods, technology and results that were obtained throughout this research.

The remainder of the foreword provides the reader with details concerning the various documents that are presented and provides a brief description of them in the order in which they appear in the table of contents.

As mentioned above, the technical paper encompasses the project in its entirety. Hence, it is not possible to concentrate on any particular aspect of the research in as much detail as is given in the relevant documents found in the appendices. The technical paper provides a literature survey into macular degeneration and the fields of usability engineering, the software design and creation of a prototype and the implementation of usability engineering techniques into the aforementioned prototype. Finally, results are given and recommendations and a conclusion drawn.

The conclusion section following the paper provides a short description of general conclusions reached in this project, whereas more specific and detailed conclusions are given in the appendices.

The reference document contains the reference list of the all the documents that were used in the course of this research. Each reference has a number associated with it that corresponds to its use in the appendices.

The appendices are divided into five sections, with the first page of each appendix detailing the specific content of each appendix. In view of the fact that the appendices are separate documents within this dissertation, the page numbers have a separate convention. Each page of the appendix has a corresponding entry that can be found a the bottom right. The convention used is the letter of the appendix followed by the page number of the entire appendix. For example, the fourth page of appendix A would have the convention, A4 of A21.

Appendix A contains a comprehensive literature survey into various aspects of the project including Macular degeneration, and some of the other visual disorders where this research and prototype may be applicable. The second half of the appendix addresses the current state of usability engineering and the methods that may be used to implement usability engineering into a product or service.

Appendix B details a brief background to the project and the initial functionality offered by the prototype, termed *Revision*, the associated modules, hardware considerations and the rationale for their implementation.

Appendix C discusses usability techniques, specifically Heuristic evaluation. The major usability concerns as found by using usability engineering knowledge and specialist understanding in the optometric field are addressed and the manner in which product evolution is implemented to improve the usability of the prototype. Additional information is given into product evolution and the style in which recommendations are implemented.

Appendix D examines usability testing and the methods that are used to implement this engineering principle. Details concerning participants and the testing environment are given. A statistical and data analysis is given and a final recommendation is provided in more detail for future development. This section ends with a conclusion drawn from the results of the data analysis and examples of the test documents are given.

Appendix E provides the original test data, including the evaluations and post test questionnaire that was used during the usability test. The spreadsheets where the data is combined for analysis is provided and separated into sheets depending on age, CAL, and one for the summary. Finally the documents that were used to conduct the usability test are attached.

Project Overview

The Handbook of Ocular Disease Management states that Age-related Macular Degeneration (AMD) is a degenerative condition of the macula (the central retina), which is responsible for sharp, central vision and colour. As a result, MD patients experience deteriation of their central vision and rely on their peripheral vision. It is the most common cause of vision loss in the United States in those 50 years or older. AMD is present in approximately 10 percent of the population over the age of 52 and in up to 33 percent of individuals older than 75. Similar Central Acuity Loss (CAL) disorders exist that have a similar effect of reducing the central vision.

It is conservatively estimated, by Retina South Africa, that there are approximately 72 000 confirmed and registered Macular Degeneration (MD) sufferers in South Africa and more than 150 000 South Africans affected by some form of retinal degeneration. In addition there are over half a million carriers of the defective gene that causes MD[1].

The United Nations Programme on HIV/Aids reports, at the end of 2003, an estimated 37 million people were living with HIV/Aids. It is estimated by the South African Department of health that in 2001, there were 4.74 million adults affected with HIV, rising to 5.3 million in 2002. It is estimated by the Bennet and Bloom Eye Centre, Louisville, USA, that 15 - 46% of these individuals will have *Cytomegalovirus* (CMV[2]) and hence experience visual disorders as a result of having a combination of CMV and HIV/Aids.

Diabetes is the leading cause of blindness amongst people aged between twenty and 74. It is estimated that 100 million in the developing world and 75 million people in developed countries are affected with diabetes [46]. The effect of Diabetes on the eye is called Diabetic Retinopathy and is the main cause of visual disorders after cataracts and glaucoma. Again, a percentage of persons with diabetes experience visual disorders.

A number of additional disorders exist, such as Glaucoma, Cataracts, Far/Near Sighted, and those associated with an increase in age. These are some instances of where a locally manufactured visual aid can be beneficial.

Currently, low vision devices are imported into South Africa from international suppliers to a local supplier. This supplier in turn adds their profit margin, increasing the already high price on these devices. The supplier will then sell these devices to prospective clients (clinics, individuals, etc.) that require them. Should a problem exist in one of these devices, the client would then contact the supplier and return the device, who in turn will attempt to either have a replacement part imported or send the device back.. As can be noted, this results in tremendous problems for the end client, which include, fluctuations in price (due to exchange rates) and protracted service delivery times.

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[1] Carriers do not exhibit conditions associated with Macular Degeneration, but they “carry” the dysfunctional gene, hence any children may be affected with MD.

[2] Infection of the Retina, ultimately leading to detachment of the Retina and eventual blindness

The purpose of this research is to address these, and other related problems, by engineering a locally manufactured prototype able to compete with its international counterparts. As a result, usability engineering techniques were implemented to ensure that a user-centric approach was adopted to ensure its success.

This project was hence done in order to address this need, by creating a prototype that would be locally manufactured and implement usability engineering techniques to ensure a successful user driven approach. The process was to initially investigate the current state of the market and the functionality offered by low vision devices. Discussions were had with a number of individuals and groups as to the required functionality of a locally created alternative. Once this was complete, an initial prototype was created using usability engineering techniques and evaluated with potential clients and experts in the low vision field.

The principle of operation of this prototype is that it employs a low cost input device (such as a 'Web Cam') connected to a computer running a specialized software package. The software captures a video stream from the camera, from which the user may manipulate the image stream using specific modules to cater for their specific needs, depending on their visual disorder. It is hence a "hybrid" combination of software and hardware (Figure 1).

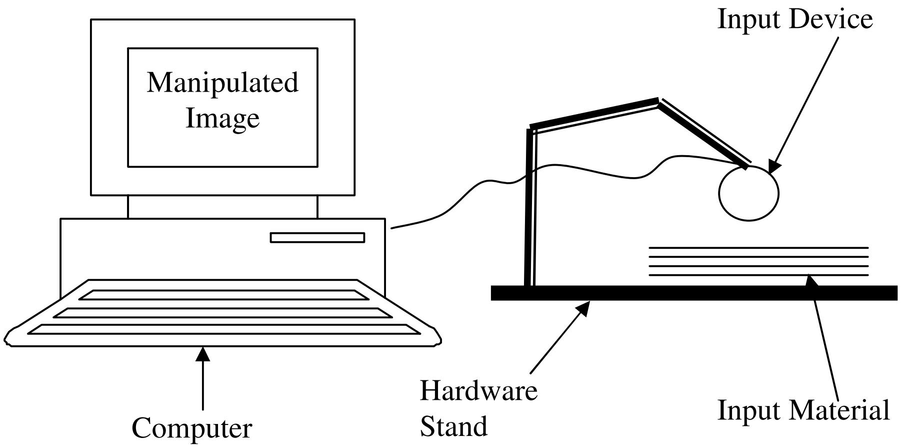

Fig 1. Operation of Device

Assessing Usability of Products in the Low Vision Domain

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Abstract – This paper presents the implementation of usability engineering into a device to meet the requirements of a Visually Impaired Person (VIP). By applying usability engineering into the design, and accommodating user requirements in the design process, usability principles are successfully implemented, meeting the aims of effectiveness, efficiency, learnability, satisfaction and context of use. The device is examined via heuristic evaluation and usability testing from specialists and end users, with comments, ratings and times recorded. Research indicates that this device successfully implements usability engineering techniques and provides a cost effective, highly functional device for the VIP.

Key Words: VIP, CAL, Macular Degeneration, AMD, Usability Engineering, Usability Testing, Heuristic Evaluation, Evolutionary Delivery, Split Module, Nielsen

1. Introduction

There are a number of vision disorders that may cause an individual to experience low vision and Central Acuity Loss (CAL). Of these conditions the most common syndromes are Macular Degeneration (MD) and Albinism. The effect of CAL is that the affected individual experiences a visual impairment that is the opposite of tunnel vision. Hence, the centre of the Visually Impaired Person's (VIP's) eyesight is distorted and the affected individual needs to utilise their peripheral vision to see objects around them.

In addition to the aforementioned disorders, there are a number of other conditions that are not CAL conditions, but affect an individual's vision, amongst these are HIV/AID's related disorders. Diabetes, Glaucoma and age related disorders.

The device to be created is termed *Revision* and is required to cost a maximum of R5,000 and offer functionality comparable to other devices (see *Table 1. Product Comparison,* for some devices available). There are a number of visual aids available to assist VIP's and these can be segmented into two subgroups; external hardware products and software based devices. There are however no devices that are a combination of the two types. In addition, available devices are not manufactured in South Africa, and range in price from R5,625 to in above R25,000 (*Table 1. Product comparison*), have extensive service times and are difficult to obtain.

Product	**Country**	**Price***	**Features**			
			Colour	**Invert**	**Split**	**Zoom**
Andromeda	Ireland	R 28,125	x	x		1-10x
Genie Pro	US	R 20,595	x	x		5.5-50x
Prisma	Ireland	R 5,625	x	x		4-35
Revision	South Africa	R 5,000**	x	x	x	Variable

*Prices taken at 1US$/R6.25
** Maximum price allowed for device

Table 1. Product Comparison [19]

Since VIP's experience CAL, low vision devices enlarge the image, thus reducing the effect of vision loss (see Figure 1. Principle of Operation). Additional functionality includes colour change, inversion and high contrast.

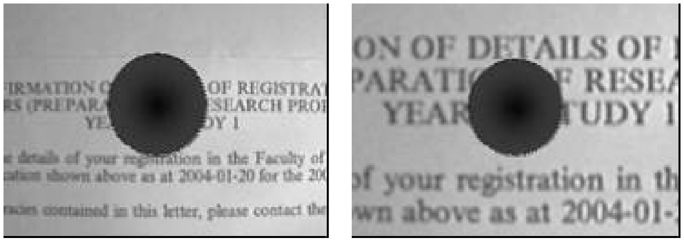


Figure 1. Principle of Operation

2. Literature Review

2.1. Macular Degeneration

Sokwa, Gurwood & Kabat (2002) [1] state that Age-related Macular Degeneration (AMD) is a degenerative condition of the macula (the central retina), which is responsible for sharp, central vision and colour. AMD is caused by the hardening of the arteries that nourish the retina.

This deprives the sensitive retinal tissue of the oxygen and nutrients that it needs to function and thrive, as a result, the central vision deteriorates.

AMD is the most common cause of vision loss in the United States in those that are 50 years or older and is present in approximately 10 percent of the population over the age of 52 and in up to 33 percent of individuals older than 75 [1]. Statistics quoted by Retina South Africa (2004) [2], confirm there are at least 71 500 confirmed cases nationwide, with another 505 900 carriers of the gene that causes retinal degeneration confirmed [2].

The progression of AMD varies widely in severity, usually affecting both eyes, and can be either gradual or abrupt. In the worst cases, it may cause a complete loss of central vision, making reading or driving impossible. In the less severe case, distortion of images may occur. Fortunately, macular degeneration does not cause total blindness since it only affects central vision and does not affect the peripheral vision.

2.2. Usability Engineering

The process of integrating usability from the onset of the design is often referred to as usability engineering [3], [4]. Usability engineering begins with the identification of users, analysis of tasks, setting usability specifications, moving through to developing and testing prototypes and continues through iterative cycles of development and testing [5].

There are two definitions of usability that provide insight and explanation into usability,

1. Nielsen (1993) [6] states , "*Usability is about learnability, efficiency, memorability, errors* (context of use)*, and satisfaction"*. This gives specific goals for usability engineering and;
2. ISO 9241-11 (1998) states [18] (Guidance on Usability) - "*the extent to which a product can be used by specified users to achieve specified goals of effectiveness, efficiency and satisfaction in a specific context of use"*

Gould and Lewis (1985) [7] recommend three key principles for developing usable products.

- Early Focus on users and tasks: That is *understanding* potential users and not just *identifying* them. If usability engineers do not understand the needs of users before creating a specification for a project, they risk developing a specification that does not reflect the user's needs [3].
- Empirical Measurement: Two factors are emphasised; actual behavioural measurements of learnability and usability and conducting these experimental and empirical studies early in the development process.
- Iterative Design: Problems must be identified and fixed with regularity; hence designs must be iterative (cycle of design, test and measure, and redesigned). An additional approach as mentioned by Good (1988) [3], is to adopt an approach, whereby developers start by building a small subset of the system, then "grow" the system, in incremental stages, through the development process. New features are added and existing features refined with successive versions of the system. The prototype evolves into the finished project [3].

2.2.1. Usability Inspection Techniques

"Usability inspection" is the general name given to the process of having evaluators inspect a user interface by using a set of cost effective ways of evaluating user interfaces to find usability problems [8]. The most common technique is *Heuristic evaluation*; the goal of which is to find usability problems in an existing design, such that they can be addressed in subsequent iterations [9], [10].

Jeffries, Miller, Wharton & Uyeda (1989) [11] have shown that heuristic usability evaluation identifies more of the minor problems associated with a user interface than any other technique. Additionally, Nielsen (1992) [9] suggests that heuristic evaluation identifies minor usability problems that are not even seen in actual testing.

2.2.2. Usability Testing

Usability testing refers to allowing "real" users to use a product in the same manner that they would in their daily tasks. It is crucial that usability testing has the following characteristics;

- Participants are real users
- Participants do real tasks
- Observe participants behaviour
- Data Analysis and Recommendations
- Results are applied

3. Research Question

The aim of this research is twofold,

1. Provide usability engineering techniques into the development of a device to meet the distinctive requirements for VIP's,
2. To create a visual aid that will address the problems of affordability of a low vision device (maximum price of R5,000), while providing adequate functionality.

The device will use aspects of both hardware and software to create a hybrid device.

4. Prototype Description

4.1. Design Methodology

The principle of operation of *Revision* is that a low cost imaging device, typically a web camera (webcam), would be used to stream images to a computer. Software would then be written that was able to utilise these images, which can be manipulated by the user, to best display the resultant image, after enhancement, onto the computer screen. User functions include zooming, and colour manipulation. The system therefore comprises both hardware (webcam, computer and stand) and specialist software to manipulate the image, to meet the needs of a VIP.

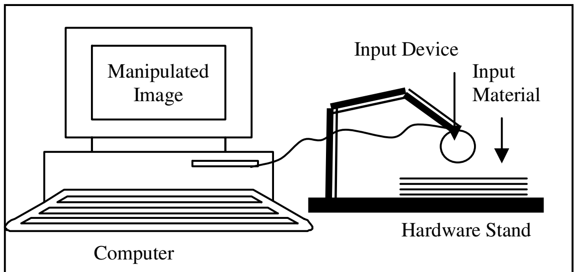


Figure 2. Operation of Device

4.1.1. Development Language

Revision was chosen to run on Microsoft's Windows Operating System (OS) as 90% of machines worldwide operate on this OS [20]. The chosen programming language needs to be object-orientated (OO), allow for visual programming and cater for Rapid Application Development (RAD). This was required to reduce the task of programming Windows based applications to the handling of objects in a visual environment. In addition, the chosen language needs to be able to handle real time processing and ideally incorporate a 32-bit compiler. Based upon these conditions, Delphi was selected as the programming language [12], [13], [14].

4.1.2. Design Model

Applying usability engineering principles, it was realised that the design had to undergo usability testing and inspection at an early stage. These changes needed to be implemented and additional user data to be gathered, hence an evolutionary approach was used [3]. An initial prototype was developed comprising of modules, which could be evolved or removed as required or additional modules added. Thus the prototype would evolve from the initial design, though iterative evaluation into the final product [3]. The hardware aspect of the device would undergo a similar process.

4.2. Initial Prototype

The initial prototype comprised a number of modules that would offer functionality comparable to the currently available visual aids (see *Table 1*). This functionality includes zoom functionality, colour manipulation and inversion. Modules were included as required, during interviews with specialists and users during the initial research phase.

4.2.1. Module Addition

The following modules were implemented and initialised by the user clicking on the appropriate button from the start page,

M1. GetVideo: streamed (extracted) images from the webcam and captured selected frames as Bitmaps (BMP) for further processing. All subsequent modules used these saved BMP image.
M2. Snapshot viewer: the user could magnify portions of the captured BMP.
M3. Invert Image: Inverted the pixels of the BMP to produce a "negative" of the original BMP.
M4. Configuration Module: used to configure the size of the strip or the hole that appeared in the previous two modules.
M5. Optical Character Recognition (OCR) and Speech: when used in conjunction with the developed software, extracted the text from the captured BMP, then using the speech Application Program Interface (API), the program was able to read this extracted text.

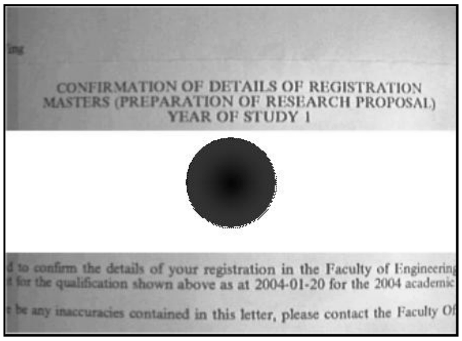
4.2.2. Innovative Modules

In addition to the above modules, two modules were added that might challenge the conventional manner in which VIP's view objects. These both compensate for the CAL that is experienced, by inserting "gaps" where the loss of vision is experienced. These modules are,

M6. Split Module: The software compensates for the CAL by inserting a varying vertical or horizontal, blank "strip" to compensate for CAL (see *Figure 3. Split Mode*), essentially creating a "paragraph break" of varying height for the horizontal strip.

M7. Wrap Around: An extension of the *Split* module, except the centre of the image was manipulated by inserting a "hole" as opposed to a strip, with the original text appearing on each side of the hole.

The premise of this is that the VIP would be able to look directly at an object, as a "normal sighted individual" and use their peripheral vision to read the compensated text (see *Figure 3. Split Mode*).



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CONFIRMATION OF DETAILS OF REGISTRATION
MASTERS (PREPARATION OF RESEARCH PROPOSAL)
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Figure 3. Split Mode

In addition to the software changes, a number of hardware stand configurations were explored to mount the webcam. Different approaches were tried that would allow the camera to be mounted relative to the input image. Lighting was considered as was a counteracting lens to oppose the distortion of the image (Barrel effect[1]). This lens was to cancel the effect of the internal convex lens of the webcam.

4.3. Device Evolution

Once the initial process in the evolutionary delivery was complete, heuristic evaluation was conducted in conjunction with the Low Vision clinic at the Optometry unit based at the University of Johannesburg, previously Rand Afrikaans University (RAU), and members from the South African National Council for the Blind (SANCB). The results (see *M1- M7*, above) from the usability inspection were applied to the prototype by refining or creating new modules, and the process repeated, until the specialists were satisfied, fulfilling the requirements of an evolutionary delivery [3]. The following key features were introduced into the device,

4.3.1. Removal of Modules

Four modules were removed from the device as they were either not necessary or did not meet usability requirements. Theses modules were snapshot viewer (M2), wrap around (M7), and configuration (M4). Additionally the OCR and speech module (M5) was removed as the functionality offered was not required at this stage of development (heuristic evaluation) due to time constraints, but consideration would be given to include these in future iterations of the device.

4.3.2. Module Evolution

Within the software program, the remaining modules were re-analyzed and improved to reduce the resources required and enhance the performance. Module one (M1) (getvideo module), the process used to obtain the image from the webcam, was configured to automatically initiate at startup using components that are distributed under the freeware license, Mozilla Public License (MPL) 1.1. The split module (M6) was reduced to supply only a horizontal split to simulate a paragraph break and the gap size could be dynamically altered.

4.3.3. Module Additions

Modules were added that increased the functionality of the device. This was determined during feedback sessions with the evaluators and formal comments and opinions were given. These modules are (listed as a continuation of the above list, see *4.2. Initial Prototype, M1- M7*),

M8. Grayscale: the initial prototype was able to convert the captured image into greyscale (black and white) using the built in drivers, but it was a complex and under utilised function.

M9. High Contrast: manipulated the image to display either "pure white" or "pure black",

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[1] Barrel Effect is attributed to the internal curvature of the webcam lens, causing images to be spherised at their centre and occurs at the edge of the lens.

unlike greyscale where an image appeared in black, white and grey or degrees thereof.

M10. Zoom Enhancement: Using mathematical algorithms, the resolution was effectively doubled, increasing the visual clarity.

M11. Luminance and Glare control: Automatically catered for poor lighting conditions (over or under exposed) on the image or parts thereof.

4.3.4. General Operation

The operation of the software was more automated at startup with modules initialized automatically; in particular the operation became "real-time". Previously users needed to control every aspect of operation including initializing of the software to start capturing in images. Additionally the Human Machine Interface (HMI) was altered such that the different modules could be initiated by mouse operations as opposed to clicking on the call buttons. This was effective as VIP's experienced difficulties in maneuvering the mouse to click on the buttons, and linking modules to mouse operations reduced these problems

The counteracting lens was removed, as the benefit of using a counteracting lens to reduce the barrel effect was minimal. In addition, the lens darkened the image and reduced its overall clarity. Lighting was addressed by the inclusion of the luminance and glare control modules to automatically compensate for poor lighting conditions. Finally different modules could be used in combination to cater for the specific needs of each VIP (e.g. zoom, grayscale and split).

4.3.5. Hardware Evolution

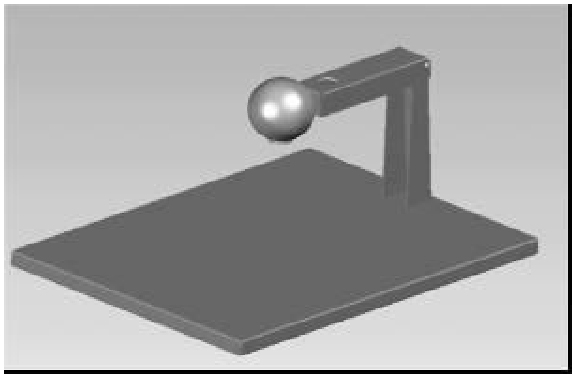


Figure 4. Hardware Prototype

The stand was made from Aluminium with the following dimensions; 145mm height, 360mm width and 270mm depth with a weight of approximately 0.8kg. The operation was that an arm (with a webcam) was mounted above a viewing surface, onto which the material to be viewed was placed. The stand was made to industrial standards and machine cut; hence it has a very "commercial" feel and is aesthetically appealing (see *Figure 4. Hardware Prototype,* above)

4.3.6. Input Device Evolution

The initial input device was a Logitech Quickcam 3000 Pro chosen due to its cost and availability; hence the majority of the initial software and hardware was created around its performance. As the project continued, and specialists consulted it became apparent that the clarity of the image was not sufficient when compared to other visual devices (see *Table 1 Product Comparison,* above). The problematic area was concluded to be the low cost webcam that was used, which gave a best resolution of 640 x 480.This equated to a resolution of 0.3 Mega Pixels (MP), whereas competitive devices operate at least 1MP. This was therefore determined to be the minimum resolution threshold.

A Closed Circuit Television (CCTV) camera was configured to work with the system by using a commercial external interface (*Grabee X),* which converted the computer's Universal Serial Bus (USB) port to the applicable CCTV connectors. The CCTV requires an external power source of 12V Direct Current (DC) and complex wiring to connect the CCTV to the Grabee X. This configuration improved the quality of the input image (above 1MP) allowing for an overall improvement in the device. However the additional connections required increased the overall price by 20% (to R6000), thus not meeting the objectives of the research (maximum price constraint of R5,000).

5. Usability Testing

5.1. Goals and Concerns

The goals set prior to the usability testing were to establish whether the product met the aims of learnability and usability (i.e. effectiveness, efficiency, satisfaction, learnability and context of use). This was to be achieved by monitoring the change in time to complete tasks (learnability) and via a post-test questionnaire to receive user's feedback (usability). A particular concern that was raised during initial heuristic evaluation was the clarity of the input image and the concept of using a mouse for the HMI. The former was especially crucial for the partially sighted that were using the product.

5.2. User Participants

Users were divided into three sample groups, depending on their age and a further group for those VIP's that experienced CAL.

Nielsen and Molich (1990) [15] found that three participants discovered not quite half of all major usability problems. Virzi (1992) [16] found that 80% of usability errors were found with four or five participants and 90% with ten participants. Additional participants were unlikely to uncover additional problems. Coupled with reliability requirements [6] at a confidence level of 80% and tolerance of approximately 20%, and the information from [16] the number of users required was estimated to be eight, per group or subgroup thereof.

5.3. Onsite Testing

The usability tests were conducted at Sibonile Primary School's[2], computer class and RAU University, optometry unit. The computer class houses approximately 20 computers and children are introduced to their operation. The optometry unit is open to the public and consults many VIP's and recommends assistance where necessary. The users would be VIP's and most likely be using a device such as this in this type of environment.

5.4. Pre-test Concerns

Prior to the usability tests, a number of tasks needed to be complete. These included a pre-test questionnaire (user data was gathered), orientation (ensure that users were familiar with mouse operation), thinking aloud scenarios (gather user's thoughts) and a pilot test to ensure operation efficiency. All user information was anonymous and only a user number made references. The Human research ethics committee (medical) of WITS University assessed the proposed testing methodology and approved the process (protocol number: R14/49 WING).

5.5. Tasks and Observations

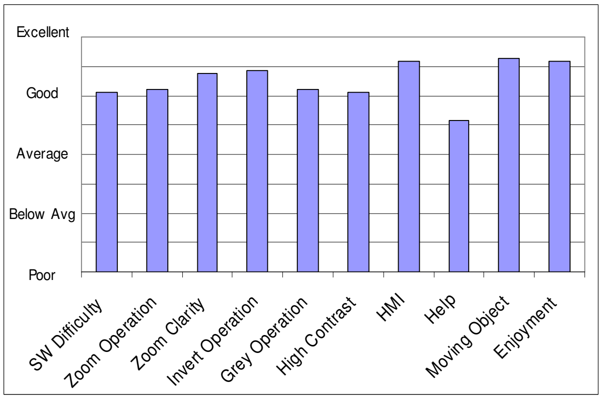
Several tasks were done to determine the ease with which the user could operate the device, e.g. maneuvering objects below the camera. The time to complete individual tasks was recorded and a final task was conducted, and was a combination of the previous tasks.

Should the time to complete that final task be less than the sum of the subparts, one of the aspects of usability engineering was met (*learnability*).

The following user observations were made (usability objective shown in brackets); time to complete the tasks (*efficiency)*, number of help referrals (*memorability)*, number of errors committed (*errors)* and finally the number of non-user errors (program errors, e.g. crashes).

5.6. Post-test Questionnaire

The post-test questionnaire was done to gather information about the user's experience and for them to rate the operation of aspects of the device on a five-point scale as recommended by Jokela, Livari, Metero and Karukka ([17]. This gave the final measure for the requirements of usability engineering, *satisfaction*. Users were encouraged to give additional comments and an overall rating of the experience. Ten questions were asked and had a rating from one to five, with one the most favourable (excellent), and five the least (poor). The results for all users are shown in *Graph 1. Average User Module Rating*.



Graph 1. Average User Module Rating

6. Data Analysis

6.1. Statistical Analysis

Users were divided into the following sub-groups (all of who are VIP's); children (up to 18 years

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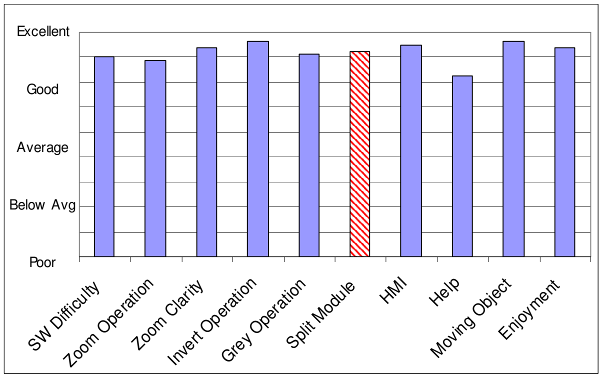
[2] School for the Visually impaired, based in Vereeninging. Currently have 143 partially sighted and blind children (August 2004).

old) adults (18-50 years), elderly (above 50 years old), VIP's with and those without CAL. Once the data was collected (test participant evaluation and post-test questionnaire), an analysis was done.

6.2. Observations

A number of observations were made from the data. These results were taken from the entire population group, although the individual subgroups exhibited similar results.

- Many users experienced difficulty with the centre scroll button, in particular with the clicking.
- The time to complete a major task, comprised of a number of smaller tasks, was less than the sum of these tasks by an average of 23.3%.
- The help document needs to be evaluated as many users gave poor feedback (average rating of 2.42; with one being the best possible rating and 5 being the worst rating).
- The concept of a mouse driven HMI was favourable with users expressing positive ratings (average rating of 1.42).
- Although the clarity was questioned during heuristic evaluation; participant feedback and ratings for the webcam operation was favorable (average rating for clarity 1.63 and operation of 1.89)
- The split module showed very encouraging ratings (average rating of 1.75). The average ratings from the CAL group are shown in *Graph 2,* with the rating for the split module shaded.



Graph 2. Average CAL User Module Rating

6.3. Recommendations

To complete the usability study, recommendations are made to improve the usability of the product. These are to be considered in subsequent iterations of the product. These can be separated into software and hardware considerations

6.3.1. Software Recommendations

- Image clarity needs to be improved to above the minimum resolution threshold of 1MP.
- Colour combinations to assist individual VIP's (e.g. blue and white), as the extent of vision loss varies for each VIP, and a colour combination tailored for the individual would assist their viewing ability.
- The allocation of modules to mouse functions needs to be investigated so that the more frequently used modules are assigned to easier mouse operations, allowing for more efficient HMI.

6.3.2. Hardware Recommendations

- The viewing area needs to be increased, as currently a standard A4 page placed under the viewing area cannot be seen at the extremes of the page borders.
- Moving materials in a strictly horizontal or vertical direction needs to be researched. Some participants found it difficult to move an object under the viewing area in only a vertical or horizontal direction. A solution may be to implement an X-Y table that only allows movement in only the horizontal or vertical directions.
- Investigate a low cost, high performance imaging device capable of incorporating a clearer image (above 1MP), reduction of the barrel effect and improve the lighting, thus increasing the clarity of the input image.
- Alternatives to the help documentation that is currently provided. The current help obtained the lowest rating (2.42). Colour or font changes or embedding the help within the program that can be viewed via appropriate mouse commands.

7. Conclusions

Statistics indicate that by using the product, users are able to complete basic tasks within an acceptable time (*efficiency)*. The statistics are within an 80% confidence interval and have a tolerance level of between 20 – 26% depending on the subgroup that was addressed. For the entire population group, a 90% confidence exists, with a 17% confidence interval. Even at the extremes of these tolerances, the data gathered would be acceptable enough to demonstrate a very usable and effective device *(context of use)*.

The most important finding is that the device rated favourably in terms of the operation of the individual modules (*satisfaction*). *Learnability* is observed as the time to complete a major task comprising of a number of smaller tasks and was less than the time to complete those individual smaller tasks (*memorability*).

With these findings and based upon the definition of usability engineering (ISO 9241-11 standard [18], Nielsen (1993) [6]) it can be seen that usability principles (effectiveness, efficiency, satisfaction and context of use) have been successfully implemented into the device, thus meeting the first goal of the research question.

The "split" module, where a "gap" is inserted into the image to introduce a paragraph break, has shown positive results and has been applauded by heuristic evaluation and may be an additional approach to alleviate the problems faced by VIP's. This could lead to a different mindset and teaching approach for CAL VIP's. The very favourable rating received during the usability testing, and the numerous comments from CAL patients that such a module offers much promise reinforces this claim.

With the low cost of materials in the hardware and the negligible cost of software development, it is concluded that this device is affordable (maximum price of R5,000), while maintaining functionality to assist the VIP (seven completed modules). This complies with the second objective of the research question.

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Conclusion

Based upon the definitions of usability (ISO standards and from Nielsen) and the extensive research and test participant evaluation, it can be seen that usability principles (effectiveness, efficiency, satisfaction and context of use) have been successfully implemented into the device.

The device that was assessed during heuristic evaluation was not the same that was tested in the user environment, having "evolved" from its initial stage. Modules that were not needed were removed, and more important modules improved and streamlined and finally additional modules were added as needed. The process repeated till the majority of usability errors were recovered.

Of the major findings from the usability test, the most important is that the device rated favourably in terms of the operation of the individual modules. Concerns raised by specialists during the heuristic evaluation about the clarity and operation of the zoom are addressed by the usability participation test, and found to have no basis when considered against the research question.

Additionally, learnability is observed as the time to complete a major tasks comprising of a number of smaller tasks, was less than the time to complete the smaller tasks individually. This indicates that participants were gaining familiarity with the device after a short period of time.

The major usability problem that was uncovered during the usability test was the regularity of crashes. Should this problem not be addressed with the next iteration, the device is rendered useless and does not meet basic usability requirements. The help documentation needs to be reviewed as it did not receive a favourable rating and may need to introduce different colours or be supplied with a reading aid, or implemented within the program itself upon a mouse operation.

The hardware portion of the device needs to be addressed as the viewing area was smaller than initially hoped as a result of changing the input device, and consideration given to introduce a X-Y table for horizontal and vertical movement. The input device needs to be evaluated to improve the clarity of the image to compete with other visual aids.

The HMI implementation of a mouse driven interface was received with great approval and user participants and evaluators alike believe that with further use it could show additional favourable results. Additional thought needs to be given to the operation of the individual modules with the more often used modules being associated with easier mouse driven operations.

The "split" module, where a "gap" is inserted into the image to introduce a paragraph break, has shown positive results and has been applauded by heuristic evaluation and may be an additional approach to alleviate the problems faced by VIP's. This could lead to a different mindset and teaching approach. This is reinforced by the very favourable rating received during the usability testing (1.75), and the numerous comments from CAL patients that such a module, upon initial reflection, offers much promise.

Furthermore, statistics indicate that using the product, users are able to complete basic tasks within an acceptable time and that learning of the product is implemented. The statistics are within an 80% confidence interval and have a tolerance level of between 20 – 26% depending on the subgroup that was addressed. Even at the extremes of these tolerances, the data gathered would be acceptable enough to show a very usable device.

This research indicates that should a user have no prior experience with visual aids, the proposed device is beneficial in all areas. However, should the user have prior experience in visual aids; the device does not offer the same quality in terms of image quality when compared to other available visual aids.

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Appendix A: Literature Survey

A.1. User Profiles

There are a number of disorders that affect a person's vision, in particular those that experience Central Acuity Loss (CAL). Some of these include Macular Degeneration (MD) and Albinism. Other vision disorders, that are better known include, HIV/Aids related disorders (Cytomegalovirus) and diabetes. There are a number of products that are available to assist persons with visual disorders, particularly Macular Degeneration, but there are none that are manufactured locally in South Africa. This creates a tremendous problem for local visually impaired persons, as the prices of these devices are dependent on foreign currencies and service times are lengthy, if at all.

The device that was designed was primarily for CAL sufferers, and in particular, Macular Degeneration sufferers, but is not limited specifically to them. This device is known as *Revision.* There are a number of areas of application for this device including HIV/Aid related visual disorders; Diabetes induced disorders (the combination of these affect, at a conservative estimation, in excess of 20 million people [40], [41], [46]). There are a number of additional disorders, too numerous to mention here (a complete list can be found in *A.1.6. Other Vision Disorders*).

Furthermore, this device may be used by specialists requiring additional magnification (e.g. stamp or coin collectors), and implemented at a corporate level in compliance with the employee equity charter [39], against discrimination of visually disabled persons.

It be seen from the definition of ISO 9241-11 [4], that the measure of usability (effectiveness, efficiency and satisfaction) are only meaningful within a clearly defined context of product use. Hence the need to analyse the possible end users to achieve the usability goals.

A.1.1 Structure of the Eye

A.1.1. Main Components

To understand the problems faced by VIP's a brief explanation of the physiology of the main components of the eye needs to be given [76].

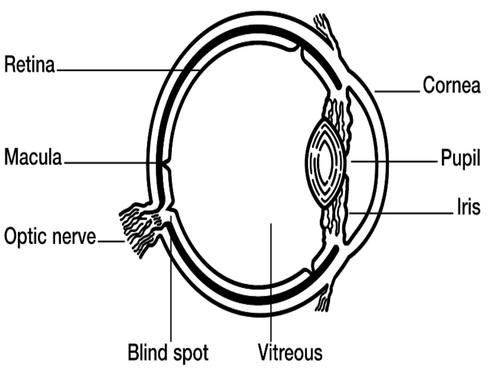


Figure A.1. Structure of the eye

Lens -focuses light onto retina
Iris – controls the amount of light that enters the eye
Retina – converts visual image into electrical signals
Optic Nerve – transmits these electrical signals to the brain
Macula – contains mainly cones, organized for inspecting detail
Vitreous – filled with organic and inorganic substances involved in metabolic reactions of the lens
Pupil – Dilates in dim light and constricts in bright light
Cornea – works with the lens to focus light onto retina, also acts as a protective layer

A.1.1.2. Retina and Macula

The retina can furthermore be examined to detail problems that could occur within the eye. The retina converts visual images into a series of electrical signals that are transmitted to the brain via the optic nerve where they are interpreted. Each retina contains 125 million rods and 5.5 million cones [76]; hence the number of individual affects can be gigantic due to the number of permutations available.

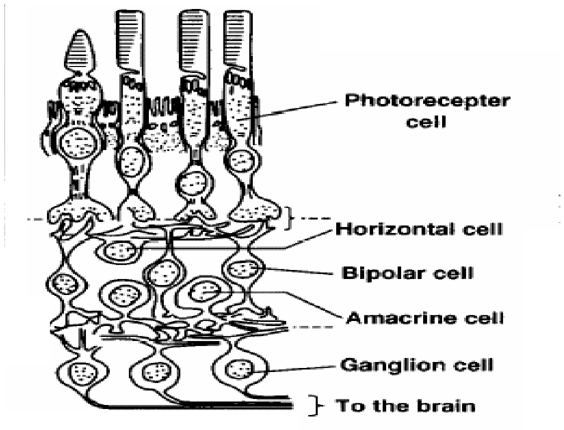


Figure A.2. Structure of the Retina

Rods mediate dim light and are not light sensitive; cones regulate bright light vision and are mostly found within the macula. The outer segment of both rods and cones, contain the visual pigment, rhodopson [76].

The thin, fragile macula within the centre of the retina is made up of several layers. The light-sensing cells produce sharp, central vision while two underlying layers nourish and help remove waste from these cells [36]. When the macula is damaged, the eye loses its ability to see detail, such as small print, facial features, small objects, etc. The damaged parts of the macula often cause *scotomas* (localized areas of vision loss) [36]. When you look at things with the damaged area, objects may seem to fade or disappear. Straight lines or edges may appear wavy [37].

A.1.2. Macular Degeneration

A.1.2.1. Physiology

The Handbook of Ocular Disease Management states that age-related macular degeneration (AMD) is a degenerative condition of the macula (the central retina), which is responsible for sharp, central vision and colour. It is the most common cause of vision loss in the United States in those 50 years or older AMD is present in approximately 10 percent of the population over the age of 52 and in up to 33 percent of individuals older than 75 [35]. AMD is caused by hardening of the arteries that nourish the retina. This deprives the sensitive retinal tissue of oxygen and nutrients that it needs to function and thrive. As a result, the central vision deteriorates.

Similar statistics appear in the South African context and are quoted, by Retina South Africa, 71 500 confirmed cases nationwide, with another 505 900 carriers confirmed.

The “carriers” are the parents that have been identified with the responsible gene (only one of two genes have MD), and “affected” are the children (both genes have MD). MD occurs when children receive the gene causing MD from both parents. The distribution of which is as follows [75],

Province	**Affected**	**Carriers**
1. Mnupumalnaga	3 900	35 000
2. Northern Province	3 900	61 000
3. Gauteng	21 500	92 000
4. Kwazulu / Natal	10 400	105 000
5. Freestate	4 900	33 000
6. Western Cape	12 600	49 000
7. Eastern Cape	7 900	79 000
8. Northern Cape	1 800	10 000
9. North West	4 400	41 900
TOTAL	**71 300**	**505 900**

Table A.1. Affected and Carriers of Macular Degeneration

These numbers are only of the confirmed numbers and are not of the total infected population. This can be attributed to the fact that not all MD sufferers will have access to the appropriate clinics where they can be registered and seek assistance. This is verified by noting that the largest incidence occurs in Gauteng and Kwazulu / Natal where clinics are readily available.

A.1.2.2. Symptoms

Macular degeneration varies widely in severity; usually affecting both eyes and can be either gradual or abrupt. In the worst cases, it may cause a complete loss of central vision, making reading or driving impossible. In the less severe case, distortion of images may occur.Fortunately, macular degeneration does not cause total blindness since it does not affect the peripheral vision.

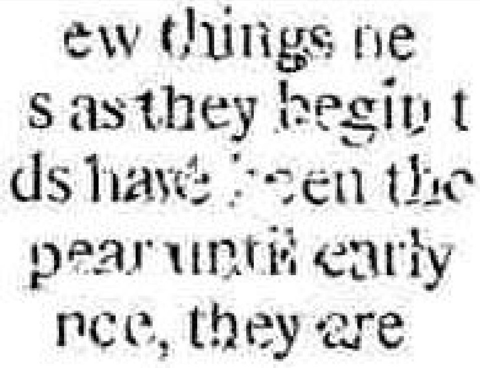


Figure A.3. Print appears distorted [36]

Figure A.4. Peripheral Vision Unaffected [36]

A.1.3. HIV/AIDS Related

The United Nations Programme on HIV/Aids reports that at the end of 2003, an estimated 37 million people were living with HIV/Aids [41]. It is estimated by the South African Department of health that in 2001, there were 4.74 million adults affected with HIV, rising to 5.3 million in 2002 [40].

A.1.3.1 Physiology

There are a number of visual disorders associated with HIV/Aids, including Kaposi's sarcoma, HIV retinopathy, syphilis, however the most common is an infection of the Retina, called *Cytomegalovirus* (CMV) [42].

CMV is found universally throughout geographical locations and socioeconomic groups and infects 50 – 80% of the general population show symptoms of CMV [44] (related to the Herpes Simplex Virus [43]), but it is the combination of CMV and HIV/Aids that causes CMV Retinitis. CMV occurs in 15-46% of Aids sufferers [42].

A.1.3.2. Symptoms

Results of CMV that ultimately affects the Retina and causes it to separate from the back of the eye, is known as retinal detachment. Resultant symptoms include "floaters" or painless loss of central or peripheral vision [42].

A.1.4. Diabetes

A.1.4.1. Physiology

Diabetes is the leading cause of blindness amongst people aged between twenty and 74 [45]. It is estimated that 100 million in the developing world and 75 million people in developed countries are affected with diabetes [46]. The effect of Diabetes on the eye is called Diabetic Retinopathy [47] and is the main cause of visual disorders above cataracts and glaucoma.

A.1.4.2. Symptoms

Over time, Diabetes affects the circulatory system of the Retina. In the earliest phase (background diabetic retinopathy), the arteries of the retina become weakened and leak, forming tiny dot like haemorrhages, causing a decrease in vision. The next stage, proliferate diabetic retinopathy; the retina becomes oxygen deprived causing more fragile vessels to develop. These vessels are likely to haemorrhage, the resulting blood flowing to the retina causing "spot" or "floaters". In the final stages, vessel growth and scar tissue may eventually lead to more serious problems such as retinal detachment or glaucoma [47].

Figure A.5. Normal Vision vs. Vision with Diabetic Retinopathy [47]

A.1.5. Other Users

Beside the aforementioned visual disorders, a number of additional applications could be found for the device that was created as part of this research (Revision). Specialists could make use of the magnification to analyze objects such as coins or stamps.

Corporate could enforced, via government support, to purchase a predefined number of these devices in order to allow equal opportunities to partially sighted employees to their peers. This would be in compliance with the employee equity charter [39].

A.1.6. Other Vision Disorders

Adapted from The Royal Institute for Deaf and Blind Children based in New South Wales, Australia, **http://www.ridbc.org.au/information/vision/vision_syndromes.html**. Last accessed 16 November 2003

Common syndromes and conditions which affect vision

The following list of syndromes is a selection of some of the vision problems found particularly in children. For more detailed information on any of them, consult your ophthalmologist.

Albinism

Albinism is a congenital condition in which a person is lacking pigment in his/her eyes, skin and hair. It is associated with reduced visual acuity, photophobia, nystagmus, strabismus and refractive errors. Albinism is usually a static condition and there is no medical treatment available. However, environmental conditions can be modified to reduce its impact, e.g., glare can be reduced with the use of sunglasses.

AIDS/HIV and the eye

Because HIV attacks the body's immune system, eye infections are common in people with the virus. Following are some common syndromes and infections:

- **Cotton wool spots**, which affects the retina (the inner layer of the eye that sends signals to the brain). AIDS can cause small amounts of bleeding and white spots on the retina.

- **Cytomegalovirus**, (CMV) causes a serious infection of the retina. CMV can harm vision permanently. CMV can cause the retina to separate from the back of the eye (become a detached retina) causing serious vision loss.

Cataracts

Cataracts occur when the lens of the eye clouds, causing blurred vision. They can be present at birth either in one eye or in both. Where sometimes a person's eyes can look red in a photo, a cataract may make the eye look white. Cataracts can develop as the result of injury or metabolic disorders and they often occur in older people. Cataract treatment involves removing the opaque lens surgically. In young babies this is done as soon as possible after diagnosis, whereas in older people a cataract will be removed only when it interferes with the person's daily living. An artificial lens can be inserted after the cataract has been removed, however artificial lenses are not normally implanted in babies until they reach the age of 3-4 years old. Hence, contact lenses and/or glasses must be worn in order to allow normal vision development and to avoid the development of amblyopia.

DC Cortical Vision Impairment (CVI)

This is vision impairment caused by a disorder in the visual areas of the brain or the posterior pathways leading to the brain. It can result from damage to the brain. There is no medical treatment available for CVI, however, there may be an improvement over time in vision as the brain regains function. A person with CVI will often experience fluctuations in vision.

Glaucoma - loss of peripheral vision - adapted from **The Canadian National Institute for the Blind**

The basic cause of glaucoma is unknown but a number of risk factors have been identified: these include age, heredity, myopia (near-sightedness), general diseases such as early heart attack and stroke, and raised intraocular pressure (IOP).

Basically, glaucoma is a condition in which pressure of the fluid inside the eye is too high. In its most common form the condition is usually painless and the loss of vision gradual, beginning with the peripheral vision. If glaucoma is diagnosed early - by simple eye test - and treatment followed, progress of the disease can be halted. Treatment may include drops and pills. However if this fails, laser therapy or even surgery may be required.

Macular Degeneration - blurred central vision - adapted from **The Canadian National Institute for the Blind**

The most common form of macular degeneration occurs in elderly people.

Macular degeneration occurs when there is damage to the macula, a small area of the retina. The retina is a thin layer of light-sensitive nerve cells and fibres that turns light into an electrical impulse that the brain understands as an image. When the macula is damaged, the retina resembles a camera with a spot on the film. The centre of the field of vision blurs and all detail is lost - macular degeneration occurs.

In a dry type of macular degeneration, symptoms tend to develop over many months or years. In the more severe wet type, leakage and often haemorrhage occur under the macula, causing the symptoms to develop over a short period.
Treatment can take the form of laser technology, but in general, people with the condition can usually continue their daily activities using their peripheral vision and making the best of their remaining vision, so that low vision aids can help to make fine work possible.

Nystagmus

Nystagmus is a repetitive involuntary movement of the eyes. The movement can be horizontal, vertical or rotary and can be exacerbated when a person is sick, stressed or tired. The cause can be of a sensory or mechanical nature, whereby the muscles that control the eye are receiving incorrect innervation. Nystagmus can be present on its own and for no apparent reason. It can also occur with a number of other conditions including cataract, albinism, high refractive errors, optic nerve hypoplasia and many more. There is no medical treatment available; however most people with nystagmus have a "null point". The null point is a position of the eyes where the nystagmoid movement is still or very minimal. In order for a person to effectively use his/her null point, they will often adopt a head posture that positions their eyes in the null point.

Refractive Errors

Refractive errors include:

- Myopia (or short-sightedness) where near objects are seen clearer than distant objects
- Hypermetropia (or long-sightedness) where distant objects are seen clearer than near objects
- Astigmatism (distorted vision) due to unevenly shaped cornea (front of eye)

Contact lenses (and glasses) can be safe and effective ways of correcting refractive errors. Contact lenses are small, curved, thin plastic disks designed to cover the cornea, the clear front covering the eye including the iris and the pupil.

Retinitis pigmentosa

Retinitis pigmentosa (RP) refers to a group of diseases that cause slow but progressive loss of vision. RP tends to be an inherited condition where there is a gradual destruction of some of the light sensing cells in the retina (the retina is the tissue lining the inside of the eye that sends visual images to the brain). Common symptoms can occur in the following order: night blindness, tunnel vision, colour vision problems, blurred central vision, loss of central vision.

There is as yet no cure for RP.

Retinopathy of prematurity - ROP

ROP is a disorder of the retina that occurs in some premature babies caused by oxygen treatment after birth. The more premature the baby, the higher the chance of the development of ROP. Sometimes the condition will spontaneously resolve while other babies may need laser treatment, cryopathy and/or surgery. The effects of ROP on vision vary greatly from no perception of light to normal vision.

Strabismus/squint

This occurs when there is a misalignment of the eyes, causing them to look in different directions. Treatment can consist of corrective lenses, patching and surgery. Strabismus can occur on its own or with other disorders such as cataracts. Types of strabismus include:

Esotropia - inward turn of the eye
Hypertropia - upward turn of the eye
Exotropia - outward turn of the eye
Hypotropia - downward turn of the eye

Usher's Syndrome

Usher's Syndrome is a genetic disorder that consists of a hearing loss and retinitis pigmentosa (RP) - see above. There are at least four types of Usher's Syndrome:

- Type 1: The child is born with a profound hearing loss. Symptoms of RP are evident early in life and the child usually has difficulty with balance due to problems with the inner ear.
- Type 2: The child is born with a moderate hearing loss in the lower frequencies and a severe to profound hearing loss in the higher frequencies. The hearing loss is not progressive and the child may benefit from the use of hearing aids. Symptoms of RP are usually evident in late childhood to early teens. Balance is not affected.
- Type 3 &4: The child is usually born with fairly good hearing but has a progressive loss. The symptoms of RP are usually apparent from childhood to early teens and the effect on balance is variable.

A.2. Usability Engineering

A.2.1. General View of Usability

There are a number of definitions for the term Usability, some of which are given by [1], [2] and [3]. Perhaps the best-known and most utilised definition is by Nielsen [3], "*Usability is about learnability, efficiency, memorability, errors, and satisfaction.*"

There is however a standard, that is becoming the main reference of usability- ISO 9241-11 (Guidance on usability) [4], that states "*the extent to which a product can be used by specified users to achieve specified goals of effectiveness, efficiency and satisfaction in a specific context of use*". Upon further analysis of ISO 9241-11 [4], we define the following terms;

- Effectiveness: the accuracy and the completeness with which users achieve specific goals
- Efficiency: the resources expelled in relation to the accuracy and completeness with which users achieve goals
- Satisfaction: freedom from discomfort and positive attitude to the use of the product.
- Context of use: characteristic of the users, tasks and the organization and physical environments.

In addition to being formally recognised in literature and having an ISO standard[1], ISO 9241-11 was recently used in the Common Industry Format, CIF, for usability testing [5]. This indicates the relevance and importance of the definition as the creation of CIF was supported by a number of corporations and stakeholders actively involved in the field of usability engineering [6].

This definition gives a wide approach to usability [7]; usability is about supporting users in achieving their goals in their work, it is not only a characteristic of a user interface.

This definition implies that usability is a function of users. Hence the following important factors emerge,

1. Usability means focusing on users of a product or system: To develop a usable product, you have to know, understand and work with people who represent the actual or potential users of the product [2]. This is especially true in Low Vision field, as the end user has specialised requirements.
2. People use products to be productive: Partially sighted individuals rely more on "external, third party" devices than their fully sighted peers. Hence the need becomes necessary that these tools allow them to have the equal advantages as others in their surroundings.
3. Users Decide when a product is easy to use: To develop usable products, you need to understand how much time and effort typical users are willing to spend on figuring out how to do a task with a product [2].

---

[1] International Organization for Standard, World's largest developer of standards; Network of the national standards institutes of 148 countries [8]

This coupled with ISO 9241-11, we can conclude that usability is a complex issue and can be elaborated as follows [6],

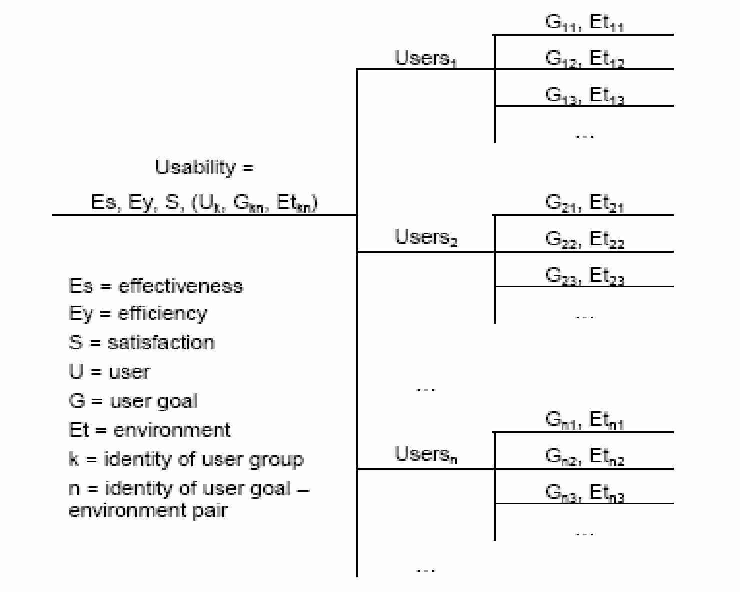


Figure A.6. Definition of Usability [6]

A.2.2. Usability Engineering

The process of building in usability from the onset of the design is often referred to as usability engineering [10], [11] to emphasise the parallels to software engineering techniques. Usability engineering begins with the identification of users, analysing of tasks, and setting usability specifications, moving through to developing and testing prototypes and continues through iterative cycles of development and testing [2]. Gould and Lewis (1985) [9] recommend three key principles for developing usable products.

A.2.1. Early Focus on Users and Tasks

Designers must understand their users, i.e. *user driven*. That is *understanding* potential users and not just *identifying* them. This is partly achieved by understanding their cognitive, behaviour, anthropometric and attitude characteristics, and in part by understanding the work they wish to accomplish. Direct contact with the anticipated end user, as opposed to reading about or hearing about them through human intermediaries or examining their user profiles, interviews and discussions and actual observations could achieve this. They could further become part of the design team from the outset when their perspectives have the most influence as opposed to post hoc as part of an analysis team of end users.

This user driven approach needs to be done prior to system design, as opposed to first designing, presenting, then reviewing and verifying with users. If engineers do not understand the need of users before creating a specification, they risk developing a specification that does not reflect the users' needs [10]. This has become a critical approach as many disciplines are adopting this approach, for example, the American Association for the Advancement of Science and the National Science Foundations have established a project to address the fact that too often technologies are developed for the disabled with no input from the disabled [12].

A.2.2. Empirical Measurement

Two factors are emphasised, actual behavioural measurements of learnability and usability and conducting these experimental and empirical studies early in the development process. This testing is to test the user and not the system. This needs to be explicitly explained to the user participant.

The measurement should not be to build a prototype to determine the performance of the prototype, but rather how people will use and react to the prototype. Hence, it is not a question of “using the prototype to match user requirements, but rather a question of finding out how easily people can learn and use that prototype” [9].

Intended users should see simulations and prototypes to see the real work, and their performance and reactions observed, recorded and analyzed.

A.2.3. Iterative Design

Generally the method for developing a software system would be to build a prototype, code software, and write documentation and review. Finally, should time permit, iterate the design. This approach is not sufficient or acceptable as a design philosophy. Even when implemented, it is usually a single iteration or revision.

Problems must be identified and fixed with regularity; hence designs must be iterative (cycle of design, test and measure, and redesigned). Generally, goals for a system are mentioned; *user friendly, easy to operate, friendly,* etc. What is needed is a process to ensure meeting these outcomes, hence the need for iterative design.

A.2.4. Evolutionary Delivery

An additional approach as mentioned by Good [10], is to adopt an approach, whereby developers start by building a small subset of the system, then “grow” the system, in incremental stages, through the development process. New features are added and existing features refined with successive versions of the system. The prototype evolves into the finished project [10].

The waterfall model and similar models of software design are useful for managing project deliverables, but they do not describe what happens in software design and development [10].

A.2.5. Reliability

Reliability is the question of whether one would get the same results if a test were to be repeated and is a problematic area because of the differences between test users.

Standard statistical tests can be used to estimate the confidence intervals of test results; hence it can indicate the reliability of the size of effects [3]. Figure A.7., shows the confidence intervals for several possible desired levels of confidence [3], the top curve being 95% confidence, the next 90% confidence, then 80% confidence, 70% confidence, etc. This graph is specific for novice users as expert users will have a different graph.

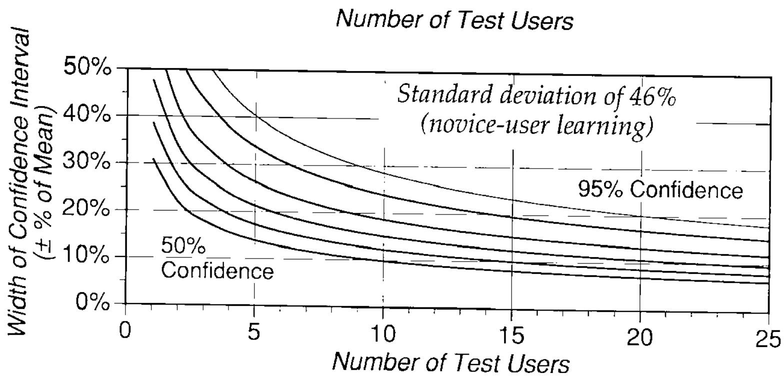


Figure A.7. Confidence Levels for Novice Users

The values on the y-axis should be interpreted as follows: the confidence interval (corresponding to the confidence level of one of the curves) is plus or minus that many percent of the measured mean value [3]. Hence if a desired level of confidence is desired, it can be obtained within a given tolerance, and the number of required users can be found using the graph.

For example, a statistical claim that the 95% confidence interval (curved line) is for the time to perform certain task is 4.5±0.2 (22.5% confidence interval width) minutes means that there is a 95% probability that the true value is between 4.3 and 4.7 (and thus a 5% probability that it is actually smaller than 4.3 or larger than 4.7).

A.3. Usability Testing

Prior to usability testing, the purpose of the testing needs to be clarified, as it will impact the type of testing to be conducted. There are two types of testing, *formulative*, to improve the interface as part of the iteration process. Hence the aim is learn which aspects of the interface can be improved. The second is s*ummative*, where the overall quality is determined [3].

A.3.1. Usability Testing Characteristics

Though there may be variations to the location and manner of the implemented usability testing, all usability tests have common characteristics [2].

A.3.1.1. Improve the Usability of the Product

This should be the primary objective of a usability test, with a subsidiary objective being to improve the process associated with the design and development of the product so as to avoid the same problems reoccurring. This characteristic differentiates it from a research study (investigate existence of a phenomena), or a quality assurance and quality test (determine if the product meets the specifications).

Within the general view of improving the usability, more specific goals can be specified, e.g. user interface through menus. These more specific goals assist in identifying which users are appropriate participants for each test and which tasks are necessary for them to perform [2].

A.3.1.2. Participants are Real Users

If the individuals testing the system are programmers and the system is designed to assist secretaries, the results will be inaccurate. Similarly, the participants need to be at the level of experience of end users, as more experience users may circumvent "minor" problems and lesser-experienced users may cause unnecessary changes and misuse of resources.

A.3.1.3. Participants do Real Tasks

The tasks must be same that the end user will use the device for, whether it is in their workplace or home situation. Hence the need becomes clear to adhere to the principles advocated by [9]. These tasks should have a high probability of uncovering any usability problems that may be apparent.

A.3.1.4. Observe Participants Behaviour

All aspects of the participants must be observed, albeit performance or comments. Opinions of the system are also recorded. The usability test must include the time to complete the tasks with the product and the time to complete questionnaires about the product.

A.3.1.5. Data Analysis and Recommendations

Data must be collected and analysed with problems identified and addressed. All the data must be analysed and the qualitative and quantitative information processed along with own observations and comments. This information is used to diagnose and document problems as well as make recommended solutions to the problem.

A.3.1.6. Results are Applied

As mentioned above, this information can be used to address problems with the product and/or the process. A usability test is only successful if it improves the product tested and the process in which it was developed [9].

A.3.2. Usability Inspection Techniques

Usability inspection is the general name of having evaluators inspect an interface by using a set of cost effective ways of evaluating user interfaces to find usability problems [13]. Several studies have shown that a combination of usability inspection methods and user testing may find most usability problems [14], [15], [16]. There are a number of inspection methods namely [13],

- *Heuristic Evaluation* [17], [18] most informal method and involves having usability specialists evaluate the user interface to determine if usability principles are adhered to (*See Below* for more information). This method is intended as a "discount usability Engineering" method [3], [27]
- Cognitive Walkthrough [19], [20], [21] uses an explicit procedure whereby user's problem solving process is simulated. It then checks if the simulated user's goals and memory can be assumed to lead to the next correct action.
- Formal Usability Inspection [22] uses a six-step procedure with strictly defined roles to combine heuristic evaluation and a simplified form of cognitive walkthroughs.
- Pluralistic Walkthrough [23], [24] are meetings where users, developers and human factors specialists step through a scenario, discussing each dialogue element [13].
- Feature Inspection [25] lists a sequence of features used to accomplish tasks, both simple and complex, in order to assess a proposed feature set.
- Consistency Inspection [26] uses designers that represent multiple projects to determine consistency between their projects.
- Standards Inspection [26] where an expert on an interface standard inspects the interface for compliance

A.3.3. Heuristic Evaluation

This technique warrants further explanation as it is the most used technique. The goal of heuristic evaluation is the finding of usability problems in an existing design, such that they can be addressed in subsequent iterations [28], [29]. This technique was originally developed for evaluators that had experience with usability principles, but were not experts in this field [18].

According to the findings of Nielsen [28], usability specialists find more errors than non-specialists and that those with experience in the applicable interface are more likely to find errors. Furthermore, groups of "double "(experience in both usability and the applicable area of application) and regular usability specialists perform better than groups of novice evaluators.

It was concluded by [28],that between three and five regular usability specialists will recover between 74% and 87% of all usability problems, two or three "double" specialists will find between 81% and 90% of errors and finally, a group of fourteen is necessary to find more than 75% of the usability problems. The results are shown graphically as follows,

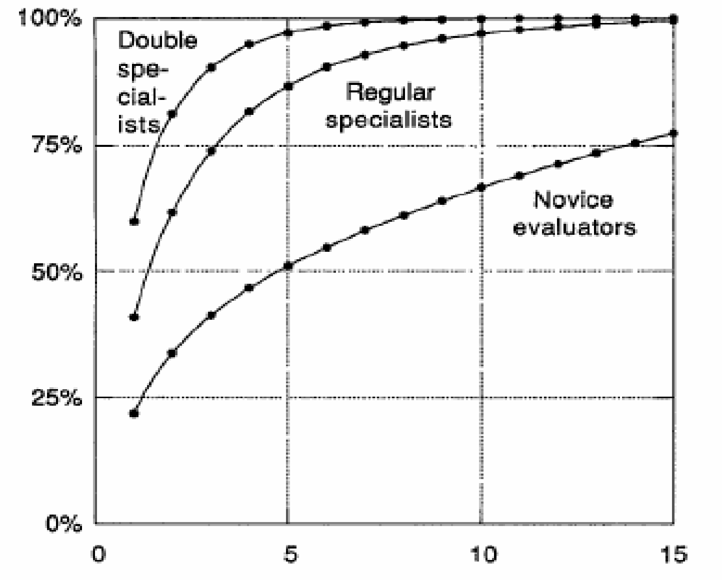


Figure A.8. Problems Found by Different Kinds of Usability Specialists [28]

Previous research has shown that heuristic usability evaluation identifies more of the minor problems associated with a user interface than any of the other aforementioned techniques [30]. Additionally, [28] suggests that heuristic evaluation identifies minor usability problems that are not even seen in actual testing.

It is suggested by [29], that the interface is reviewed at least twice. The first to obtain a general view of the flow of interaction and the general scope of the interface. The second time, to focus on specific interface aspects.

A.3.4. Usability Lab

Usability labs typically have sound proof, one-way mirrors that separate the test team from disturbing the usability participants. Typically the lab is equipped with several recording devices (video cameras, recorders) to gather information during the usability tests. This information, from multiple streams, is then collated into a single resource for further analysis.

A usability lab may be a convenience, but is however not always necessary to conduct a usability test [2], [3]. Should usability become a regular task, a usability lab would be recommended as it yields the following benefits [3];

- Simulate the environment that the user will be using the product
- Record events and collect user information without disturbing the test participant in their tasks
- Members of the test team can easily discuss results without disturbing the test participant.

A.3.5. Pretest Questionnaire

The purpose of the pretest questionnaire is to gather data on the qualifications of the test participant. This data will be used to interpret the data once the usability test is concluded

A.3.6. Posttest evaluation

Once the test has been completed, data is gathered to obtain users usability perspective of the product. It is crucial that during the conducting of this test that evaluators do not attempt to influence feedback from the users.

There are two types of questions in conducting a posttest questionnaire – General and Specific.

A.3.6.1. General Questions

These questions could apply to any product and may include the following [2];

- How do you rate the overall ease of use or difficulty?
- What do you like most/least about the product?
- How easy was it to find information in the help manual?

A.3.6.2. Specific Questions

Evaluators are able to use this to address specific usability issues in their product. Often the designers will know the areas of concern and these areas may be addressed at this stage.

A.3.7. Performance Measures

User performance is always measured by evaluating test users perform a predefined set of tasks while collecting the time and error data [3]. In order for the performance to be clearly measure, the exact goals need to be determined, with even smaller objectives defined. It is important, while evaluating, that a clear definition exists as to when a task starts and ends. These are known as *performance* measures. Typical quantifiable usability measurements may include [2], [3];

- Time to complete a specific task
- Number of errors committed during a task
- Frequency of referrals to help/manual
- Observations of frustration
- Observations of confusion

An additional area is to collect the *subjective measures.* That is people's perceptions, opinions and judgements and can be quantitative or qualitative. For example, asking users questions and getting them to rate on a five point scale and ask about the difficulty. The judgement is then subjective, but a quantitative response is drawn [3].

Some examples of subjective measures are,

- Ratings of ease of learning
- Using the product
- Ease of completing a particular task

A.4. Participant Evaluation

Generally, usability testing is done with one participant working at a time. Help is typically available, but is only used when asked by the participant. This is done to simulate the environment that the product will be used in. The participants need to be encouraged to "thinking aloud" their thought process as they complete required tasks.

A.4.1. Thinking Aloud

This may be the single most valuable usability engineering technique [3]. Essentially it involves a test participant verbalizing their thoughts while they use a product. This allows the evaluator the opportunity to understand how the user evaluates the system and identify its major shortcomings [3]. This method was initially used as a psychological research method [69], but has more recently been used as a practical evaluation tool for HMI's [70].

The problem with this technique is that often users find thinking out loud as unnatural. This may make a user test more difficult to conduct and "skew" results shown under test conditions (slow the process, problem solving abilities may be reduced).

There have been two additional techniques that have proven to be successful [2], *Co-discovery* and *active intervention.*

A.4.2. Co-discovery

Two participants work together and to perform the required tasks. In the process, they will talk to each other. This is more effective as talking to another person is more natural than speaking aloud. Hence, co-discovery typically reveals more information into what the users are thinking and the strategies involved in solving the tasks. Hackman and Biers [38], confirm that co-discovery participants make useful comments that provide insight into design.

A.4.3. Active Intervention

Active intervention is when an evaluator sits with the participant and takes a more active role on the test. These activities could include, questioning the participants actions, probing the participant actions and understanding. This is contrary to the more standard technique of questioning at the end, as during the process, thoughts are "fresh" and more insight is obtained into the participants evolving mental mode of the project. Furthermore, an impression given after a task is complete is often sketchy and may gloss over difficulties that were eventually overcome [9].

Additionally, this is useful as it was found by [29], that most users don't access help, even if they are struggling. It was further found that only 10% of all users utilise the help available [29].

This technique is particularly useful early on in the design process especially when used with prototypes, as it provides a wealth of diagnostic information. This method is not recommended should timing be a crucial factor [2]. In order for this test to be implemented successfully, goals and concerns need to be planned beforehand, as well as the questions, probes and care needs to be taken as not to bias participants by asking leading questions [2], [9].

A.4.4. Training

The essential objective is to allow all users the opportunity to begin testing from the same level of skill or knowledge. A training script needs to be made to ensure that all users receive the same level of training. It is rare that a test is started without training being done first [2].

A.5. Data Analysis

Usability tests generate a large amount of data. Some of the data collected may include the following [2],

- Problematic areas in the system
- Quantitative data on times, errors and other performance measures
- Qualitative data on subject ratings and other questions during after the session
- Participants comments and/or recommendations
- Additional notes from the test team, made during the interview process.
- Background data on each of the users, including experience and applicability in the chosen areas.

This data needs to be analysed to overcome “real” problems that the eventual end user may have. It is recommended that all problems be grouped together to determine the applicability of problems mentioned. This would give a framework for considering the data in totality.

A.5.1. Tabulating and Summarising Data

This will aid in the collecting and analysis of the quantitative data. It is recommended that the information be collated into a spreadsheet as this will aid in the statistical analysis. Statistics that may be valuable include, the frequency of scores, average (or median) of values, amount of variability (range of scores) [2].

A.5.2. Trend Analysis

Usability testing is an empirical evaluation method, hence the problems found will need to be justified by the data collected. Trends will give an indication that the problem is commonplace and not an isolated occurrence. It should be noted that trends might be due to the experience of the users in question.

A.5.3 Outliers

This is a value that is much more different from the other values and could indicate a substantial problem for an (group of) individual. These values need to be taken seriously as when the number of participants is small, the one value may be indicative of a larger subset of eventual users that will experience similar problems. It may be that the outlier is an anomaly, but this can only be validated by iterative testing [2], with persons with a similar background and experience.

A.6. Usability Engineering Background

A.6.1. Integrating HCI and Software Engineering

Human – computer interaction (HCI) may be taught in departments of psychology, cognitive science or ergonomics as well as certain departments of computing [31]. However, many of these students have little or no training in software engineering, hence they lack credibility when they interact with and attempt to influence attitudes and activities of commercial programmers. Additionally, many software engineers have very limited, if any, experience in usability and user needs. This is astounding as between 50% and 80% of all source code is concerned with user interface [32], [33]. Users want systems to work for them and not the other way around [34]

HCI is often only taught at a theoretical level and not implemented in practice. Engineers frequently concern themselves with the operation of the system and see interfaces as a means to an end. Hence usability has suffered and the HCI often been neglected. Additionally, an increasing number of tools make it possible to design a graphical user interface (GUI), (Visual Basic, Delphi, etc.) These tools undermine the complexities involved with the development of a user interface that has sound software engineering and usability principles, i.e. the use of these tools are not governed by usability considerations or even of the principles of software engineering [31].

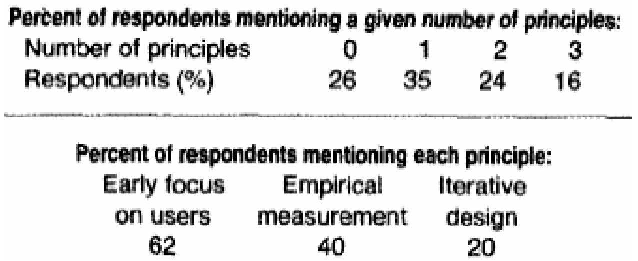
It is concluded by [31] that "*a unification of HCI and software engineering knowledge is required in order that the accumulated expertise of both communities can be effectively employed for the benefit of the end users*". This person be termed a usability engineer and would see the product through from the start to the end of the process. Additionally, as they would posses firm understanding of both the principles of software engineering and an appreciation of the needs of the user, these engineers would be capable of designing a system that users need and deserve [31].

A.6.2. Mis-Understanding of Usability Principles

Usability engineering has been recommended since the 1970's [9], it has however not been well established into the design cycle of most products. To understand the misconception and applicability of usability, *Gould and Lewis* [9], conducted a survey in 1981/1982, during which they had five groups of system planners, designers, programmers and developers detail the major steps to be followed in developing and evaluating a new computer system for end users. The selected individuals (447 people) were attending human factors talk and were the ones designing interfaces based upon usability principles. Hence they provided an excellent indication of the intuitiveness, obviousness, regularly advocated and practised the principles of usability engineering [9].

The responses to basic questions surrounding usability were graded very liberally, with credit given for the mere mention of factors relating to any of the three factors (*See below*) mentioned above [9], irrespective of the lack of completeness or degree of "correctness".

The results of the survey are shown below in Table A.2. [9],



Percent of respondents mentioning a given number of principles:

Number of principles	0	1	2	3
Respondents (%)	26	35	24	16

Percent of respondents mentioning each principle:

Early focus on users	Empirical measurement	Iterative design
62	40	20

Table A.2. Summary of Six Surveys of Opinions of Key Steps Necessary in Developing a Computer System for End Users [9]

The key conclusions of the survey are as follows [9],

- 26% of the individuals made no mention of the fundamental principles mentioned above
- 35% mentioned one of the principles
- Only 2% mentioned all of the principles

Of the individual principles mentioned, the breakdown of specific principles were [9],

- 62% mentioned something about *early focus on users*
- 40% mentioned something about *empirical measurement*
- Only 20% mentioned something about *iterative design principles*.

Appendix B: Prototype Description

B.1. Background

B.1.1. Initial Version - Magnificam

This project was initiated in 2001 as the final year design project to fulfill requirements for a Bsc (Eng)/ Elect degree at the University of the Witwatersrand. The Optometry and Orphomology unit at the Rand Afrikaans University initially requested it. The project was required to create a digital magnification device for people with "Low Vision" using a webcam and enhance the input image. The project was termed "Magnificam" [48], [49], and achieved limited success in terms of functionality

B.1.2. Project History

8.1.2.1. Undergraduate Project

The project was offered in 2002, again to fulfill the requirements of the Bsc (Eng)/ Elect degree. Two groups undertook this project with two students each. The working arrangement was then that the two groups work independently and the results, upon completion, analyzed. Upon successful completion of the project and subsequent qualification, the project was left as the relevant parties took up positions in the working environment.

B.1.2.2. Postgraduate Studies

In the middle of 2003, amid constant consultation with the project supervisor, Professor Barry Dwolatzky, the author returned to continue work on the project as part of a postgraduate dissertation.

B.1.3. Design Goals

The project was given with very broad goals,

- The input device needed to be a low cost device; a webcam was supplied (Logitech Quickcam Pro 3000).
- The Device had to assist "Low Vision" sufferers using a software approach.

With no experience in the field of low vision, in depth research had to be undertaken to obtain an understanding of the current industry standards and customer profile and needs. This would initially be conducted from the specialists (optometrists, etc.) [60], [65], then with the partially sighted themselves.

B.1.4. Software Language

B.1.4.1. Performance Criteria

A number of programming languages were considered, but the criteria was that the selected language needed to be an object orientated language (OOL), and be able to operate in a modular fashion, as well have plentiful resources available. In addition, the selected package needed to have a powerful compiler to handle real time applications.

Many alternatives were considered including Visual Basic, Java, Pascal, C, C++, and Adda. After much consideration it was decided that the language to be implemented would be Delphi.

B.1.4.2. Delphi 6

Delphi is a true object orientated, visual programming environment for rapid application development (RAD) [50]. It reduces the complicated task of programming Windows based applications to the handling of objects in a visual environment [51].

The key component of Delphi is that it is based upon the Object Pascal Language [52]. This essentially incorporates the power of a 32-bit Pascal code compiler [50], while utilizing the functionality and allowing for ease of use through its visual toolbar. The Pascal compiler allows for real time applications and is thus suited to video capture. Features of Delphi include integrated development environment (IDE) [50], ready to use library of functions, classes and components and a suite of RAD design tools [50] [52]. Use of click-and-drop design to allow for automation of repetitive programming [50], automatic creation of a native code compiled executable (.exe) upon the building of a project [50].

Delphi hence met the requirements as stipulated above In addition, Delphi offers a more user-friendly environment with powerful syntax and easily accessible libraries, tutorials and bulletin boards.

B.1.5. Design Process

In the waterfall model [Royce, 1970], the design of the system is compartmentalised, with verification and validation being done near the end of the stages (see Figure B.1), much like a quality assurance test. Once the verification is complete the designer moves onto the next stage. This process would only involve the user at the end of the process and not throughout; hence most of the work would not be able to be evaluated by eventual users until the end. This does not fulfil the basic requirement for usability testing, i.e. user-drive.

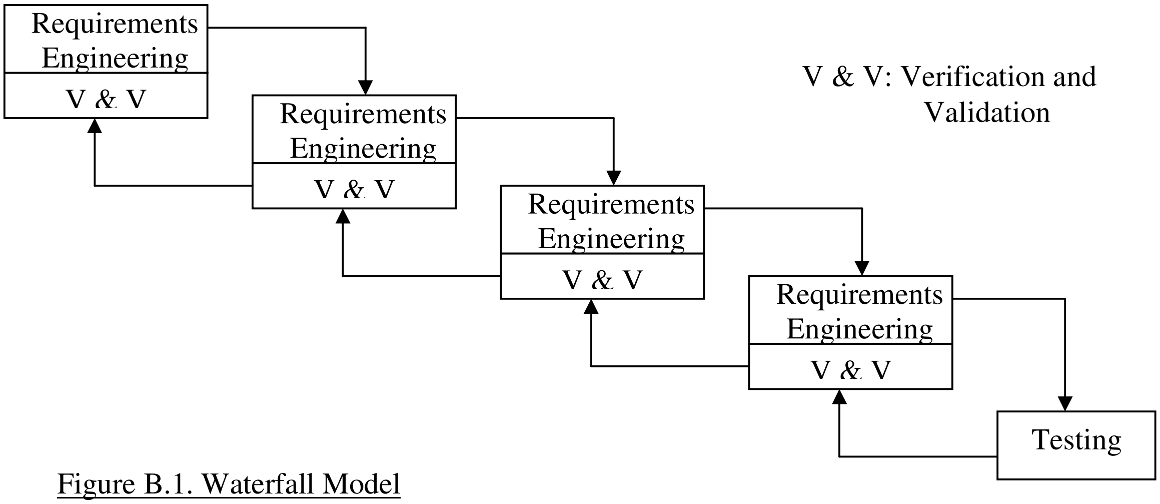


Figure B.1. Waterfall Model

As this device was to be used primarily for the partially sighted, it was realised that the design had to be tried out with usability specialists and users at an early stage. These changes needed to be implemented and more user data to be gathered. Hence an evolutionary delivery was used [10], which is an extension to iterative design or incremental development [10]. An initial prototype was developed, whereby new features were added to the initial prototype and existing modules were refined or discarded.

Additionally, once it was established that Delphi was the language to be used, it was decided that in order to maximise the power of Delphi a modular approach was to be implemented. This approach would give a number of benefits,

- More efficient usability studies into different modules
- Easier design and fault tracing
- Easier expansion for future modules
- Customization for different end users

Each module, where possible, would be programmed within its own form and would then be grouped together in a project group. The individual modules would be called by the corresponding call functions when activated by the clicking of the appropriate button(s) from within the main form. These modules would be able to be run separately by the execution of the applicable executable files.

The modules were, where applicable, based upon open source material to reduce the effective time to create the initial prototype in line with the evolutionary delivery model. Where Open source modules have been used, the original authors have been credited in the references.

B1.6. Principle of Operation

The principle of operation of the device is that a low cost device, typically a web camera (webcam), would be used to stream images to a computer. The written software would then extract the images which would be manipulated using software and mathematical techniques with the results outputted to the computer screen.

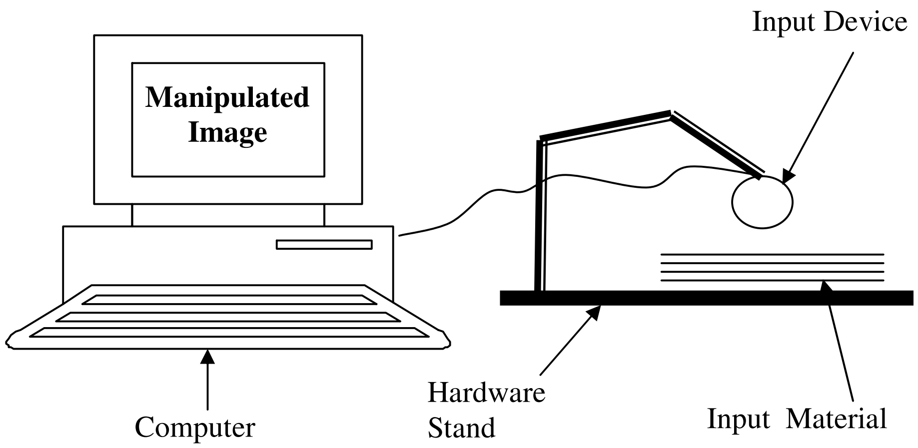


Fig B.2. Operation of Device

B.2. Initial Prototype

The following three modules were the minimum that needed to be implemented to compare the functionality as offered by other devices on the market [60].

B.2.1. Get Video Module

In order to meet the requirements, it became necessary to incorporate a module capable of capturing video. This module should be capable of recording a live video stream then capture a snapshot of a chosen image. This image should ideally be able to be saved for further processing (*see B.2.2.Snap Shot Viewer).*

In order to program the video module, the following Delphi source files (also termed .DCU files) were used, *DirectDraw* [53], *DirectShow* [54], *DirectSound* [55], *DirectXGraphics* [56], *DXCapture* [57], *DXCommon* [58]. These source files are based upon DirectX 7.0 and/or DirectX 8.0 developed by Microsoft. Hence no modifications were made to these files, these as this would infringe upon licensing and copyrights.

B.2.1.1. Capture Device

The video module has the option of allowing the user to select the video device that is preferred. This allows for multiple input devices and the user now has the preference to decide upon the best device for their applications. For example, one webcam may be more suited for close image capture (due to the barrel effect[1]), whereas another may be more applicable for video streaming. The same applies for an audio input, as the webcam has a built in microphone. This was done by using the DXCapture source file.

B.2.1.2. Saving Images

As mentioned above, it was required that the video module be capable of taking a snapshot of the images captured by the webcam. These snapshots can be captured into either a JPEG of Bitmap, depending on the requirements of the user. The JPEG image is of slightly lower quality due to the compression ratio, but takes up less storage space. It is however not recommended as the other modules only work on a bitmap image.

It was decided that the best way to save files would be to save them under incremental filenames, i.e. “capture0”, “capture1”, “capture2” etc. This would reduce the need to save the files under a user-defined filename since for a VIP; this would present an unnecessary problem. Each time the video module was launched, the filenames would be saved from “capture0” again, overwriting the previous screenshots by the same name.

B.2.1.3. Other Functionality

The video module allows for the recording of the image stream into an AVI format. Only one instance of a video capture can be saved at a time. To incorporate the different capturing formats, an option is allowed to define the number if frames captured per second, as a video stream is essentially a number of snapshots that are

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[1] Barrel Effect, caused by the curvature of the video lens, resulting in curving or “barrelling” of an image.

shown in a sequence that simulates motion. Hence, the option to define the number of frames will determine the size of the AVI file.

B.2.2. Snapshot Viewer Module

Once the video module captured the screenshot, it was vital to incorporate a module able to enlarge the captured image. This module was not limited to a maximum possible magnification rate, as every click caused a magnification of 1.25 the current picture size. It was noted, however that as the magnification rate increased, the resolution of the image became reduced. The DsZoomNavigator [59] .DCU file was used in the programming of this module.

Based upon the built in filter options of DsZoomNavigator, only files with .bmp file extension may be opened. Once the file has been opened, a preview button becomes available to ensure that the user will be opening the correct graphic. The navigator is used to give a reduced picture of the actual zooming module allowing the user to determine the position of the magnified image relative to the original image.

B.2.3. Invert Image Module

Upon consultations with [60] and [65], it was recommended to attempt to incorporate a module capable of inverting the colours of text, thus producing a white on black instead of a black on white as this increased the readability. This would produce a “chalk board” effect.

B.2.3.1. Procedure

This module needed to read into memory each pixel of the bitmap and then invert the image. This was achieved by creating an array into which the pixels could be read and a pointer to each element in the array (i.e. each pixel), for further processing. Before the inverting process could commence, the loaded graphic needed to be interpreted into a suitable manner

B.2.3.2. Conversions and Inverting

Graphics can be interpreted in a number of colours ranging from 2 bits (black or white only), to up to 32 bits in Delphi using the “pf” command. This command determines the manner in which each image is displayed and how the pixels of the bitmap are stored in memory [61].

Once this was achieved, the images colours were inverted by use of the scanline command and knowing the number of colours in a pf24bit format. The scanline command in Delphi is used only with device independent bitmaps for image editing tools that do low-level pixel work [61]. Each colour in the colour spectrum is composed of the three primary colours- red, green and blue. Hence an inverted image can be obtained by setting each of these colours equal to the inverse of itself. This can be done by either specifying 255 minus the primary colour itself, or “not-ing” (logical operation) the primary colour.

B.2.4. Splitter Module

This section is an addition to the previous modules and it is here that engineering principles are implemented in an attempt to work around the loss of central vision loss.

Upon further analysis of the effects of macular degeneration, it was felt that perhaps one of the most functional and practical manners to deal with the problem would be to work around the problem itself. Macular degeneration and other central vision disorders remove the central portion of the VIP's vision. Hence it was felt that if it were possible to remove a "strip" of text, either horizontally or vertically from the text, this would reduce the problem faced by VIP's. It is emphasized that this module is recommended only for the viewing of text and not graphics. A separate module is recommended (*see, B.2.5. Wraparound*), see below be used for graphics.

B.2.4.1. Rationale

This module was added in response to the statement made by [9], in why usability principles are undervalued, "*Many users have never considered alternate or improved ways of performing their tasks and are unaware of the options available for a new design*" [9]. By implementing this module, it is hoped that macular degeneration sufferers will have another way to compensate for their loss of central vision.

B.2.4..2. Horizontal and Vertical Splitting

To implement this module a new image needed to have a canvas with the size of the removed piece larger than the original image. This was achieved by creating a temporary bitmap image with the canvas of the required size. The extra canvas strip that was added was either positioned at the bottom (for the vertical split) or at the right (for the horizontal split). Once this was achieved, the original image was subdivided into 16 quadrants as follows (Figure B.3.),

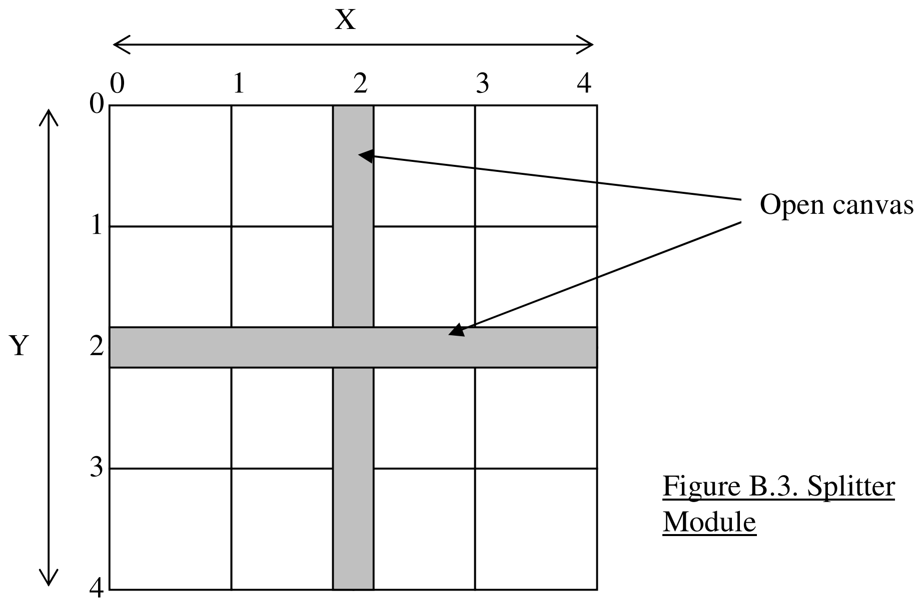

Figure B.3. Splitter Module

The area located on either side of the central strip numbered "2" needed to be copied and placed either right (horizontal split) or below (vertical split) of the central portion. This was achieved by the use of the "copyrect" and "rect" commands in Delphi. The "copyrect" function allowed for a rectangular shape to be copied to a destination pre-determined by the given co-ordinates. These co-ordinates were specified by using the "rect" function and had to be passed the following parameters in the correct sequence-

"left", "top", "right", "bottom". Once this was achieved the bottom and the top (or left and right) sections simply needed to be anchored in the correct position to allow the bitmap to be shown correctly.

B.2.5. Wrap Around Module

This module was essentially an extension of the splitter module mentioned above. Using Figure B.4., below and using the same programming philosophy as above, this module was created successfully. The first and last rows needed to be copied exactly as shown into the new canvas, while the central squares needed to be "squashed" into an area half the original size. Hence the area that is shaded will be reduced in size.

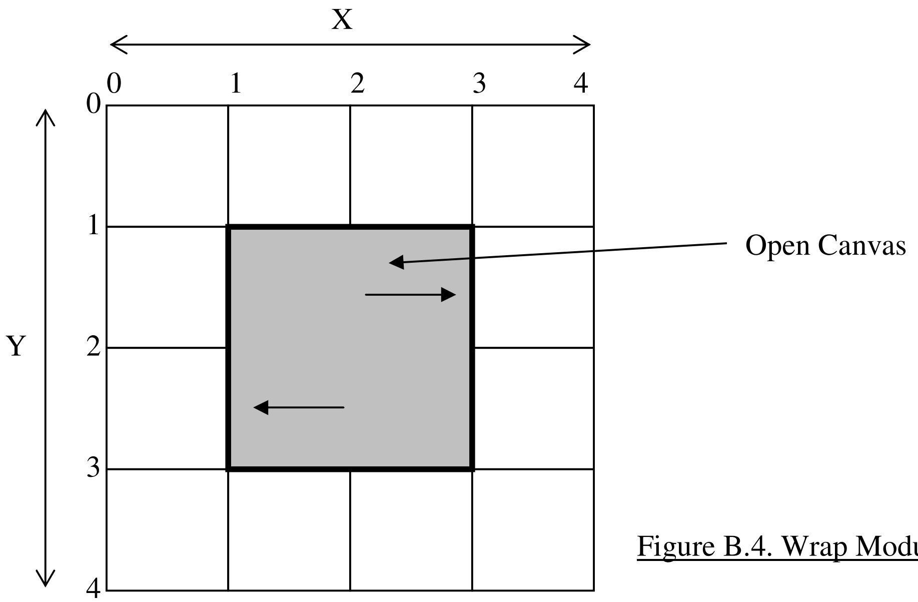

Figure B.4. Wrap Module

This module is only recommended for the viewing of bitmaps, as text would be distorted and compressed adding unnecessary complications.

B.2.6. Configuration Module

Once the above splitter and wrap around modules were completed successfully, it was felt that in order to achieve optimum results, a configuration module was needed to maximize the effect of these modules. This was since, the severity of macular degeneration varied from patient to patient depending on the deterioration of the cones and rods of the macular that control vision.

The interface was designed to be as simple, but as functional as possible. This was achieved by requesting the patient to select the greatest viewing area that was unaffected. Upon the selection of the area, the size of the viewing area was written to a file called "revision.conf", which was to be opened and the variables copied to be used for the above two modules.

B.2.7. OCR and Speech engine integration

An additional module was added to the initial prototype that incorporated two smaller "building blocks", an optical character recognition (OCR) module and a read back module. This added additional functionality, albeit at a very premature stage of its development.

B.2.7.1. Optical Character Recognition (OCR) Module

The programmers did not write this module but a third party program was used. Transym Computer Services LTD developed the OCR (TOCR) engine used [73]. The program is a trial version that allows for 100 pages to be scanned. Hence, no license agreements were violated nor any copyrights broken. In the future our own OCR engine would be developed. TOCR was called by using the shell execute command and supplying the necessary parameters to launch the program from within the main form.

In order to use TOCR, the chosen .bmp file must be loaded then the X and Y dpi (dots per inch) need to be specified for the program to be able to compare the characters with those stored in its libraries. Once this has been achieved the extracted text can be saved in a text file for further processing.

8.2.7.2. Read back Module

This module uses Microsoft Speech Application Interface Software Development Kit (SDK) and the associated text-to-speech engine [74]. In order to develop a module able to read the text that was converted from the picture captured from the webcam, Microsoft Speech Application Programming Interface (SAPI) was used which allows for use with Microsoft Windows or Windows NT operating systems [74].

The read back module allows for the computer to read any text that was entered into the text box or any text file that is loaded into the box. The text that was extracted from TOCR was used to read back from the captured image

B.2.8. Hardware Stands

Even though this project was essentially software based, a certain degree of hardware needed to be implemented to allow for the VIP the best use of the available software.
A prototype was developed which would allow the user the ability to manoeuvre the webcam relative to the viewing area. Several prototypes were developed that served this purpose, but were based upon different philosophies

B.2.8.1. Prototype I

The first prototype's concept was that a rigid stand would offer the best solution to holding the webcam. Hence it incorporated two vertical beams to allow for vertical movement and a two "cross beams" to allow for horizontal movement. The combination of these then catered for complete movement in the two dimensional X-Y plane. The holder was placed upright as suggested by [60], as some VIPs would require a stand capable of viewing upright images, such as a teacher in front of a class of students.

B.2.8.1.1. Vertical Beams

Mounted on the vertical beams was a straight "track" onto which "teeth" were cut. The "cross beams" were mounted onto the vertical beams by means of a holder that incorporated circular gears. The system of gears and of the vertical track was used in conjunction to ensure that the vertical movement was smooth and that slipping did not occur. A gear ratio of 1:1 was chosen so that the exact movement up the vertical beam would match the rotating motion of the gears.

B.2.8.1.2. Cross Beams

Two beams were used to support the holder that housed the webcam that were used to eliminate the rotating action that would exist should only one beam be used, as a result of circular motion. Each beam would counter the rotating action of the other and hence provide stability to the housing. Other options that were considered were to use a single circular vertical beam through the centre of the holder. This was not implemented as upon testing it provided a more "bulky" and ineffective solution. The other option was to use square beams as opposed to circular beams as this would negate the rotational movement.

B.2.8.1.3. Housing

The housing of the webcam was manufactured from circular tubing available from the Genmin laboratories. The length of the housing was chosen to allow for the easy insertion of the webcam and the dual crossbeams would then hold the webcam in place. A perspex lens was cut that would hold the webcam lens in position and ensure the upright positioning of the webcam. Slots running along the horizontal axis of the housing were bored out to allow the housing to be easily mounted upon the crossbeams. These slots were oversized relative to the cross beams to allow for easy horizontal movement by allowing the housing to slide across the horizontal beams.

B.2.8.2. Prototype II

The second stand was a lot simpler in design and was manufactured with versatility in mind to oppose the complexities of Prototype I. This flexible approach allowed for the webcam to be pointed at any object in three-dimensional space as opposed to the first that only catered for two dimensions. It was also intended with portability as a design consideration.

B.2.8.2.1. Stem

The stem attached the webcam to the base and also allowed for wiring to be easily placed to allow for lighting (see *B.2.9 Lighting,* below). The stem was constructed from three single metal reinforcing wires that were then braided together. A lighting wire was then threaded between the braiding and the entire stem then encapsulated in a plastic enclosure which was heated to ensure that the internal contents were protected.

B.2.8.2.2. Holder and Base

The holder was simple and consisted of the internal three metal cores spread apart to hold the webcam. These wires were then coated to ensure the webcam and it's casing was not damaged.

The base was manufactured out of tabletop board and needed to be heavy enough to hold the entire weight of the webcam and the webcam's USB wiring. The underside of the base then had holes drilled to hold the stem and lighting wire. The entire underside was then held in place with a perspex covering.

B.2.8.3. Prototype III

A third prototype was designed and built based upon the operation of a desk lamp. The globe holder was removed and a similar housing to that mentioned above (B.2.8.*1.3.Housing*) was used to house the webcam. This configuration was then mounted upon a base similar to the one constructed for Prototype II. The original lamp wire was left to accommodate future lighting.

B.2.9. Counter Acting lens

As stated above, the barrel effect proved to be a problem encountered in the design of this project. This was since the barrel effect warped the images (letters and sentences) and caused additional unnecessary problems.

The internal lens of the Logitech Quickcam Pro 3000 is a converging lens and the barrel effect was an extreme hindrance when the image to be magnified was placed well within the focal length of the webcam. To reduce this focal length and possibly eradicate the barrel effect a counter acting diverging lens with the same curvature would need to be manufactured.

Upon consultation with a contact lens manufacturer [62], it was found, by using a radio scope, that the internal lens was a combination of four internal lenses and not one as previously thought. These lenses varied in the amount of power and curvature, but could not be measured individually as the internal lens of the webcam could not be disassembled. A lens was then manufactured and delivered with an overall diameter (O.D) 10.5 mm and focal length along the Rx plane.

B.2.10. Lighting

Upon closer analysis of the currently available low vision aid systems [60], [65], it was noted that all of them had a lighting system that increased the readability of text. This was essential as it improved both the contrast and readability of the image below. This was especially true if the material was text based.

A 45-Watt energy saving globe was attached to prototype III, but as the light source was only originated from one side, the extra lighting caused more shadows on the text. This could not be compensated for due to the construction of the chosen prototype.

Appendix C: Usability Inspection

C.1. Usability Inspection

Once the initial stage of the evolutionary process of the prototype was complete, it became necessary to conduct a usability inspection. Throughout the design process, a user centric approach was adopted to keep user needs in mind. Once this was completed, a heuristic approach was chosen. This was as this was seen as the most effective method when resources are a minimum (see above) [18]. Additionally, specialists in the field (e.g. Optometrists from RAU and specialist at SANCB) were willing to participate and add feedback. This coupled with their experience in the low vision field and knowing the end users needs makes them invaluable in the usability evaluation phase. Furthermore, the specialists from the SANCB were also partially sighted (Macular Degeneration) that allowed them to experience the device from an anticipated end user's perspective.

They could along with the authors usability experience, amount to being a double specialist [28]. The information and feedback obtained here would be used to iterate the design to make it more usable [28], [29]. The process was repeated with subsequent iterations and additional data obtained. What follows are the key findings from the initial prototype.

C.1.1. General Operation

The opinions from the double specialists were comprehensive and upon further initial evaluation with potential end users most of usability problems were located,

- The Interface involved too much user interaction, i.e. button clicking. This detracted from the overall functionality and reduced the user centric approach. This involved the process of initiating the camera, taking a picture, and editing using the functions, with each process requiring locating the appropriate module, initiating the procedure, closing the window and repeating the sequence if desired.
- The opening and closing of appropriate files to view and process was complicated and needed to be reviewed. This was complicated in having to find the location of the desired file.
- Real time operation may require resources that are not available on "older" computers.

C.1.2. GetVideo

- The image stream that was captured was not truly "real time". A slight delay was apparent that might be an inconvenience for VIP's.
- The viewing area needed to be maximised, as magnification was the key criteria for a good product.
- The method of saving files in the form of "capture0", "capture1", etc. was cumbersome
- The option to save the image stream was void and should it ever be initiated created too large a file, creating a misuse of resources.
- The use of the built in driver's functions (brightness and contrast control) was cumbersome and barely utilised, as it required fine adjustments to be made.

C.1.3. Snapshot Viewer

- The resolution of the captured image dropped off with increased resolution.
- Even though the preview pane was useful, it occupied crucial viewing space of the image.

C.1.4. Splitter Module

The idea was unique, but the vertical split could be complicated, as it requires a change in mindset, whereas the horizontal split is akin to a paragraph split.

C.1.5. Wrap Around Module

Although the theoretical implementation of this module was correct, the practical implementation was ineffective. This was that as the central portion was "squashed" into a smaller area (half the canvas) and this distorted the viewing of the image.

C.1.6. Configuration Module

This module needed to be evaluated and possibly re-engineered as it again detracted from the overall appeal of the operation.

C.1.7 Hardware

C.1.7.1. Prototype I

This stand proved to be very ineffective as the complexity involved in the vertical movement of the webcam was not fluid, because of the gearing involved. The horizontal movement was similarly affected

C.1.7.2. Prototype II

Although this stand was suitable for most situations, it was felt that the stand was not rigid enough and when the webcam moved it would lose focus, the holder would typically only settle within a few seconds. This would translate into unnecessary movement of the image and cause additional unneeded problems.

C.1.7.3. Prototype III

This Prototype proved to be the most effective as it was held in the horizontal position that allowed for the easy placement of text beneath it. It also allowed for writing below the webcam. The head could also be swivelled to allow the VIP to monitor external vertical activities as recommended by [60]. The only shortcoming for this design was its aesthetic appeal.

C.1.8. Counteracting Lens

The lens provided little effect to reduce the barrel, effect. The trade-off was that the lens reduced the light that was available through the aperture to the internal lens(es), which essentially compounded the lighting problem (see *C.1.9. Lighting)*.

C.1.9. Lighting

In varying light conditions (lack or excess), the prototype performed extremely poorly. The placing of light was crucial as an even light was needed or shadows would be cast that would compound the problem.

C.2. Evolutionary Delivery

Once the first iteration of the evolutionary design was complete [10], it became necessary to revisit the prototype operation with subsequent usability inspection results as a guideline. Successive iterations were performed adding additional functionality and refining existing modules. Following the usability inspection results mentioned above, the entire process was to be redesigned. This would ensure a more user-centric program as to fulfil the criteria of a "usable" product.

C.2.1. Human Machine Interface

The design process was re-engineered, with each module now being written as a sub-procedure within the program as opposed to separate forms that were initiated by button clicking. The HMI (Human-Machine Interface) was thus redesigned, in that instead of the interface being button operated, the user was now able to access the functionality using various mouse operations. Once the call procedure was initiated, flags were toggled to activate the desired procedure. The following table depicts the available operations.

Action	**Feature**	**In module**
Left mouse click	Reset the image	*ImageMouseDown*
Middle mouse click	Grey Enable/Disable	*ImageMouseDown*
Left mouse double click	Exit Webcam capture	*ImageMouseDown*
Right mouse double click	Image Enhancement	*ImageMouseDown*
Middle mouse double click	Change split mode (H/V)	*ImageMouseDown*
Right Mouse Click	Invert Enable/Disable	*ImageMouseUp*
Mouse wheel	Zoom in/out	*FormMouseWheel*
Mouse wheel + right button down	Split extent change	*FormMouseWheel*

Table C.1. Mouse Functions

The operation of having to save an image, then reopening it with the appropriate module was thus negated and the entire process became smoother. In effect, the program was initiated at start-up and all functions were accessed via mouse commands.

C.2.2. Video Streaming

The prototype's core components, the video streaming process, was re-engineered and re-programmed using an alternative to DXCapture file, DSPack[1] [63]. Additionally DSPack is distributed under the (Mozilla Public License) MPL 1.1. This addressed three areas of concern of the initial prototype, the program did no longer require as much resources, the speed of response was improved and full screen functionality was possible. Key factors were,

- The viewing area was maximised allowing for a full screen image to be seen.

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[1] DSPack is a set of Components and class to write Multimedia Applications using MS Direct Show and DirectX technologies. DSPack is designed to work with DirectX 9 on Win9X, ME, 2000, and Windows XP operating systems [63].

- Instead of having to first save an image for processing, the current video frame was passed to a buffer for further processing. This reduced the operating time and required resources.
- The ability to record an image stream was removed, as it was inconsequential.
- Access to the built in driver's functions was removed. This was as additional modules were created to cater for the automatic correction of brightness and contrast.

C.2.3. Zoom Module

Although a key component was to remove the preview pane, which was achieved; the more pressing matter was that the clarity of the image diminished with an increase in the zoom. This problem was found to be an issue with the input device (initially a webcam) and not the internal workings of the program.

The image was placed at the centre of the screen and any magnification was done for the centre of the image. Should another portion require to be magnified, the source area needed to be repositioned in the centre under the viewing area.

C.2.4. Compensation Module

The functionality of the split module remained the same although a key difference was that the split was now dynamic in nature (i.e. it could be modified from within the split function, as opposed to "pre-configuring" via the configuration module).

The configuration module and wrap around module were thus rendered void and removed.

C.2.5. Hardware

The previous stands were used as a basis for the final stand. Initially a technical specification needed to be drafted and submitted to the external company selected to manufacture the device. This specification was evaluated by the company consultant and recommendations given to improve the operation, aethstetics and construction.

The basic construction was made from Aluminium with the following dimensions; 145mm height, 360mm width and 270mm depth with a weight of approximately 0.8kg. Figure 12, depicts a CAD (computer aided design) drawing that was created of the stand.

The operation of which was that an arm was mounted above a viewing surface onto which the material to be viewed was placed. This arm could then be moved into a vertical position to comply with the recommendations of [60]. The stand was made to an industrial standard and machine cut, hence it has a very "commercial" feel and is aesthetically appealing and has been very well received [60], [65].

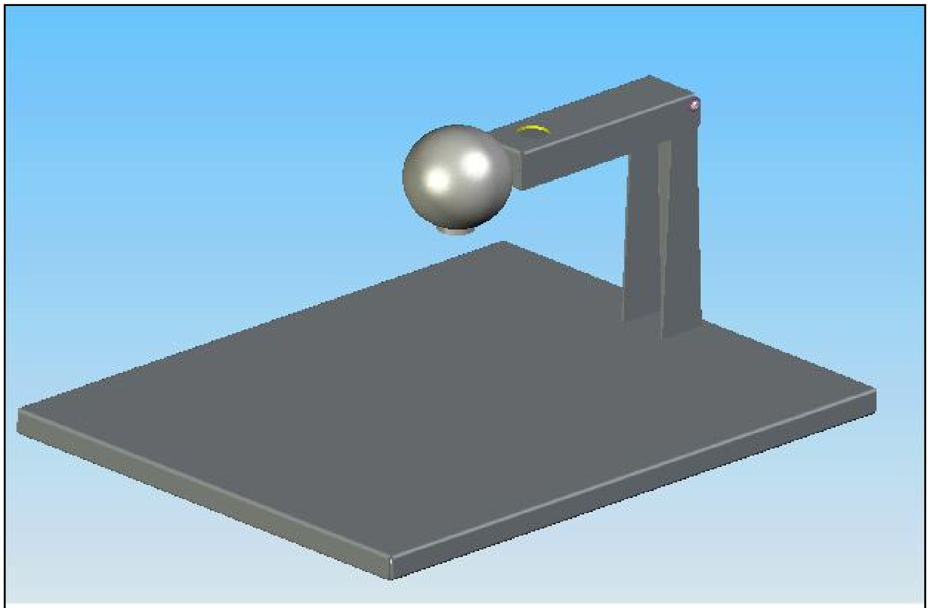


Figure C.1. Final Hardware Prototype with webcam

C.2.6. OCR and Speech Engine integration

It was decided that although the OCR and speech engine integration showed promise, efforts needed to be made to “streamline” the evolutionary process so that the more critical modules were completed first. Should it be possible, this would be revisited because of the potential that was shown with its application.

C.3. Product Evolution

Once the “basic” functionality was completed, additional modules were added to assist the VIP in their daily operation. These included user defined modules (greyscale, high contrast and zoom enhancement), automatic modules (luminance level and glare control), and hardware modification.

C.3.1. Greyscale

The initial prototype was able to convert the image into greyscale by using the built in driver options. The difficulty was that in order to convert to greyscale, the driver options first needed to be accessed and the correct function accessed. This proved to be a complicated task, as most users were not aware of this functionality.

This module thus allows a user to easily convert and image by using mouse functionality. Once activated, the image pixels will be examined a row at a time and will be converted from its RGB (red, green, blue) value to the corresponding grey value.

C.3.2. High Contrast

This module was included as it was noted from [60], that many alternatives have a function that converts the image into either “pure white” or “pure black”. Since the operation only operated on greyscale images, the image first needed to be converted to greyscale using the module above (*C.3.1 Greyscale).*

Once this was done, a threshold value was obtained for 40 segments in each line, by using the maximum and minimum values for brightness and luminescence. Hence a dynamic value was obtained, as various parts of an image, or images, may have different graphic properties. The image is then processed in relation to this threshold value. This approach was held in high regard as the reading process was easier for VIP’s [60], [65].

C.3.3. Zoom Enhancement

This module uses a discrete convolution algorithm to increase the resolution of the image by a factor of two. The algorithm was adopted from [64]; a report regarding image enhancement in hand held devices. The image is first enlarged by a factor of two, and then each pixel value in every row is recalculated based on a *sinc* function weighted average. A pixel in an even column position is averaged using three pixel values from the original image (from itself, the pixel on the left and from the one on the right). In the even position the original pixel value is in the centre of the *sinc* function weighting average. The odd pixel is calculated similarly, except that the *sinc* function averaging is shifted. The distance of the weighting values sampled from the *sinc* function are dependant on the resolution increase factor (two in this case) [64].

This process is then repeated for each even and odd row in order to generate the enhancement on the vertical scale as well. This creates a higher resolution image, instead of a simple enlargement, where no advantage of the extra pixels is taken to improve visual clarity of the image.

C.3.4. Luminance Level

This automatic module can be used to improve the appearance (brightness and contrast) of an image in poor light conditions (overexposed or underexposed). A minimum and maximum reference threshold level is determined from the various lines in an image. These lines are then changes according to the deviation from this threshold.

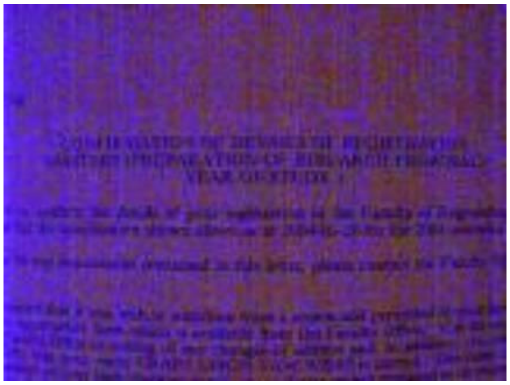
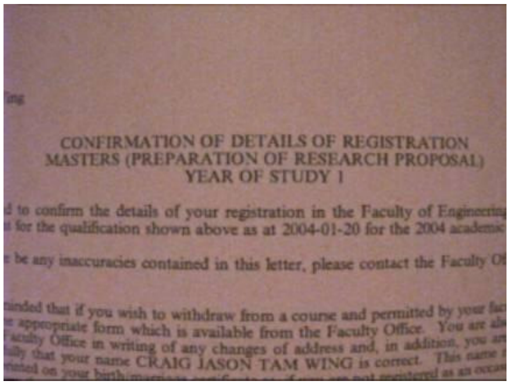


Fig C2. Windows built in webcam



CONFIRMATION OF DETAILS OF REGISTRATION
MASTERS (PREPARATION OF RESEARCH PROPOSAL)
YEAR OF STUDY 1

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Fig C.3. Revision webcam

This module can only be used in situations where image data is available, i.e. in a completely dark surrounding; this module will not operate, as the initial image does not have sufficient "starting data". In these situations, the image will remain unusable.

C.3.5. Glare Control

The difference for this module would be where a portion of an image is underexposed or overexposed, as opposed to an entire image being subject to poor lighting conditions. The same operation as above is used (threshold is analysed), except a global threshold is calculated as opposed to a line threshold.

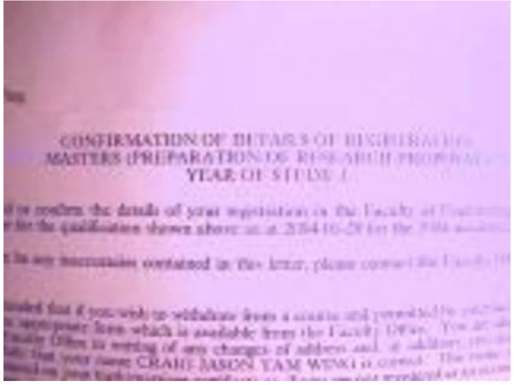

Fig. C.4. Windows built in webcam

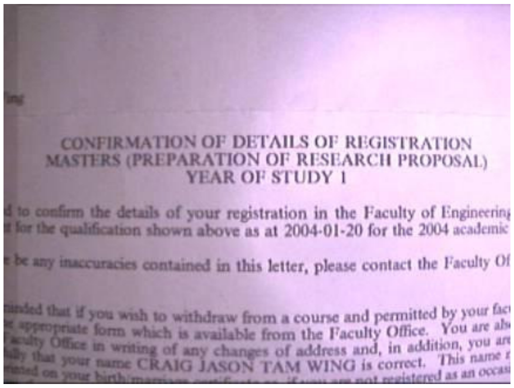

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Fig. C.5. Revision webcam

C.3.6. Combination of Modules

Whereas previous iterations of the program were unable to utilise a combination of modules, this version allows users that functionality. This is to cater for the varying specific requirements of individual users. The toggling of "flags" in the program does this. Hence when different flags are set, different functions can be used. An example would be to use the following, zoom, greyscale and split, while luminance levels are run automatically, to cater for the needs of macular degeneration sufferers.

C.3.7. Capture Device

One of the initial product goals defined at the onset of the project was that *the input device needed to be a low cost device*. Hence, initially a webcam was used as it met the required cost limitations. However upon consequent reviews, it was concluded that the poor image quality was attributed to the input device, the webcam.

It was found that an inherent problem with webcams in general is that the resolution is kept at a maximum of 640x480. It is unknown why, as it is possible to capture a still image at a much higher resolution, the streaming resolution is kept at this maximum.

C.3.7.1. Logitech Quickcam Pro 3000

In addition to the above problem, it was noted that the Logitech Quickcam Pro 3000 exhibited severe barrelling effects (*see C.3.7. Capture Device)*. Based upon the usability inspection, it was decided to substitute this webcam with alternatives to determine if a difference could be noted in the image quality.

C.3.7.2. Logitech Quickcam Pro 4000

Even though the logical progression would be to examine the performance of the "next model up", this replacement was enforced as it was noted that the Logitech Quickcam Pro 3000 was discontinued and replaced with this model [66]. This information was ascertained from one of three vendors of Logitech Devices to South Africa [66].

The performance of the Quickcam 4000 was similar to the 3000, except that less barrelling was found. This was extremely favourable, but the image was also more "blurred" around the peripherals. In addition, the image was larger than for the Quickcam 3000.

Other webcams were considered, but upon consultation [66] and examination, it was found that the image quality was equal or less than the Logitech 4000.

C.3.7.3. Closed Circuit Television

An alternative to the webcam was a closed circuit television camera (CCTV). It was suggested by [65] that a CCTV be used, as there are many instances where this technology was applied with limited success. In all the previous situations, the CCTV is connected directly to a television set via its RCA[2] BNC[3] connections. However interfacing directly with a computer would prove to be more intricate, and the CCTV would require an external power source[4].

Computers are able to accept external video connections via the S-Video, analogue connection found on some video cards. This connection is not compliant with the RCA connections found on CCTV cameras. Upon further consultation [67], it was noted that CCTV's could be connected to a computer via a dedicated card. This card would be able to host from 6 connections upward. The processing required was extensive and it is recommended that a Pentium IV be used to handle with the

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[2] Derived from the Radio Corporation of America (RCA)

[3] Bayonet Neill-Cencelman (sometime incorrectly referred to as the British Naval Connector) is a type of RF (Radio Frequency) Connector

[4] Webcams derive power via the USB port, +5V supply

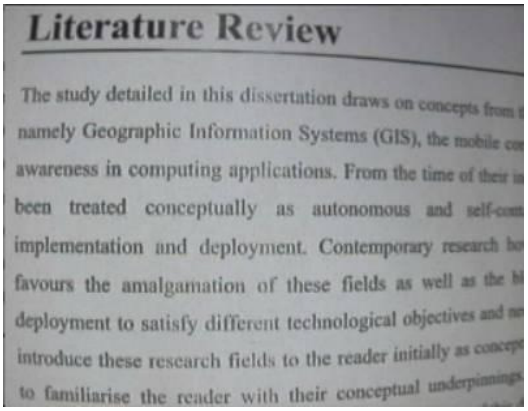
operation. The implementation of this type of device would typically be for security applications (e.g. monitoring).

This was unsatisfactory as the price would be beyond the project goals (*Low cost Device*). In addition, a single input needed to be connected as opposed to several, and the dedicated processing required was unacceptable.

Upon further research, it was discovered that a component existed that would allow the conversion from a computer's USB (universal serial bus) (1.1. or 2.0) to the applicable RCA connections [68]. The USB 2.0 conversion was chosen as this incorporated newer technology and the speed of response (25 FPS) would be faster than the older USB 1.1. This component was the *USB 2.0 Video Grabee X* and derived its power directly from the USB interface.

The connection was still not complete and an additional interface was needed to convert the RCA connection output to the input of the CCTV. A unique cable needed to be manufactured that would meet this requirement. This cable converted the male RCA connection to a female RCA BNC connection and also as an extension for the required external power source

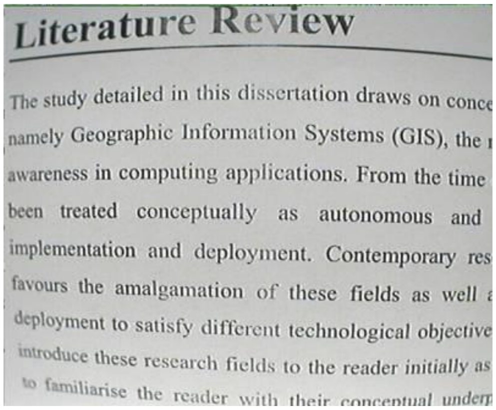
The results found (picture clarity and resolution) were favourable once a suitable CCTV was chosen (See Fig C.6. and C.7, below). The specifications of the selected CCTV can be found below, *C.3.7.4. CCTV Camera Specifications Configuration Specifications.*



Literature Review

The study detailed in this dissertation draws on concepts from
namely Geographic Information Systems (GIS), the mobile
awareness in computing applications. From the time of their
been treated conceptually as autonomous and
implementation and deployment. Contemporary research
favours the amalgamation of these fields as well as the
deployment to satisfy different technological objectives and
introduce these research fields to the reader initially as
to familiarise the reader with their conceptual underpinnings.

Fig. C.6. Webcam Image



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to familiarise the reader with their *conceptual*

Fig. C.7. CCTV Image

Upon further consultations with [60] and [65], the following was noted in the next iteration of the evolutionary design;

- Even though the image quality was significantly improved, it was still not sufficient as the image quality was reduced at higher zoom rates
- The image was placed closer than the recommended focal point for the CCTV, hence optimum performance was not possible.
- The image captured via the CCTV was an analogue signal and was converted to a digital image. This resulted in an additional time delay in processing of images.
- The connections required (power, interface and CCTV) were complex and VIP's would have tremendous difficulty in achieving this.

It was hence decided that although the image quality was improved, the additional problems, and cost implications involved, negated the use of this alternative.

C.3.7.4. CCTV Camera Specifications

Full Cone Pinhole Camera, 0.5Lux / F2.0

Major Specifications are;

Dimensions:	25mm (W) x 25mm (V)
Lens Options:	f 3.7mm, 5.0mm
Imager:	¼” DSP Color CCD
Horizontal Resolution:	380 TV Lines
Picture element (pixels):	N: 290K P:320K
Min illumination:	0.5 Lux at F2.0
Scanning System:	2:1 Interlaced
S/N Ratio (AGC) off:	More than 48dB
Gain Control:	Auto 4dB -> 30dB
Power Source:	DC 12V (tolerance: 9V-15V)
Operating Current:	90mA w/regulated power in
Weight (approx.g):	60

Power Supply Unit

Model:	YJ500T
Input:	240V – 50Hz
Output:	9V
Current:	500mA 9W

C.3.8. Minimum Specifications for Revision

- Windows 2000/XP various SP installed
- Tested on P3 and P4 systems with low end graphics card
- Recommended Configuration
    - Pentium III 500Mhz
    - 128 Meg Ram Memory
    - 17” Monitor
    - 64 Meg Video Card
    - Windows XP Operating System

Appendix D: Usability Testing

D.1. Usability Testing

D.1.1. Goals and Concerns

The goals set prior to the usability testing were to establish whether the product met the aims of learnability and usability (i.e. effectiveness, efficiency, satisfaction and context of use). This was to be achieved by monitoring the change in time to complete tasks (learnability) and via a posttest questionnaire to receive user's feedback (usability).

General concerns include, ease of use for those that have / have not used a system of this nature, general help, will errors become a frustration for users, etc.

A particular concern that was raised during initial heuristic evaluation was the clarity of the image and the concept of using a mouse for the HMI. The former was especially crucial for the partially sighted that were using the product

D.1.2. User Participants

In determining the number of participants, it should be noted that a usability test is used to uncover the most serious problems that users may encounter with a product [2]. It has become an area of debate amongst usability specialists as to the number of participants needed for a usability study. Nielsen and Molich [18] found that three participants discovered not quite half of all major usability problems. Virzi [71] found that 80% of usability errors were found with 4 or 5 participants and 90% with 10 participants. Additional participants were unlikely to uncover additional problems

When this was coupled with the reliability required (*see Appendix, A.2.5. Reliability)* at a confidence level and interval (tolerance) of 80% and 20% respectively, and the information from [18], [71] the number of users required was estimated to be 8.

User participants were divided into groups depending on age, children (under 18 years), adults (18-50 years old) and the elderly (over 50 years of age). A further group was specified for users that experienced CAL. Eight users were sought for each group, however due to time constraints and access, some groups had less than eight CAL sufferers (most potential participants were repeat customers at RAU's optometry clinic).Smaller subgroups had a reduced confidence interval (*see Appendix, A.2.5. Reliability)*. The breakdown of each group is shown below

Group	Number in Sub Group	Confidence Interval	Confidence
Children	8	± 20%	80%
Adult	5	± 26%	80%
Elderly	6	± 24%	80%
CAL	8	± 20%	80%
Non – CAL	11	± 18%	80%
Entire Population	19	± 17%	90%

Table D.1. Subgroup Specifications

Even though there were reduced numbers in some of the subgroups, it was discovered by Virzi [71], that 80% of the usability errors could still be found with at least 4 participants.

D.1.3. Onsite Testing

The usability test was conducted at the computer class at Sibonile Primary school[1] and at RAU University, Low Vision Unit. These venues were selected as it would allow testing to be conducted where users are most likely to use a product such as this. In addition, it would give objective information as the test participants were unlikely to have used other visual aids and hence their opinions would not be biased. RAU specialises in low vision patients (CAL patients in particular) and is open to consulting to the general public, hence the participants used here would be varied in both their condition and general suitability to the research.

D.1.3.1. Equipment Setup

A computer was setup in the classroom that met the minimum specifications and had a copy of the program loaded on it. It was then configured such that the user could operate the device with minimal interference.

D.1.3.2. Material Setup

Materials needed were to be setup whereby test participants were able to use the device and an analysis conducted. The test material included samples of text that were to be used to determine the applicability of the functionality offered as well as printed text on a sheet of paper to test whether users could manoeuvre objects under the webcam such that they became visible on the computer (see *Appendix E).* A help page was prepared to show the users the functionality of the device and how it could be implemented in the program screen (See *Appendix E).*

D.1.4. Pretest Questionnaire

The pretest questionnaire gathered important information about the test participants and the information that was gathered included,

- Age
- Visual status and condition,
- Number of years affected (if applicable)
- Relevant Computer experience

It was found that all had a visual impairment (e.g. partially sighed in single eye, short sighted, myopia nystagmis), but most could not give specific details pertaining to their condition. Most were affected from birth and all stated that they had previous computer experience, though this is questionable.

D.1.5. Training and Orientation

A training script was prepared to ensure that all participants were given equal training to afford them all equal “starting points” prior to the onset of the usability test. The test was comprised of introducing the operation of the mouse, as this was the HMI.

This is especially crucial since the following situation needed to be avoided [3], *“…users will have to be trained in the use of the mouse before it is relevant to use them as test users of a mouse-based system. Using a mouse is known to be hard for the first several hours, and it is almost impossible to use a mouse correctly the first few minutes. If users are not trained in the use of the mouse and other standard*

---

[1] School for the Visually impaired, based in Vereeninging. . Currently has 143 partially sighted and blind children.

interaction techniques before they are asked to test a new interface, the test will be completely dominated by the effects of the user's struggle with the interaction devices and techniques, and no information will be gained as to the usability of the dialogue"

Hence users were shown the general operation of a mouse and how it could be used to operate the interface. Special emphasis was given to the ability to single and double click the left, right and scroll (centre) buttons. The last function was a new experience to all, as previous mouse experience was limited to mouse's without a scroll button. This negatively affected the results (see D.3. Data Analysis*, below*).

The usability testing procedure was then explained to the participant to ensure that they understood the purpose of the test (the prototype was tested; not them) and that times were to be taken for them to complete certain tasks. The test would conclude with a questionnaire (posttest questionnaire), for their opinions and comments.

It was vital that prior to the usability test that the participants were reminded that it was not their performance that was up for evaluation, but rather the performance of the prototype. Hence, should they at any time feel uncomfortable with the testing process that they were allowed to terminate the testing.

D.1.6. Posttest Questionnaire

The posttest questionnaire was done in order to gather additional information about the users experience and for them to rate the operation on a five-point scale as recommended by [3]. Questions included information to the different modules and the opportunity for additional comments and finally with an overall rating of the experience.

Questions had a rating from one to five, with one the most favourable, and five the least. A final question was asked about the overall enjoyment of the software experience.

D.1.7. Testing Methodology

The following tasks were to be completed by the test participants. During these tasks, times were recorded for analysis after the completion of the test.

1. Zoom on rectangle till it fills the screen
2. Zoom on sentence till you can read it
3. Invert the image on the screen
4. Convert the image to grayscale
5. Enable high contrast or split
6. Move item relative to camera in the following sequence
    i. Block 1 – Top left
    ii. Block 2 – Top right
    iii. Block 3 – Bottom right
    iv. Block 4 – Bottom Left
7. Complete the following sequence, Grayscale, Invert, zoom till block fills the screen
8. Exit then restart

The first five tasks were to examine the ease with which users could complete basic tasks, as well as test the zooming capability. The sixth task was to determine if users could move objects under the viewing area as they needed. The seventh task was to determine if learnability was shown, as this task encompassed some of the operations of the previous tasks and the last to exit and start the program again.

During the course of the usability testing it was found that certain aspects of the usability test were not necessary. These were the high contrast or split module and exiting from the program and restarting. These modules were hence not evaluated and not rated during the posttest questionnaire.

The former was that the high contrast module was not offering additional functionality as expected. Since this module essentially "doubled" the number of pixels, it should have increased the resolution of the image, making it clearer. During usability testing, it was found that this was not the case, and the doubling of pixels was not apparent to most users. The split module was similarly not necessary for non-CAL patients as they would have no need to utilise this functionality.

The latter was omitted from the test, as the concept of starting the program was the same as any other Windows based application, i.e. double clicking on the icon. Exiting was not necessary as it was determined that the program was to be operational all the time.

D.1.8 Thinking Aloud

Users were to be introduced to the concept of thinking aloud by participating in an example. First the evaluator would explain the steps involved (audibly) in making a jam sandwich, and then the participant would follow with explaining the steps involved in making a cup of tea. This proved useful in both allowing familiarity with the concept of "thinking aloud" and secondly, relaxed any tensions and stress that may have been apparent, as many users were visibly more relaxed after this exercise.

D.1.9. Pilot Test

A pilot test was run prior to the usability test to fulfil a dual purpose. Firstly, to ensure that the equipment was operating correctly and that it was free from "bugs" and secondly, to practise the activities that would be conducted during the usability testing. This was completed successfully and hence no "last minute" adjustments needed to be made.

D.1.10. Observing Test Participants

Once the test user was introduced to the device, information gathered and orientated to thinking aloud, users were asked to complete the tasks one at a time. During the tasks, users were allowed to use the help documentation, and measurements were taken. The measurements taken included

- Time to complete each task
- Number of referrals to help
- Number of errors
- Number of crashed in the program

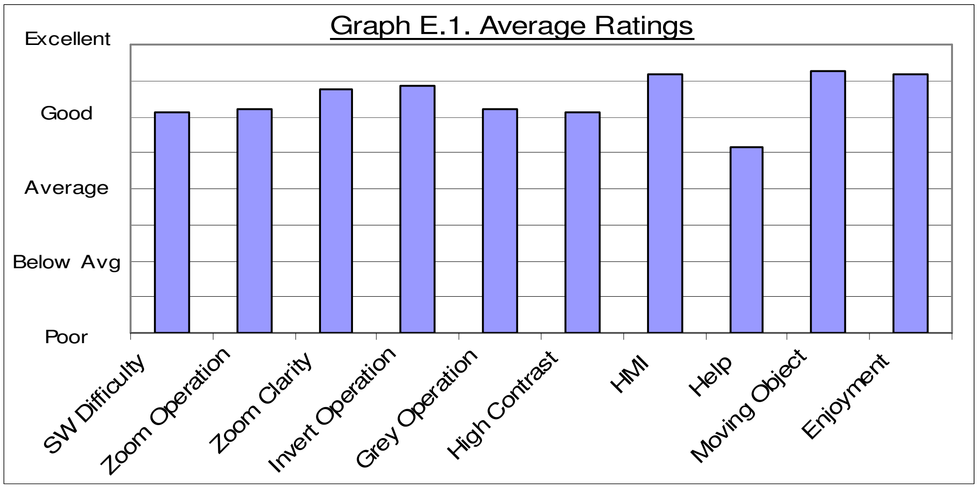
D.2. Statistical Analysis

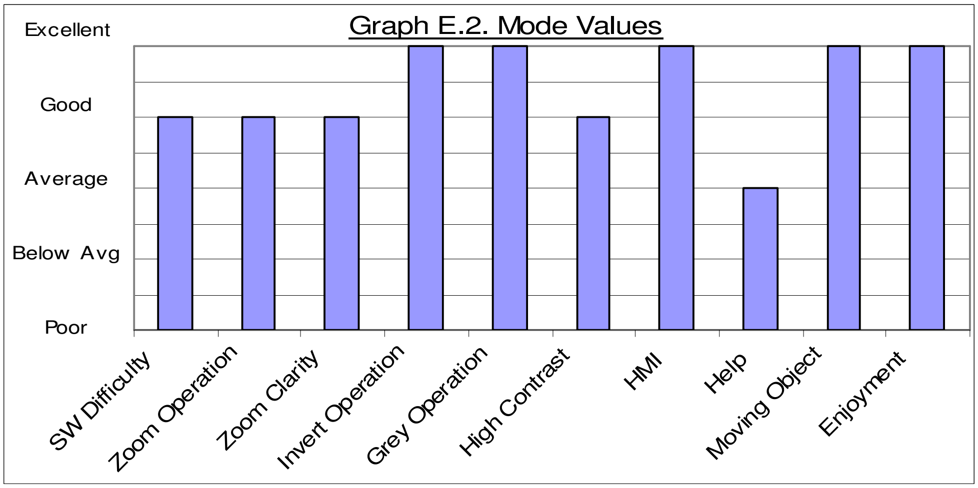
Once the data was collected (test participant evaluation and posttest questionnaire), a statistical analysis was taken. The measures that were taken to describe the data were,

1. The average (mean) of the scores
2. Variance
3. Standard Deviation
4. Median, middle score when the tasks are listed from highest to lowest
5. Mode, value that occurs the most often
6. Tolerance in values (confidence interval), depending on number of users

It was further noted during comparisons between the various age groups that the elderly, showed the lowest average times to complete the various tasks. Additionally, CAL patients similarly showed a lower average time than the general population, with the exception of the zoom module time. A similar observation was made with the number of errors committed and the help referrals.

The graph below shows the average values for the entire population group irrespective of age or condition (i.e both CAL and non-CAL). Due to the sample size, the results shown below are for a confidence of 90% and a corresponding confidence width of 17%. Taken at the extremes of this tolerence, excellent results can still be observed





D.3. Data Analysis

The data collected during the usability analysis was tabulated and analyzed (see *Appendix E,* for original test documents and results) The following results are based upon the entire sampled group, i.e. children, adults, elderly and CAL combined, with each subgroup exhibiting similar results

D.3.1. Trend Analysis

Upon further analysis of the tabulated data, a number or trends were noted. Outliers were included in the analysis, as these numbers may be an indication of a larger population group that may have similar experiences.

D.3.1.1. Scroll Button Operation

The users in general experienced problems with the concept of the clicking of the scroll button (to initialize the grayscale and high contrast modules). The average times for these functions were higher than for the other modules (zoom and invert), i.e. 28.40 sec and 22.46 sec respectively as opposed to 14.38 sec and 20.37 sec.

The concept of single and double clicking was not problematic however due to the similarities of the times for both functions (28.40 sec and 22.46 sec). Additionally this can be verified by the number of help referrals and errors committed for the first instance of the scroll click.

The same cannot however be said to the scrolling and clicking of the scroll button. The times, on average, to complete the functionality associated with the two functions (zooming and grayscale), yielded a significant difference in times, 14.38 sec and 22.48sec.

This can be attributed to the fact that the scroll button could be rolled and clicked, and it became evident that users were unsure of the latter functionality with the former being more natural. This trend can be reinforced to the numerous comments and observations that test participants were only accustomed to a mouse without the scroll button.

D.3.1.2. Learnability

A fundamental requirement of usability is that "*Usability is about learnability, efficiency, memorability, errors, and satisfaction."* – Nielsen [3].

By analysing the statistical data, it can be seen that this requirement has been met, as the average time to complete the scenario test, that compromised of a number of tasks (greyscale, invert, zoom), was less than the average time to complete the individual tasks, i.e. the average time to complete the scenario task was 43.925 sec compared to a total time of 57.225 sec for the total addition of the individual tasks. This is reinforced by a similar observation on the reduction of the number of errors and help referrals.

Comments during the posttest questionnaire that using the device would lead to an easier experience enforces that learnability has been successfully applied.

D.3.2. Outliers

Outliers were found in both the test participant evaluation and the posttest questionnaire, but were included in the overall analysis of the device.

D.3.2.1. Test Participant Evaluation

The major conclusions from the analysis of the data of the test participant evaluation, with respect to outliers were;

- Of the eleven outliers (the two for exiting and restarting the device were not considered as explained above), nine erred on the higher side. The remaining two were during the high contrast or split modules evaluation.
- Of these nine, seven were from two users (user six and ten) and these were for the scenario test and for elements of the scenario test (zoom, grayscale and invert). This indicates that these two users experienced severe difficulty in using the device.

D.3.2.2. Posttest Questionnaire

The major conclusions from the analysis of the data of the user ratings from the posttest questionnaire were;

- All nine outliers were for values that were higher than the average
- 30% of the outliers were concerning the help documentation, and these users committed more errors than the average
- User 14 gave two outliers and though this person performed extremely well during the usability testing, also tended to give poorer results than the average (2.8 compared to the average of 1.75)

D.3.3. Usability Concerns

The areas of concern were addressed with sufficient data such that a conclusion could be reached (*see D.1.1. Goals and Concerns,* above);

D.3.3.1. Learnability

By observing the trends in the data analysis, it can be concluded that the goal of learnability has been met (*see D.3.1.2.Learnability*, above). This is further verified by the many user's comments that the interface was excellent and that more use would make the program operation easier.

D.3.3.2. Usability

Within the context of usability (effectiveness, efficiency, satisfaction and context of use), by analyzing the feedback from the posttest questionnaire, we note the following

- All users met the requirements of the usability test (effectiveness), i.e. all requested tasks were completed without major problems
- The average time to complete the individual tasks was less than half a minute (efficiency)
- From analysis of the posttest questionnaire, an average rating of 1.78 was given for all the tasks performed (1 being the best value). Additionally, the modal value for all questions pertaining to the product was either a one or a two and the overall enjoyment of the product received a 1.42 (satisfaction).
- The users were all exposed to the product in their normal working environment (context of use)

Hence it can be concluded that from the results shown above, the goal of usability has been met.

D.3.3.3. Help

This was an area of concern as there was no help that was catered specifically for the partially sighted. A general document was made with instructions on how to operate the product in large font. During the posttest questionnaire, the help received an average value of 2.42. This value was the worse value, with a mode of "3". It was noted by comments and evaluators that the help could be improved (See *D.4. Recommending Changes*, below)

D.3.3.4. Clarity of Image

During heuristic evaluation of the interface it became an area of concern that the clarity of the zoom function was not sufficient. Upon evaluation of the device it was noted that all users were able to clearly read a sentence written in 12-size font, Times New Roman, without additional zoom.

Furthermore, the average rating for the clarity was 1.63 for the entire sample, and 1.625 for CAL patients. It can be concluded that since all the users were not exposed to other visual aids, this rating was not a comparison with other devices, but rather an initial impression of how the device could assist them. Hence, the aims of the research have been met, that the device does indeed assist VIP's with no previous experience with other visual aids.

D.3.3.5. Mouse Driven HMI

This approach was untested during heuristic evaluation and an addition as part of the evolutionary design process. It was felt that a mouse driven HMI would lessen the problems experienced by the partially sighted. The results were extremely positive, with an average rating of 1.42 and 1.5 being given by all users and CAL patients.

D.3.4. Program Errors and Crashes

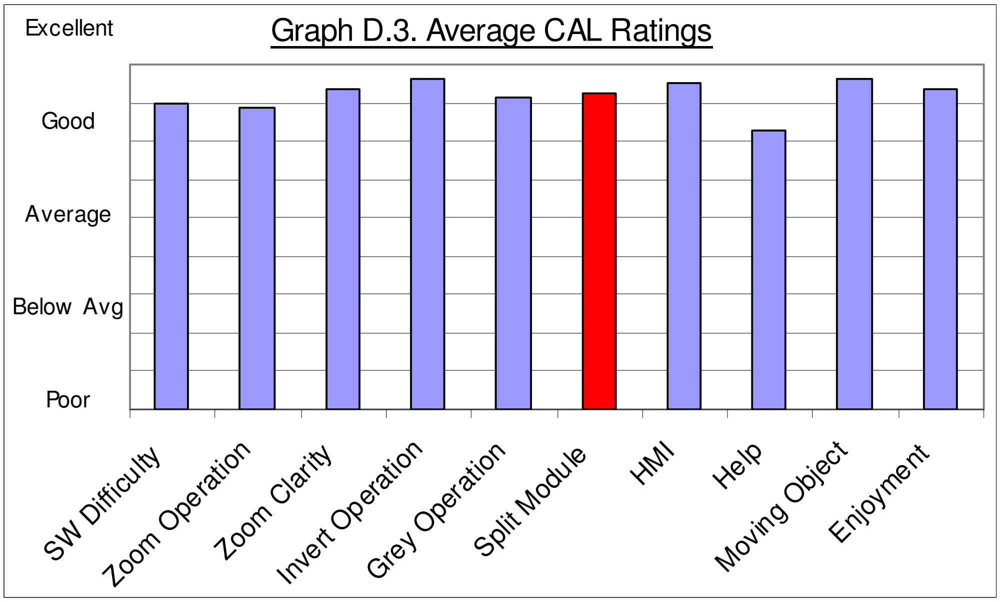
A major concern that was noted during the usability testing was the number of crashes (eight) that occurred during the entire usability test. This number is undesirable as it defeats the purposes meeting usability criteria. It was noted that of the eight crashes, five errors were attributed to a conflict with Windows XP © operating system, and the remaining three were due to program errors (such as memory associated errors).

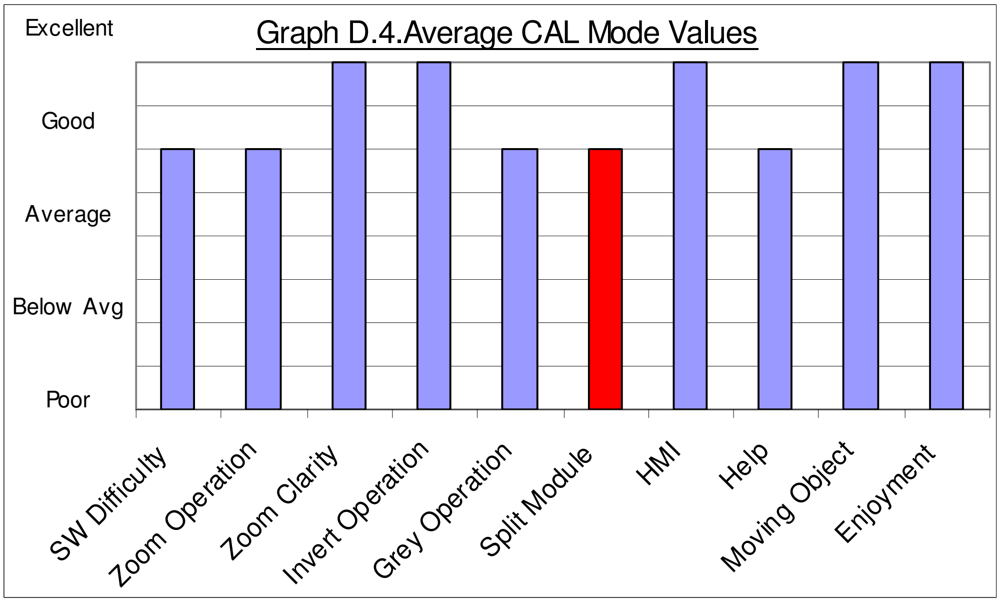
Of the five errors, two occurred during the zooming module and another three during the scenario test, in specific during the zooming process. This can be attributed to the high resource (memory) use during the zooming process and could be from a memory allocation problem or memory leak. This is verified by monitoring the resource monitor during the operation of the zoom module.

D.3.5. Split module

The split module was only tested by VIP's that experienced CAL. The major observation was that this module received an average rating of 1.75, with the mode and median value being "2". With a confidence level of 80% and a tolerance of 20%, this indicates that 80% of the population would give a rating of this module between

1.4 and 2.1. These values are extremely favourable, considering the amount of time that participants had evaluating this module.





Comments during the posttest were synonymous that upon initial reflections, this module could be very useful and with additional exposure they may ease the difficulties associated with CAL.

D.4. Recommending Changes

To complete the usability study, recommendations are required to be made to improve the usability of the product to be implemented in subsequent iterations of the product.

D.4.1. Software

In general the software operation was favorable but there were ways in which the usability could be improved.

D.4.1.1. Zoom Module

Although the zoom module was given unfavorable feedback from the usability specialists in terms of the reduction of image quality with increase zoom rate, it was found during the usability test, that test participants rated very highly the operation and clarity of the final zoom module (1.89 and 1.63 respectively, with 1 being the best possible rating).

It is assumed that this is because the test participants were not exposed to alternative viewing devices as opposed to the usability specialists. This indicates that the developed prototype may aid new sufferers, but does not compare favorably when compared to other viewing devices. It would then still be necessary to improve the clarity of the image to increase the number of VIP's that this device could assist.

This could be corrected by implementing additional software image processing techniques. One such technique that may achieve this is termed *SuperResolution*[2]. This process has been researched on a very preliminary basis. Another method to correct this problem would be to find an alternative to the current input device (See *D.4.3. Input Device*, below).

D.4.1.2. Color Change

There were comments that different colors would be preferred to be used in the grayscale, high contrast and split module, i.e. instead to black and white, blue and white and the "split" placed in an image be a different color, not white. This is because of the different ways in which VIP's vision is affected by their individual conditions. This can be implemented in software by pixel manipulation and should be investigated further to determine the best color combinations. Alternatively, prior to using these modules, the user could be prompted to their color preferences, which would subsequently be realized.

D.4.1.3. HMI

Users and specialists alike commended the overall perception of a mouse driven interface (user rating of 1.42). However feedback was that the operation of modules assigned to mouse commands needed to be re-evaluated, this was reinforced by the times and errors to compete operations using the scroll button. It is believed that functions used more often be moved to more common mouse operations (e.g. single and double left click) and less used modules be "mapped" to less used mouse commands (e.g. double scroll click).

---

[2] SuperResolution is a process that takes a set of four images and combines them together to produce a single, high-resolution image [72]

D.4.1.4. Crashes

The number of crashes that were observed during the usability testing is unacceptable as this factor alone renders the product useless and defeats the purpose of creating a usable product. The process would be to determine the conflict between the Windows XP© operating system and to determine if Microsoft has released updates and patches that may correct this error, starting with the recently released service pack 2.

D.4.2. Hardware Stand

Although the hardware stand met the requirements given by heuristic evaluation and the data analysis demonstrated that users had no difficulty in maneuvering the source material relative to the viewing area (average rating of 1.368), a number of concerns were raised.

D.4.2.1. Viewing Area

The eventual viewing area of the product was too small to be truly effective when source material needed to be read from below it. An example was that the largest area that could be read was a newspaper article with the usual column widths. Anything in excess of that made reading problematic. This could be attributed to the change in webcams from an initial Logitech Quickcam Pro3000, to the later Logitech Quickcam Pro 4000. The latter introduced a larger image and reduced the viewing area.

D.4.2.2. Moving source material

Although the time taken to move images from below the webcam was favorable (average time of 25.46 sec), it was found during observations that all participants experienced difficulty in moving the source in a vertical or horizontal direction. This could be overcome by incorporating an X-Y table as used by many other visual aids.

This device would allow the material to be placed upon a tray that would assist movement in either only the vertical (Y) or horizontal (X) direction. This would require additional hardware resources, but would alleviate this problem.

D.4.3. Input Device

In order for the product to become a more usable device, it is necessary that the input device be re-evaluated. The input device has become the “bottleneck” in creating a truly usable product and affects the clarity of the image, which ultimately affects the entire operation of the product.

Subsequent iterations of the product need to investigate a low cost, high performance device capable of incorporating a clearer image, reduction of the barrel effect and improve the lighting, without requiring additional resources.

D.4.4. Help

It was noted during usability testing that a large portion of time used by test participants was to find the correct command to initiate a module from the help document. Careful consideration needs to be given to cater for VIP’s that are not able to read text without additional aid. The text could be formatted by using different colour combinations or by supplying an external reading aid (magnifying glass) to read the text. An alternative could be for the help to be implemented within the program itself and can be viewed upon a certain mouse operation.

D.5. Conclusion

Based upon the definitions of usability (ISO standards and from Nielsen) and the extensive research and test participant evaluation, it can be seen that usability principles (effectiveness, efficiency, satisfaction and context of use) have been successfully implemented into the device. This is since usability engineering techniques have been introduced at an early stage of the evolutionary delivery process to meet user needs, with subsequent iterations addressing the issues as raised by heuristic evaluation and usability tests.

The device was tested and evaluated from both an engineering and optometric perspective from specialists from various associations such as the South African National Council for the Blind, RetinaSA and RAU University. The heuristic evaluation conducted with these associations yielding invaluable feedback.

The device that was assessed during heuristic evaluation was not the same that was tested in the user environment, having "evolved" from its initial stage. Modules that were not needed were removed, and more important modules improved and streamlined and finally additional modules were added as needed. The process repeated till the majority of usability errors were recovered.

The usability testing was conducted at strategic locations where access to VIP's was assured. Furthermore, at RAU University, optometrists were available to observe the usability testing process and give comments and feedback from their professional experience. Users were tested on various aspects of the device and their times recorded.

Of the major findings from the usability test the most important is that the device rated favourably in terms of the operation of the individual modules. Average ratings being between 1.4 and 2 were given (confidence level of 90%, confidence interval of 17%), with the exception of the help documentation. Concerns raised by specialists during the heuristic evaluation about the clarity and operation of the zoom are addressed by the usability participation test, and found to have no basis when considered against the research question.

Additionally, learnability is observed as the time to complete a major tasks comprising of a number of smaller tasks, was less than the time to complete the smaller tasks individually. This indicates that participants were gaining familiarity with the device after a short period of time.

The major usability problem that was uncovered during the usability test was the regularity of crashes. Should this problem not be addressed with the next iteration, the device is rendered useless and does not meet basic usability requirements. The help documentation needs to be reviewed as it did not receive a favourable rating and may need to introduce different colours or be supplied with a reading aid, or implemented within the program itself upon a mouse operation.

The hardware portion of the device needs to be addressed as the viewing area was smaller than initially hoped as a result of changing the input device, and consideration given to introduce a X-Y table for horizontal and vertical movement. The input device needs to be evaluated to improve the clarity of the image to compete with other visual aids.

The HMI implementation of a mouse driven interface was received with great approval and user participants and evaluators alike believe that with further use it could show additional favourable results. Additional thought needs to be given to the operation of the individual modules with the more often used modules being associated with easier mouse driven operations.

The “split” module, where a “gap” is inserted into the image to introduce a paragraph break, has shown positive results and has been applauded by heuristic evaluation and may be an additional approach to alleviate the problems faced by VIP’s. This could lead to a different mindset and teaching approach. This is reinforced by the very favourable rating received during the usability testing (1.75), and the numerous comments from CAL patients that such a module, upon initial reflection, offers much promise.

CAL patients are currently taught to read using their peripheral vision by reading above the desired text. Using the split module would allow the user to look directly at the text as per normal, except that the middle section of text would be moved higher or lower to cater for their loss of central vision. This change in philosophy may ease the adaptation for CAL patients when faced with initial vision loss, when reading and viewing objects.

This research indicates that should a user have no prior experience with visual aids, irrespective or vision disorder, the proposed device is beneficial in all facets including the zoom operation and clarity. However, should the user have prior experience in visual aids; the device does not offer the same quality in terms of image quality when compared to other available visual aids.

Furthermore, statistics indicate that using the product, users are able to complete basic tasks within an acceptable time and that learning of the product is implemented. The statistics are within an 80% confidence interval and have a tolerance level of between 20 – 26% depending on the subgroup that was addressed. For the entire population group, a 90% confidence exists, with a 17% confidence interval. Even at the extremes of these tolerances, the data gathered indicate that this device is usable irrespective of the condition or age of the user.

Appendix E: Usability Test Documentation

Appendix E.1. Usability Test Orientation Document

Usability Test Orientation

Training on how to use a Mouse

1. Moving the mouse cursor on the screen
2. Left click
3. Right Click
4. Scroll roller
5. Single and Double Click (left, right, scroll)

Thinking out Aloud

- Explain to me how to make a jam/Peanut butter Sandwich
- Explain to me how to make a cup of tea
- Explain how to play hopscotch
- Explain what to do before you go to bed
- Etc.

Task List

1. Zoom on rectangle till it fills the screen
2. Zoom on sentence till you can read it
3. Invert the image on the screen
4. Convert the image to greyscale
5. Enable high contrast or split
6. Move item relative to camera in the following sequence
    i. Block 1 – Top left
    ii. Block 2 – Top right
    iii. Block 3 – Bottom right
    iv. Block 4 – Bottom Left
7. Complete the following sequence, Greyscale, Invert, zoom till block fills the screen
8. Exit then restart

Appendix E.2. Revision Commands

Revision Commands

Program Start/Stop

Starting:	Double Click on “Revision” Icon
Exiting:	Double Left Click

Zoom Commands

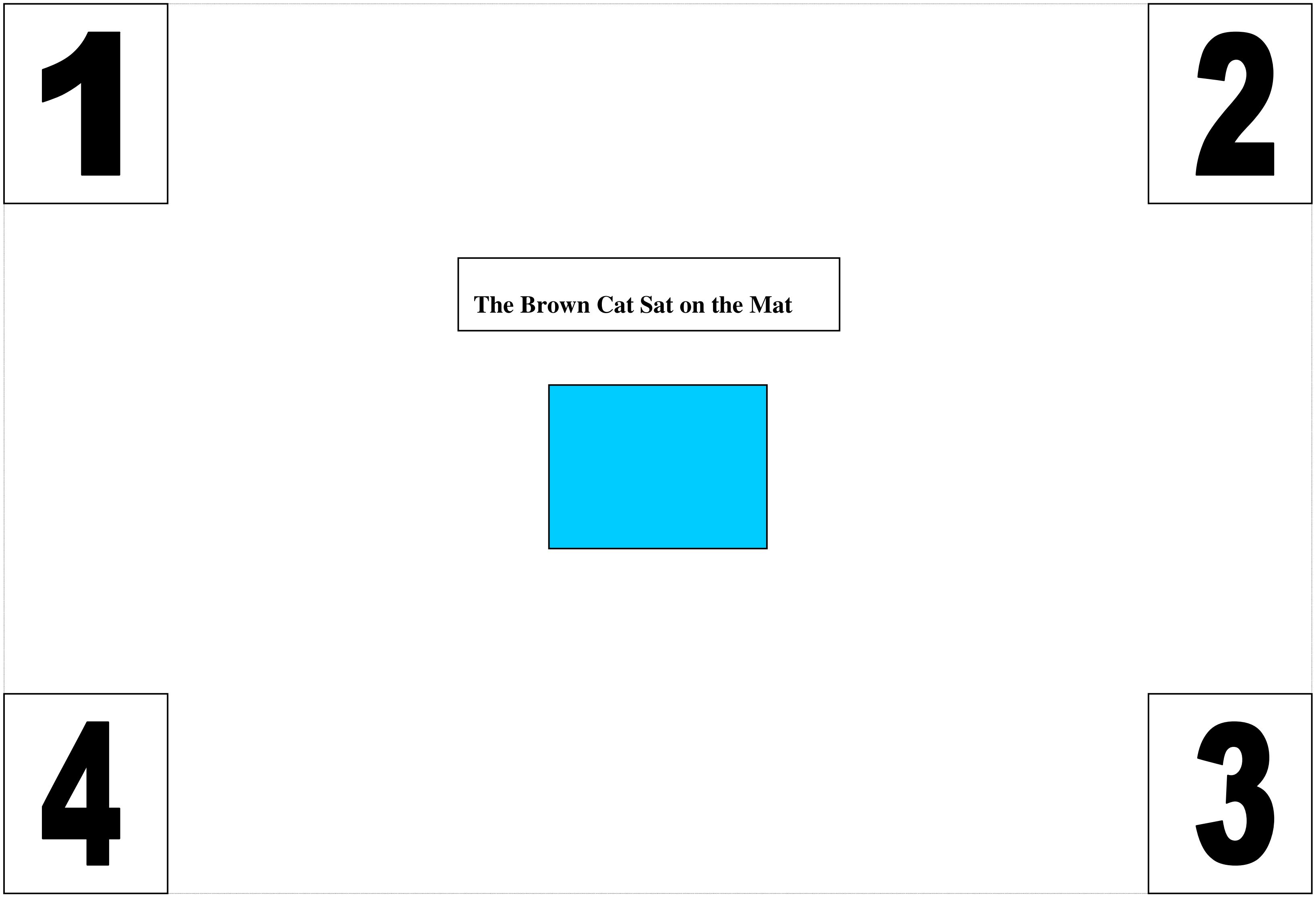
Zoom in:	Scroll Up
Zoom Out:	Scroll Down

Image Commands

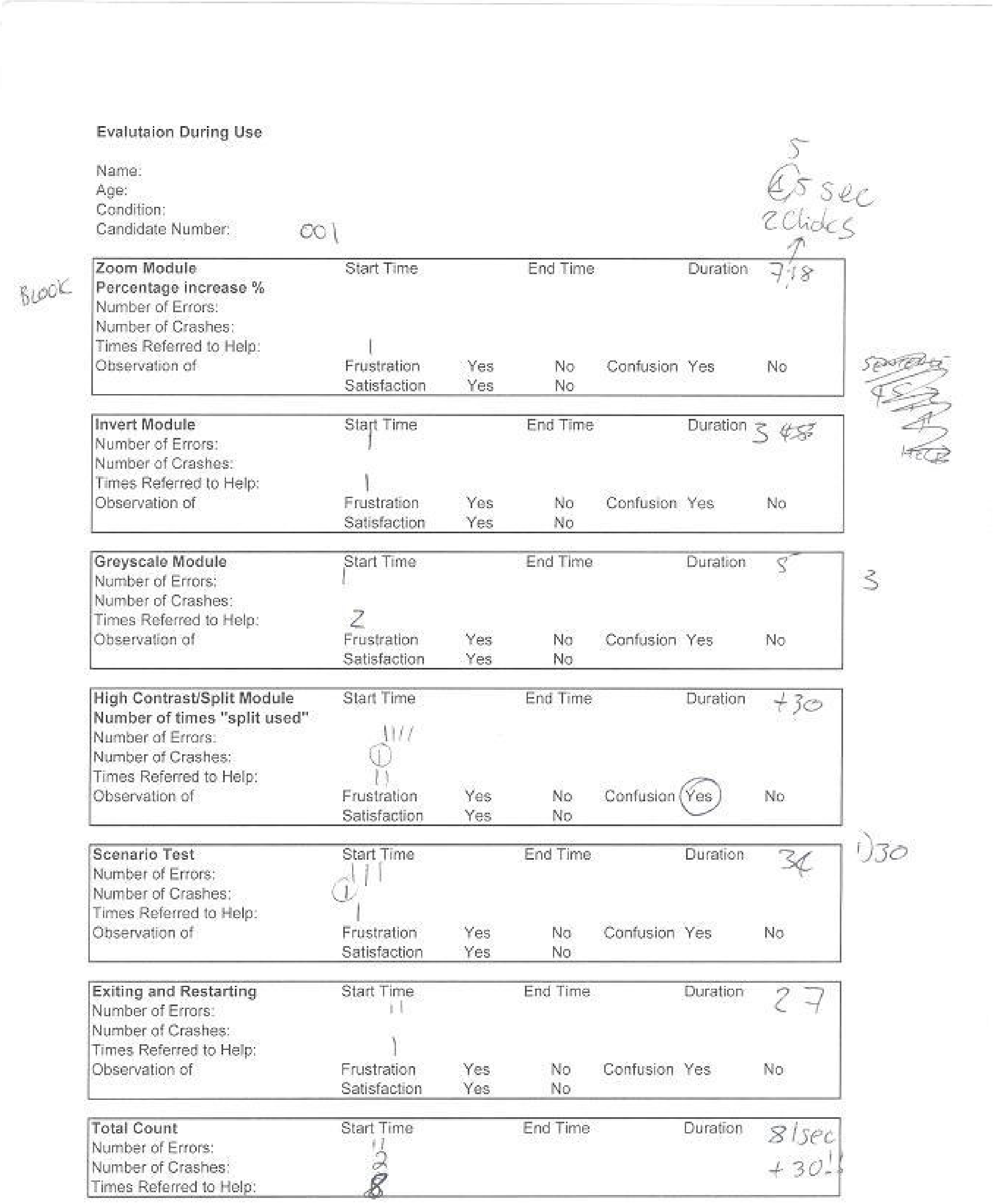
Reset Image:	Single Left Click
Invert Colors:	Single Right Click
Greyscale:	Single Scroll Click
High Contrast:	Double Click Scroll

Special Commands

Split Image:	Right Button Down +Scroll
Image Enhance:	Double Right Click


1
2
The Brown Cat Sat on the Mat
4
3

Appendix E.4. User Evaluation Sheets



Evalutaion During Use

Name:
Age:
Condition:
Candidate Number: 001

5
④5 sec
2 Clicks

BLOOK

Zoom Module Start Time End Time Duration 7:18
Percentage increase %
Number of Errors:
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 3 45
Number of Errors: |
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Greyscale Module Start Time End Time Duration 5
Number of Errors: |
Number of Crashes:
Times Referred to Help: 2
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

3

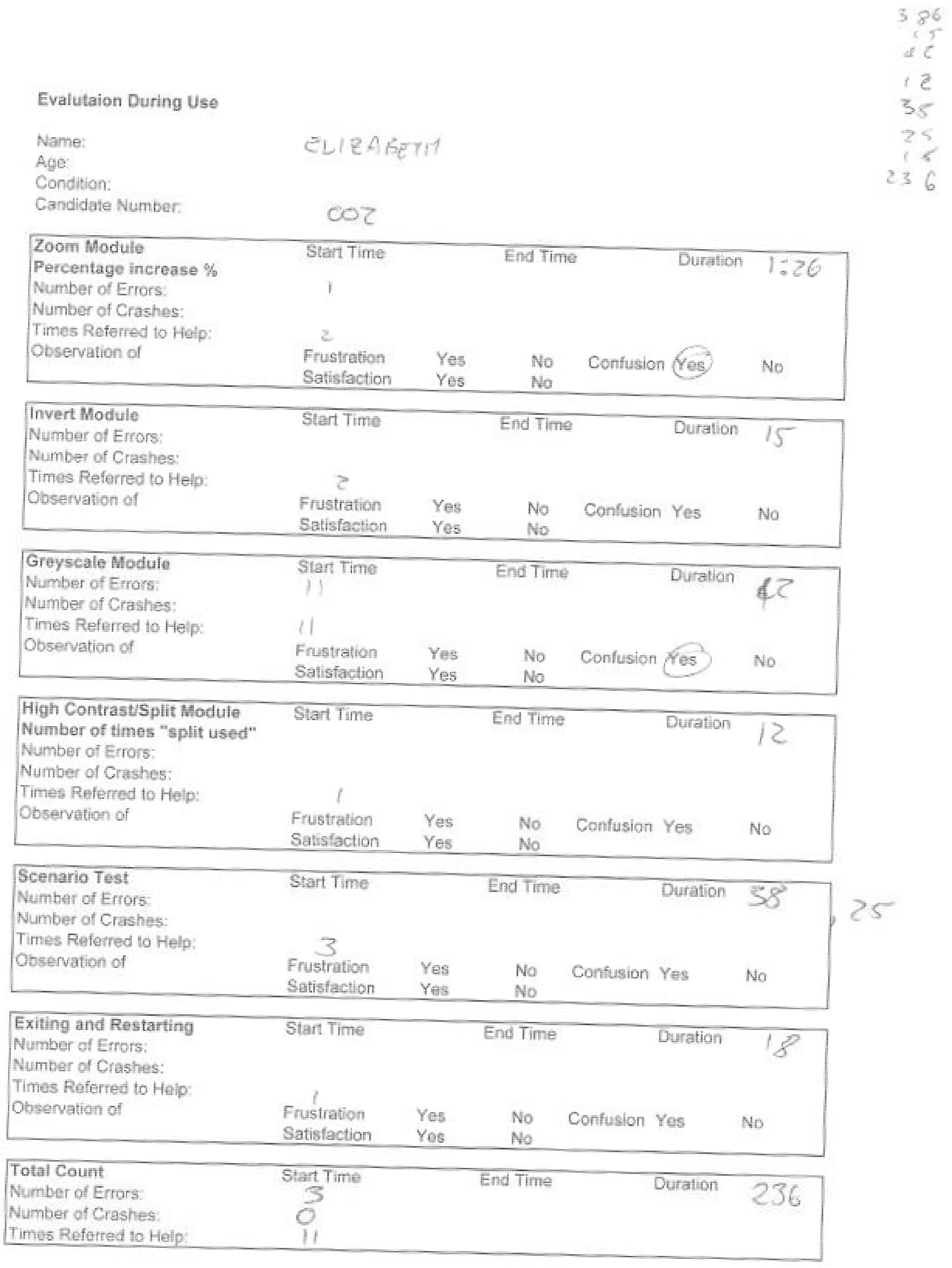
High Contrast/Split Module Start Time End Time Duration +30
Number of times "split used"
Number of Errors: ||||
Number of Crashes: ①
Times Referred to Help: ||
Observation of Frustration Yes No Confusion [✓ Yes] No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 34
Number of Errors: |||
Number of Crashes: ①
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

1)30

Exiting and Restarting Start Time End Time Duration 27
Number of Errors: ||
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration 81sec
Number of Errors: 11
Number of Crashes: 2
Times Referred to Help: 8
+30!!



3 86
15
42
12
35
25
18
236

Evalutaion During Use

Name: ELIZABETH
Age:
Condition:
Candidate Number: 002

Zoom Module Start Time End Time Duration 1:26
Percentage increase %
Number of Errors: 1
Number of Crashes:
Times Referred to Help: 2
Observation of Frustration Yes No Confusion [✓ Yes] No
Satisfaction Yes No

Invert Module Start Time End Time Duration 15
Number of Errors:
Number of Crashes:
Times Referred to Help: 2
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

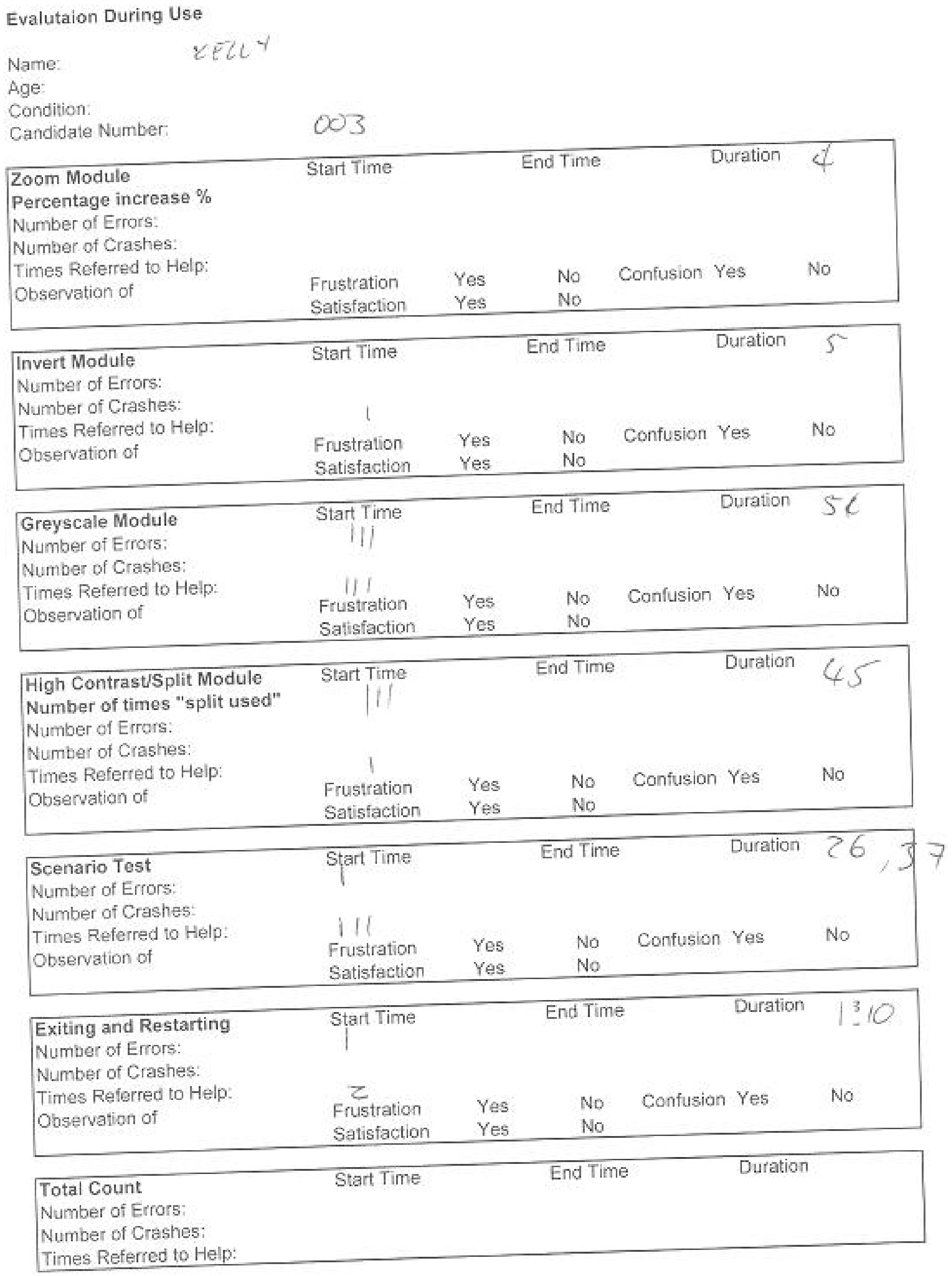
Greyscale Module Start Time End Time Duration 42
Number of Errors: 11
Number of Crashes:
Times Referred to Help: 11
Observation of Frustration Yes No Confusion [✓ Yes] No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 12
Number of times "split used"
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 38, 25
Number of Errors:
Number of Crashes:
Times Referred to Help: 3
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration 18
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration 236
Number of Errors: 3
Number of Crashes: 0
Times Referred to Help: 11



Evalutaion During Use

Name: KELLY
Age:
Condition:
Candidate Number: 003

Zoom Module Start Time End Time Duration 4
Percentage increase %
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 5
Number of Errors:
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

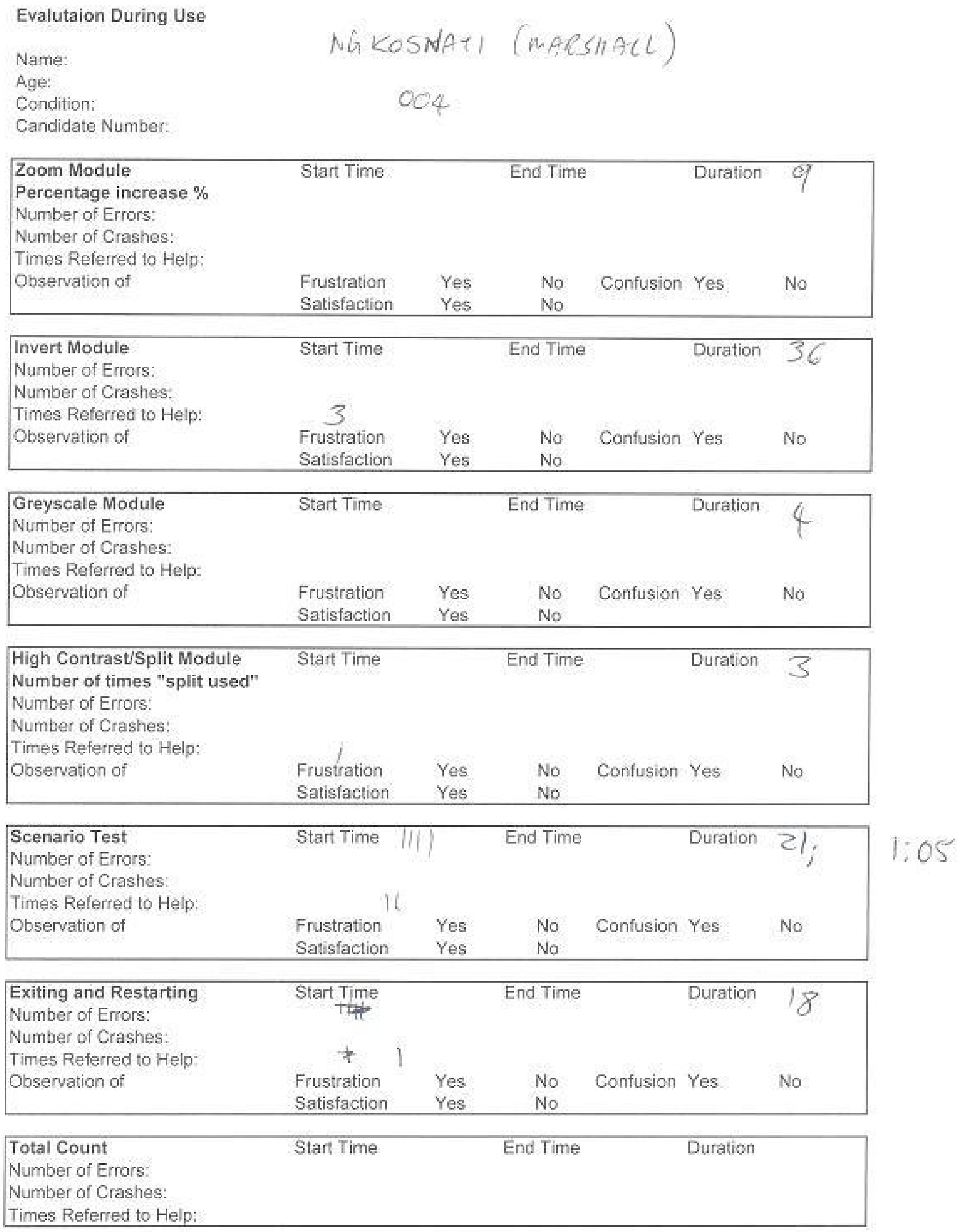
Greyscale Module Start Time End Time Duration 56
Number of Errors: |||
Number of Crashes:
Times Referred to Help: |||
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 45
Number of times "split used" |||
Number of Errors:
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 26, 37
Number of Errors: |
Number of Crashes:
Times Referred to Help: |||
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration 1^{3}:10
Number of Errors: |
Number of Crashes:
Times Referred to Help: 2
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evalutaion During Use

Name: NG KOSNATI (MARSHALL)
Age:
Condition:
Candidate Number: 004

Zoom Module Start Time End Time Duration 9
Percentage increase %
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 36
Number of Errors:
Number of Crashes:
Times Referred to Help: 3
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

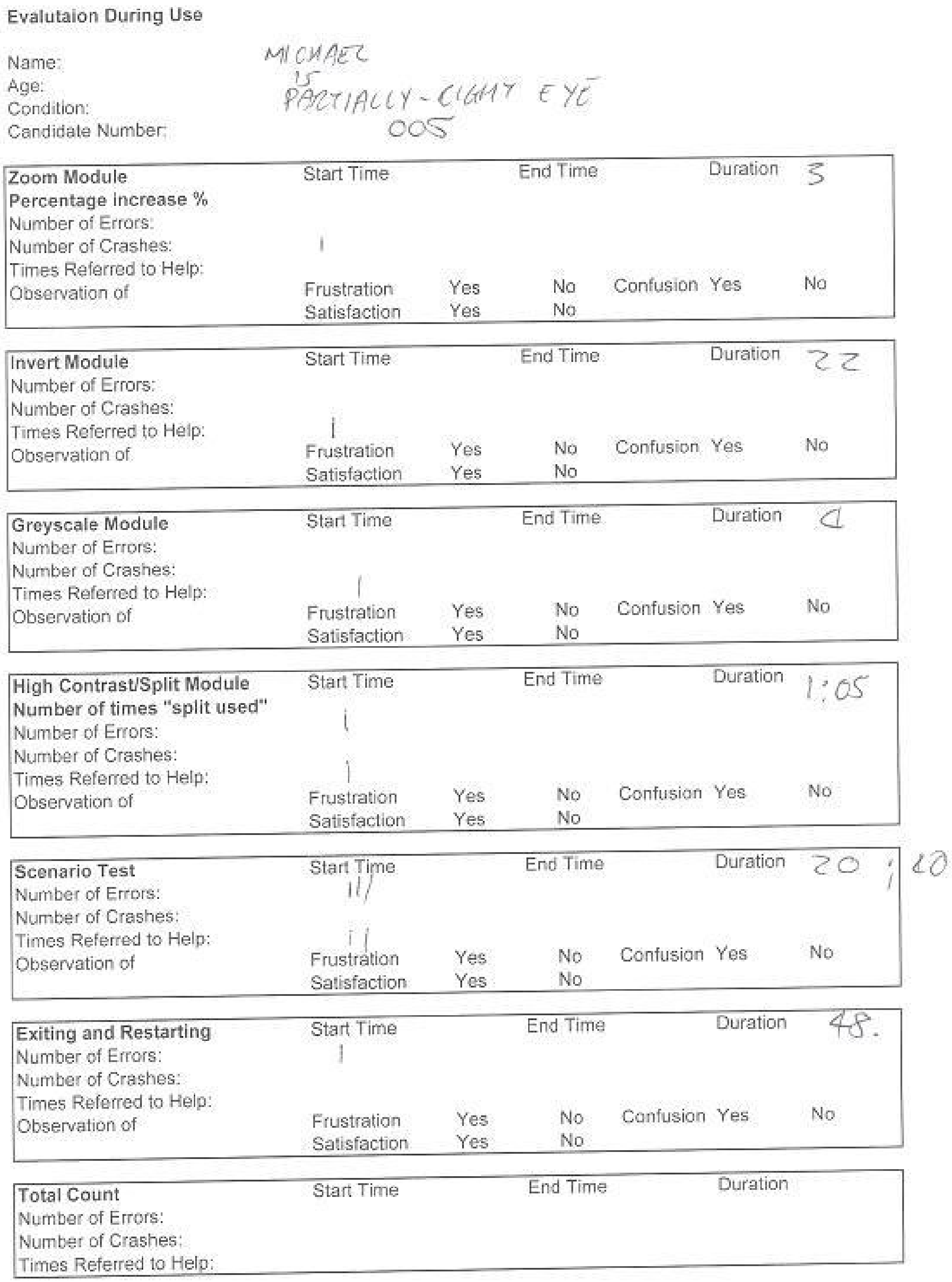
Greyscale Module Start Time End Time Duration 4
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 3
Number of times "split used"
Number of Errors:
Number of Crashes:
Times Referred to Help: /
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time |||| End Time Duration 21; 1:05
Number of Errors:
Number of Crashes:
Times Referred to Help: 11
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration 18
Number of Errors: ~~||~~
Number of Crashes:
Times Referred to Help: + 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evalutaion During Use

Name: MICHAEL
Age: 15
Condition: PARTIALLY - CIGHT EYE
Candidate Number: 005

Zoom Module Start Time End Time Duration 3
Percentage increase %
Number of Errors:
Number of Crashes: |
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 22
Number of Errors:
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Greyscale Module Start Time End Time Duration 4
Number of Errors:
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 1:05
Number of times "split used"
Number of Errors: |
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 20 ; 10
Number of Errors: ||/
Number of Crashes:
Times Referred to Help: ||
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration 48.
Number of Errors: |
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:

Evalutaion During Use

Name: THANDEKA
Age: 12
Condition:
Candidate Number: 006

Zoom Module Start Time End Time Duration 12
Percentage increase %
Number of Errors: 1/(Maj)
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 1:05
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

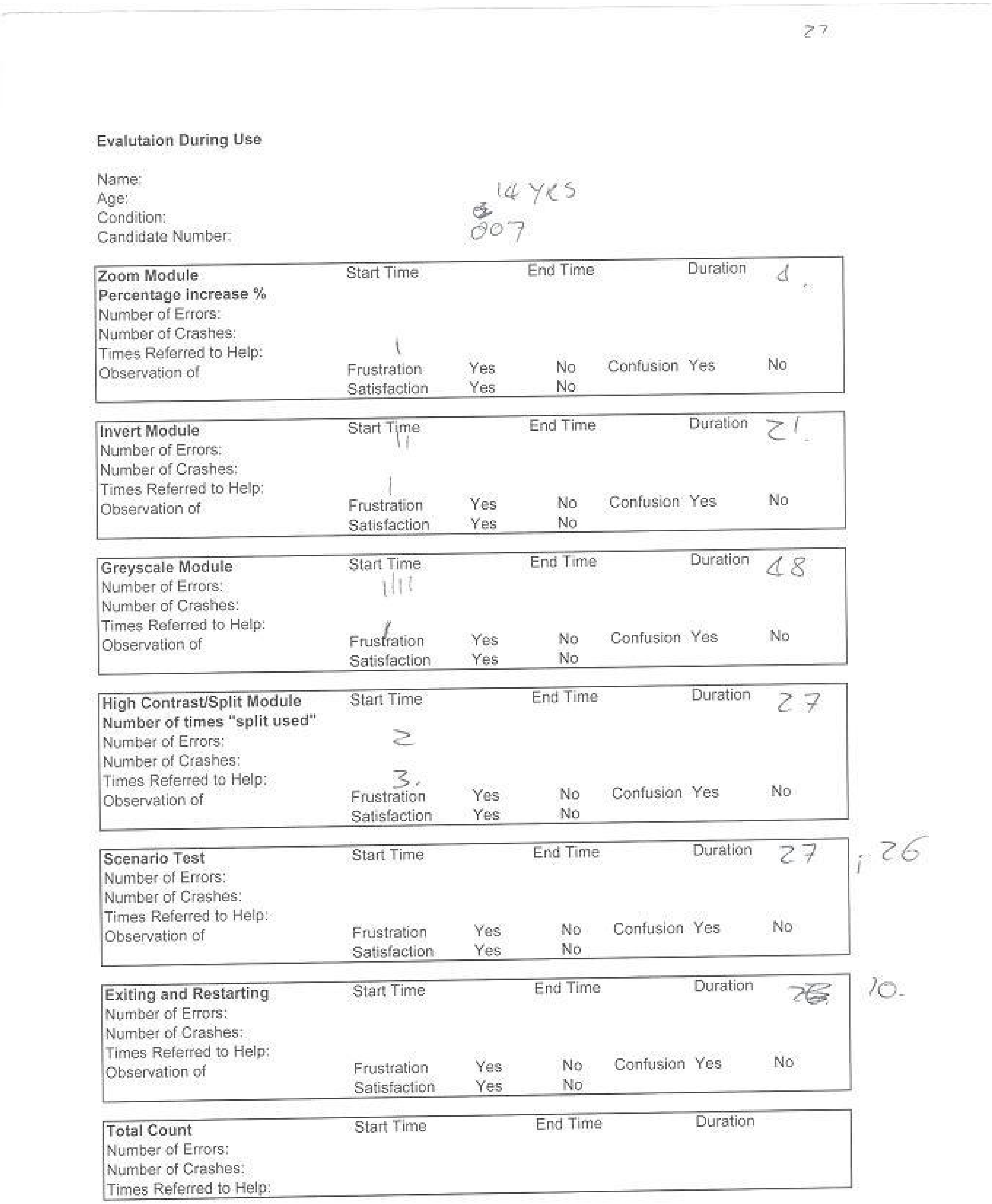
Greyscale Module Start Time End Time Duration 1:02
Number of Errors: 卌
Number of Crashes:
Times Referred to Help: 111
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 56
Number of times "split used"
Number of Errors: 11
Number of Crashes:
Times Referred to Help: 11
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 1:02 1:08
Number of Errors:
Number of Crashes:
Times Referred to Help: 4
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration ~~[illegible]~~ 1:13
Number of Errors: 11
Number of Crashes:
Times Referred to Help: 11
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



27

Evalutaion During Use

Name:
Age: 14 YRS
Condition: [illegible]
Candidate Number: 007

Zoom Module Start Time End Time Duration 4.
Percentage increase %
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 21.
Number of Errors: ||
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Greyscale Module Start Time End Time Duration 48
Number of Errors: ||||
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 27
Number of times "split used"
Number of Errors: 2
Number of Crashes:
Times Referred to Help: 3.
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 27 ; 26
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration [illegible] 10.
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:

Evalutaion During Use

Name: THUMI
Age: 16.
Condition:
Candidate Number: 008

Zoom Module Start Time End Time Duration 14
Percentage increase %
Number of Errors:
Number of Crashes: 1-7MAJ
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 17
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

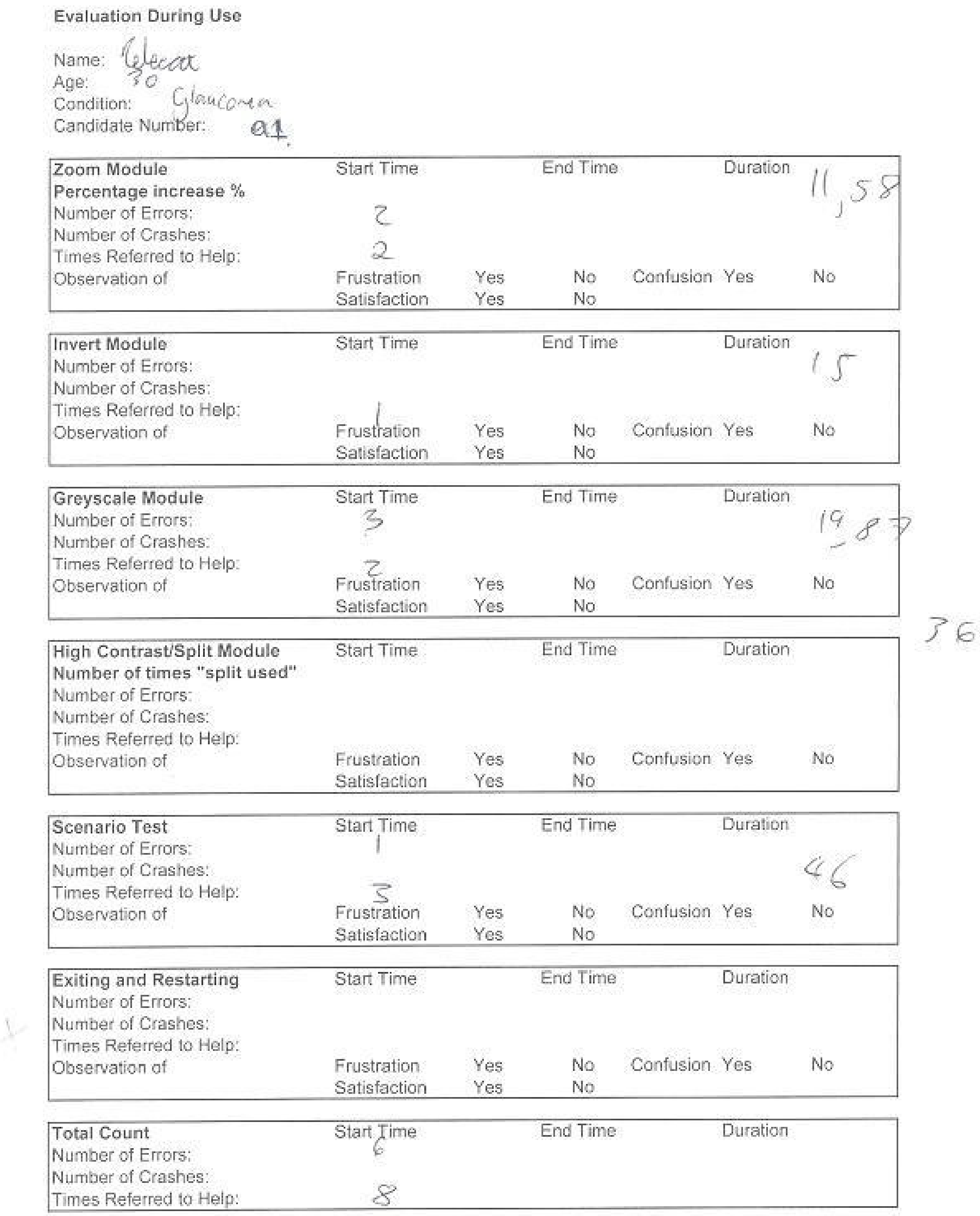
Greyscale Module Start Time End Time Duration 34
Number of Errors: IIII
Number of Crashes:
Times Referred to Help: III
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 16
Number of times "split used" 1
Number of Errors:
Number of Crashes:
Times Referred to Help: 2
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 27 1,47
Number of Errors: II
Number of Crashes:
Times Referred to Help: 3
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration 18
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evaluation During Use

Name: Celecat
Age: 30
Condition: Glaucoma
Candidate Number: 01.

Zoom Module Start Time End Time Duration 11,58
Percentage increase %
Number of Errors: 2
Number of Crashes:
Times Referred to Help: 2
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 15
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Greyscale Module Start Time End Time Duration 19,87
Number of Errors: 3
Number of Crashes:
Times Referred to Help: 2
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

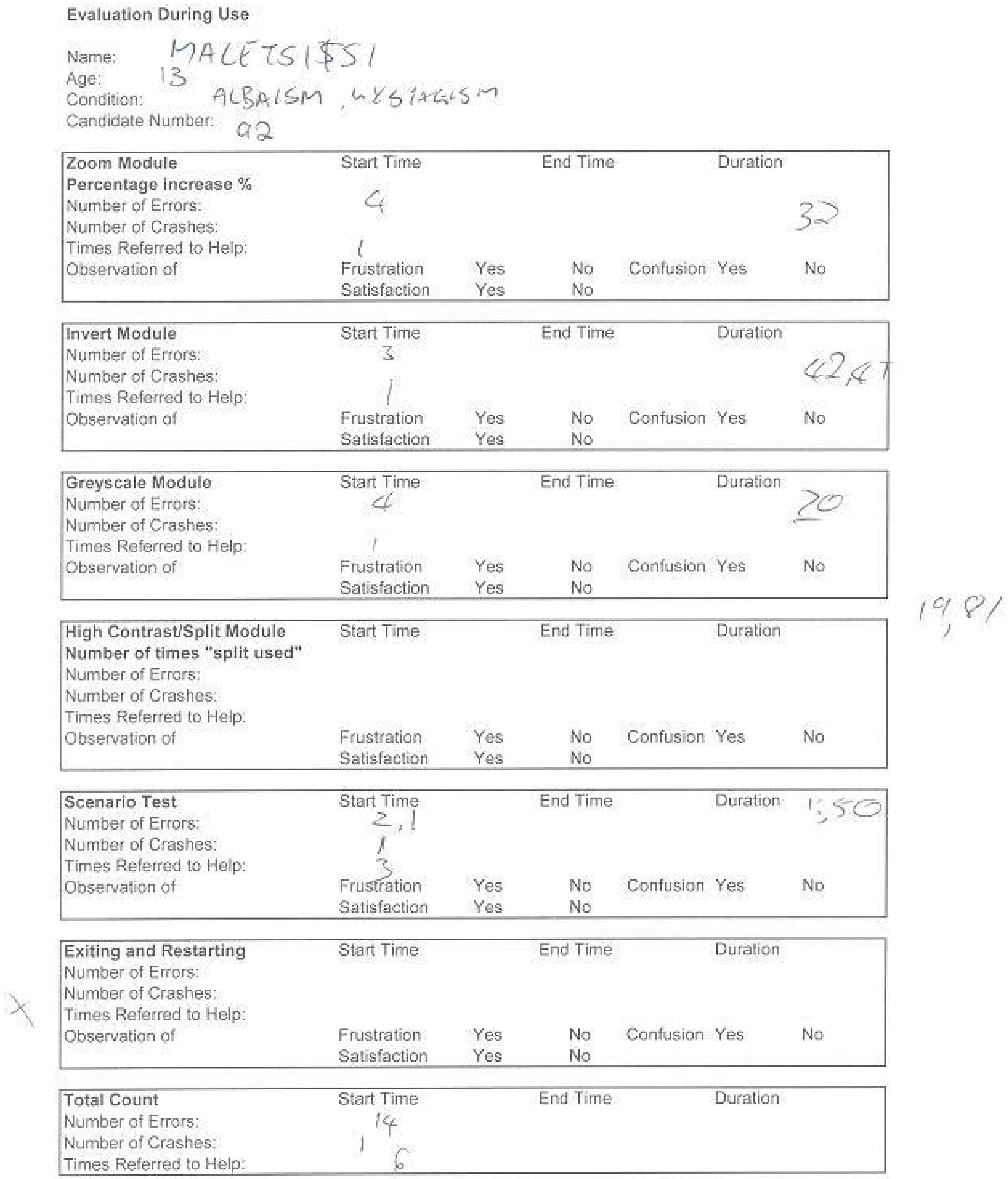
36

High Contrast/Split Module Start Time End Time Duration
Number of times "split used"
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 46
Number of Errors: 1
Number of Crashes:
Times Referred to Help: 3
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors: 6
Number of Crashes:
Times Referred to Help: 8



Evaluation During Use

Name: MALETSITSI
Age: 13
Condition: ALBAISM , NYSTAGISM
Candidate Number: 92

Zoom Module	Start Time		End Time		Duration	
Percentage increase %						
Number of Errors:	4					
Number of Crashes:					32	
Times Referred to Help:	1					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Invert Module	Start Time		End Time		Duration	
Number of Errors:	3					
Number of Crashes:					42AT	
Times Referred to Help:	1					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Greyscale Module	Start Time		End Time		Duration	
Number of Errors:	4				20	
Number of Crashes:						
Times Referred to Help:	1					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

19,81

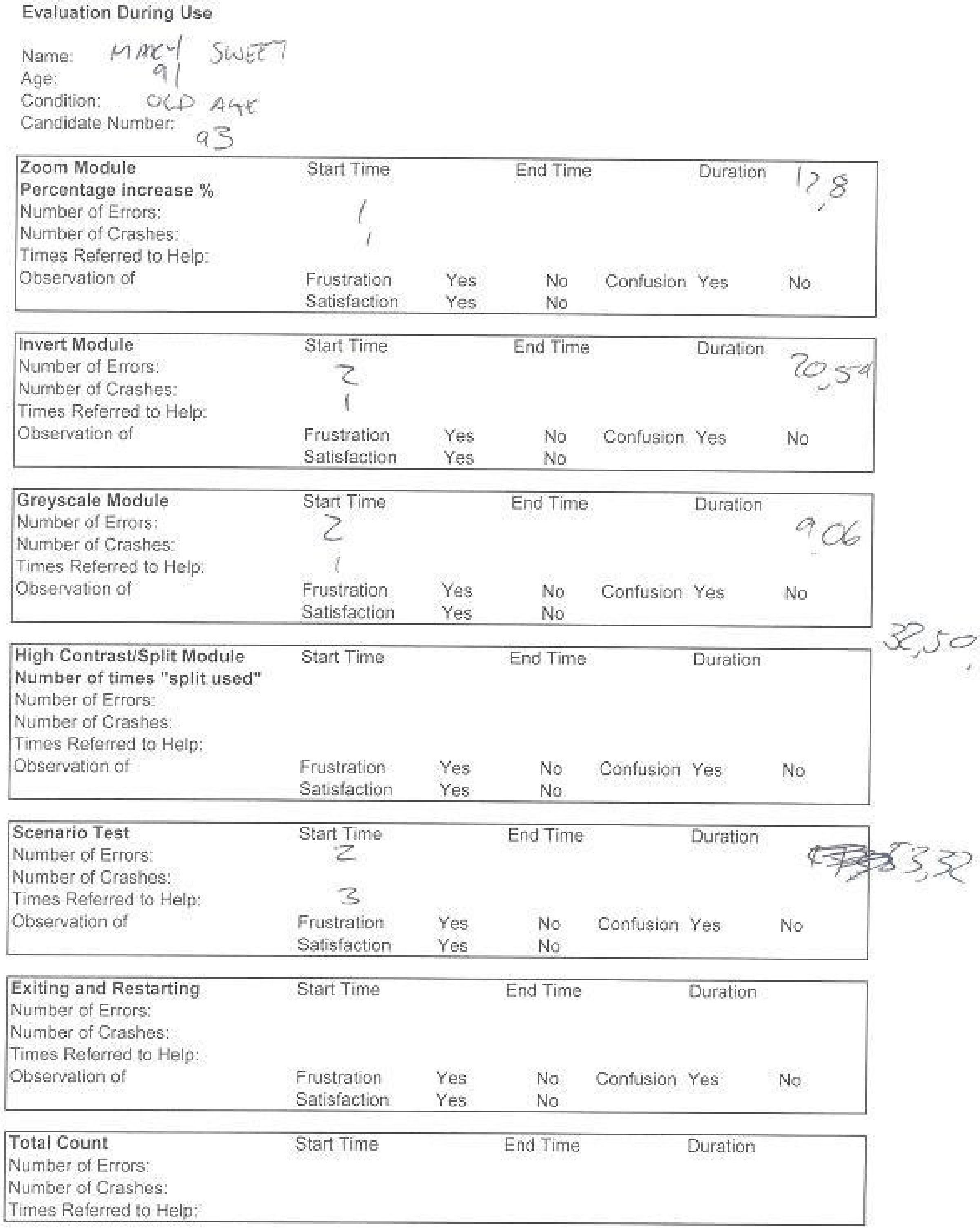
High Contrast/Split Module	Start Time		End Time		Duration	
Number of times "split used"						
Number of Errors:						
Number of Crashes:						
Times Referred to Help:						
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Scenario Test	Start Time		End Time		Duration	1:50
Number of Errors:	2,1					
Number of Crashes:	1					
Times Referred to Help:	3					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

X

Exiting and Restarting	Start Time		End Time		Duration	
Number of Errors:						
Number of Crashes:						
Times Referred to Help:						
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Total Count	Start Time		End Time		Duration	
Number of Errors:	14					
Number of Crashes:	1					
Times Referred to Help:	6					



Evaluation During Use

Name: MARY SWEET
Age: 91
Condition: OLD AGE
Candidate Number: 93

Zoom Module	Start Time		End Time	Duration	17,8
Percentage increase %					
Number of Errors:	1				
Number of Crashes:	1				
Times Referred to Help:					
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Invert Module	Start Time		End Time	Duration	20,54
Number of Errors:	2				
Number of Crashes:	1				
Times Referred to Help:					
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Greyscale Module	Start Time		End Time	Duration	9,06
Number of Errors:	2				
Number of Crashes:	1				
Times Referred to Help:					
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

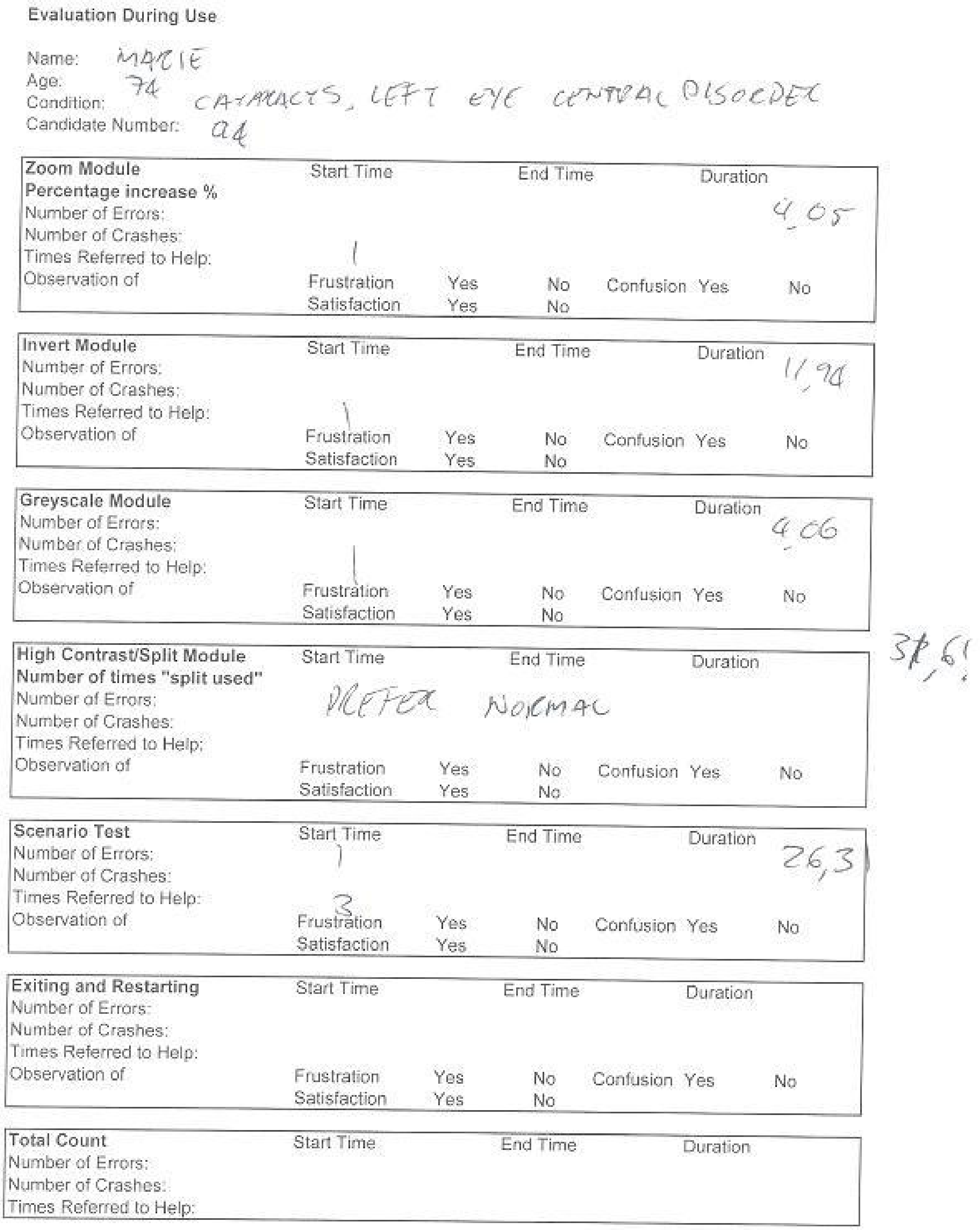
32,50

High Contrast/Split Module	Start Time		End Time	Duration	
Number of times "split used"					
Number of Errors:					
Number of Crashes:					
Times Referred to Help:					
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Scenario Test	Start Time		End Time	Duration	3,32
Number of Errors:	2				
Number of Crashes:					
Times Referred to Help:	3				
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Exiting and Restarting	Start Time		End Time	Duration	
Number of Errors:					
Number of Crashes:					
Times Referred to Help:					
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Total Count	Start Time	End Time	Duration
Number of Errors:			
Number of Crashes:			
Times Referred to Help:			



Evaluation During Use

Name: MARIE
Age: 74
Condition: CATARACTS, LEFT EYE CENTRAL DISORDER
Candidate Number: 04

Zoom Module
Percentage increase %
Start Time End Time Duration 4,05
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module
Start Time End Time Duration 1,94
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Greyscale Module
Start Time End Time Duration 4,06
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

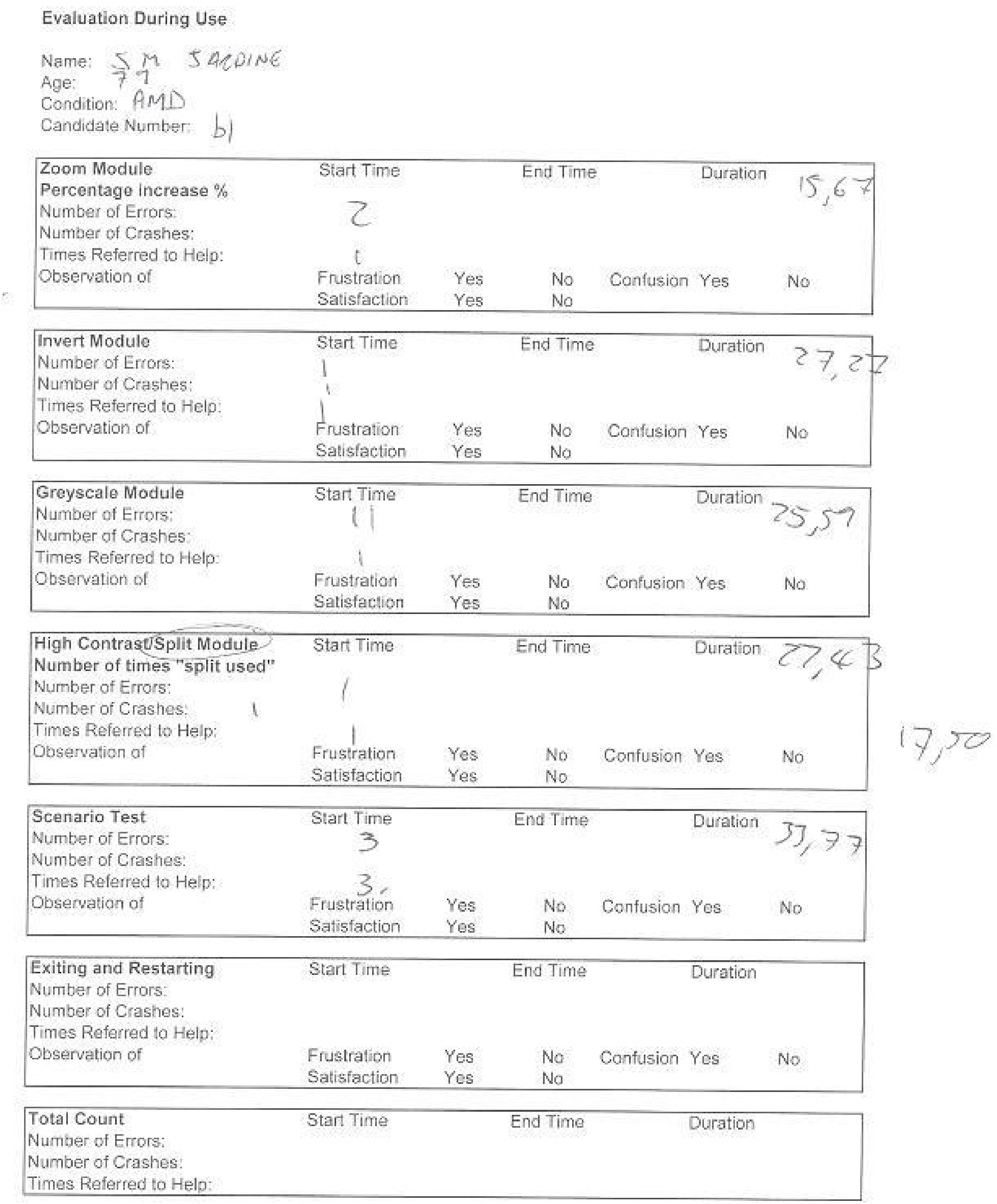
37,61

High Contrast/Split Module
Number of times "split used" PREFER NORMAL
Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test
Start Time End Time Duration 26,3
Number of Errors: 1
Number of Crashes:
Times Referred to Help: 3
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting
Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count
Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evaluation During Use

Name: S M SARDINE
Age: 77
Condition: AMD
Candidate Number: 61

Zoom Module Start Time End Time Duration 15,67
Percentage Increase %
Number of Errors: 2
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 27,27
Number of Errors: 1
Number of Crashes: 1
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Greyscale Module Start Time End Time Duration 25,59
Number of Errors: 11
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

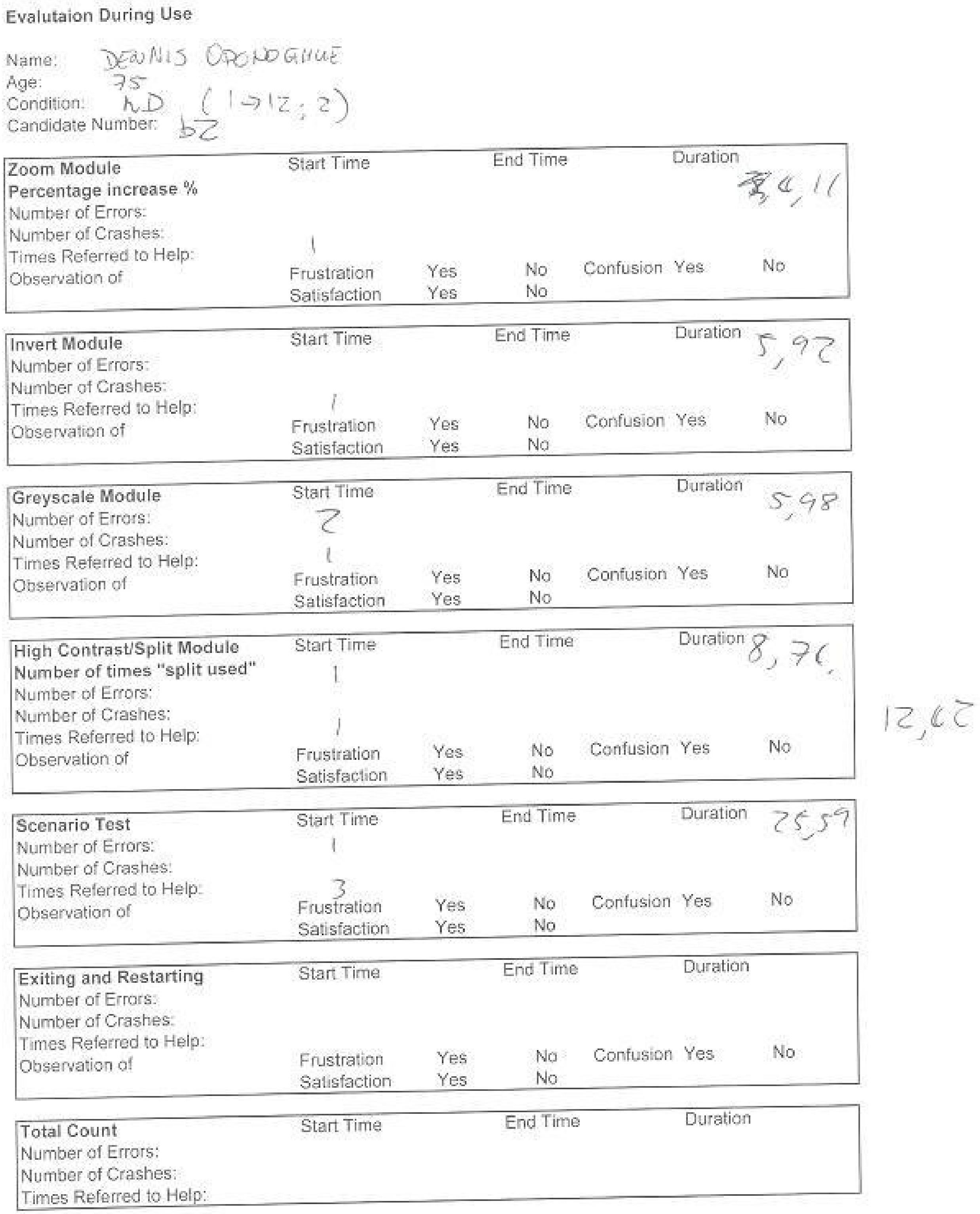
High Contrast/Split Module Start Time End Time Duration 27,43
Number of times "split used"
Number of Errors: 1
Number of Crashes: 1
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

17,50

Scenario Test Start Time End Time Duration 37,77
Number of Errors: 3
Number of Crashes:
Times Referred to Help: 3,
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evalutaion During Use

Name: DENNIS ORONOGHUE
Age: 75
Condition: AD (1→12; 2)
Candidate Number: 62

Zoom Module
Percentage increase %
Start Time
End Time
Duration ~~3~~4,11
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of
Frustration Yes No
Confusion Yes No
Satisfaction Yes No

Invert Module
Start Time
End Time
Duration 5,92
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of
Frustration Yes No
Confusion Yes No
Satisfaction Yes No

Greyscale Module
Start Time
End Time
Duration 5,98
Number of Errors: 2
Number of Crashes:
Times Referred to Help: 1
Observation of
Frustration Yes No
Confusion Yes No
Satisfaction Yes No

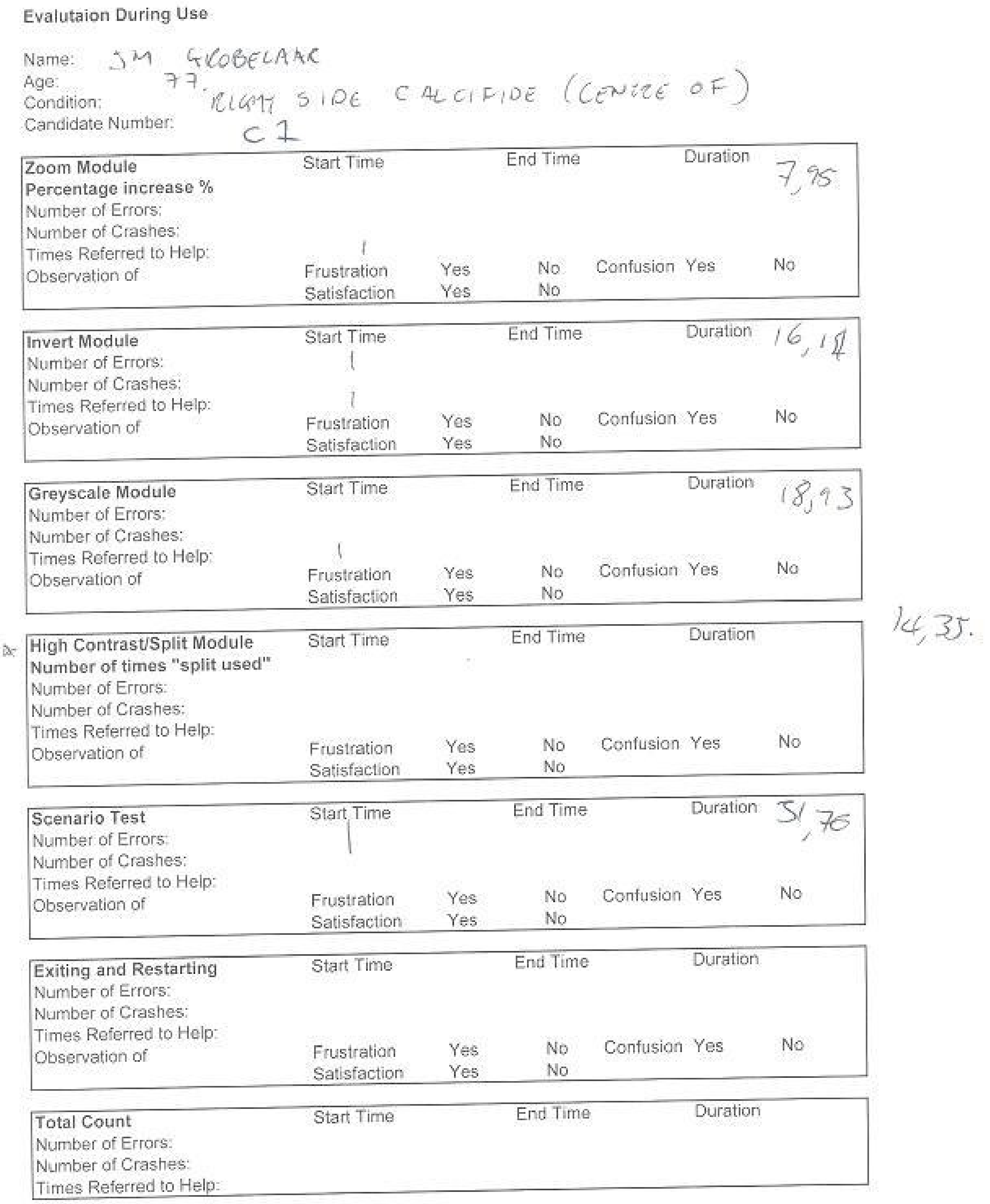
High Contrast/Split Module
Number of times "split used" 1
Start Time
End Time
Duration 8,76
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of
Frustration Yes No
Confusion Yes No
Satisfaction Yes No

12,62

Scenario Test
Start Time
End Time
Duration 25,59
Number of Errors: 1
Number of Crashes:
Times Referred to Help: 3
Observation of
Frustration Yes No
Confusion Yes No
Satisfaction Yes No

Exiting and Restarting
Start Time
End Time
Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of
Frustration Yes No
Confusion Yes No
Satisfaction Yes No

Total Count
Start Time
End Time
Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evalutaion During Use

Name: JM GROBELAAR
Age: 77.
Condition: RIGHT SIDE CALCIFIDE (CENTRE OF)
Candidate Number: C1

Zoom Module Start Time End Time Duration 7,95
Percentage increase %
Number of Errors:
Number of Crashes: |
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 16,14
Number of Errors: |
Number of Crashes:
Times Referred to Help: |
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

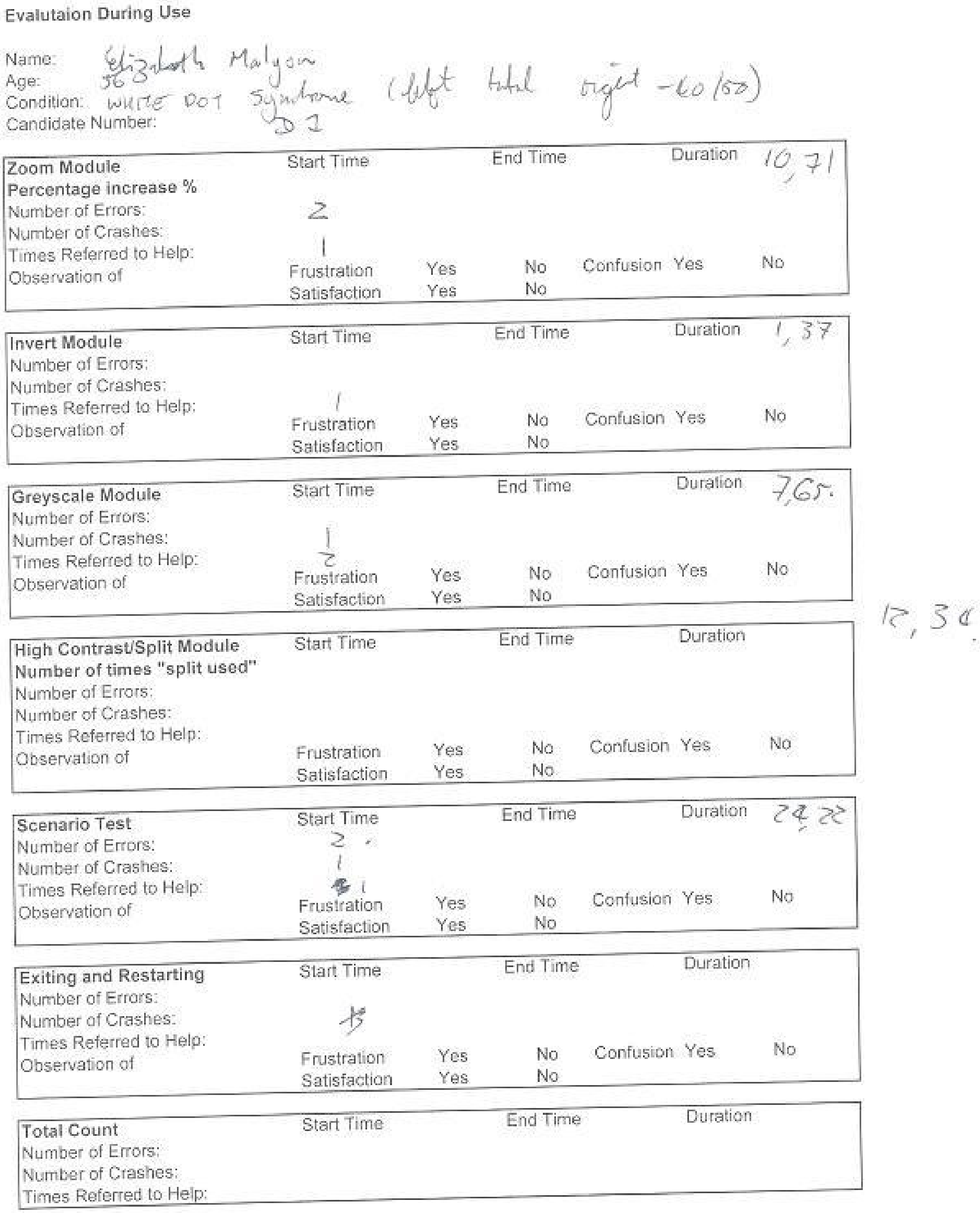
Greyscale Module Start Time End Time Duration 18,93
Number of Errors:
Number of Crashes: |
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 14,35.
Number of times "split used"
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 51,76
Number of Errors: |
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evalutaion During Use

Name: Elizabeth Malyon
Age: 56
Condition: WHITE DOT Syndrome (left total right -60/60)
Candidate Number: D1

Zoom Module Start Time End Time Duration 10,71
Percentage increase %
Number of Errors: 2
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 1,37
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

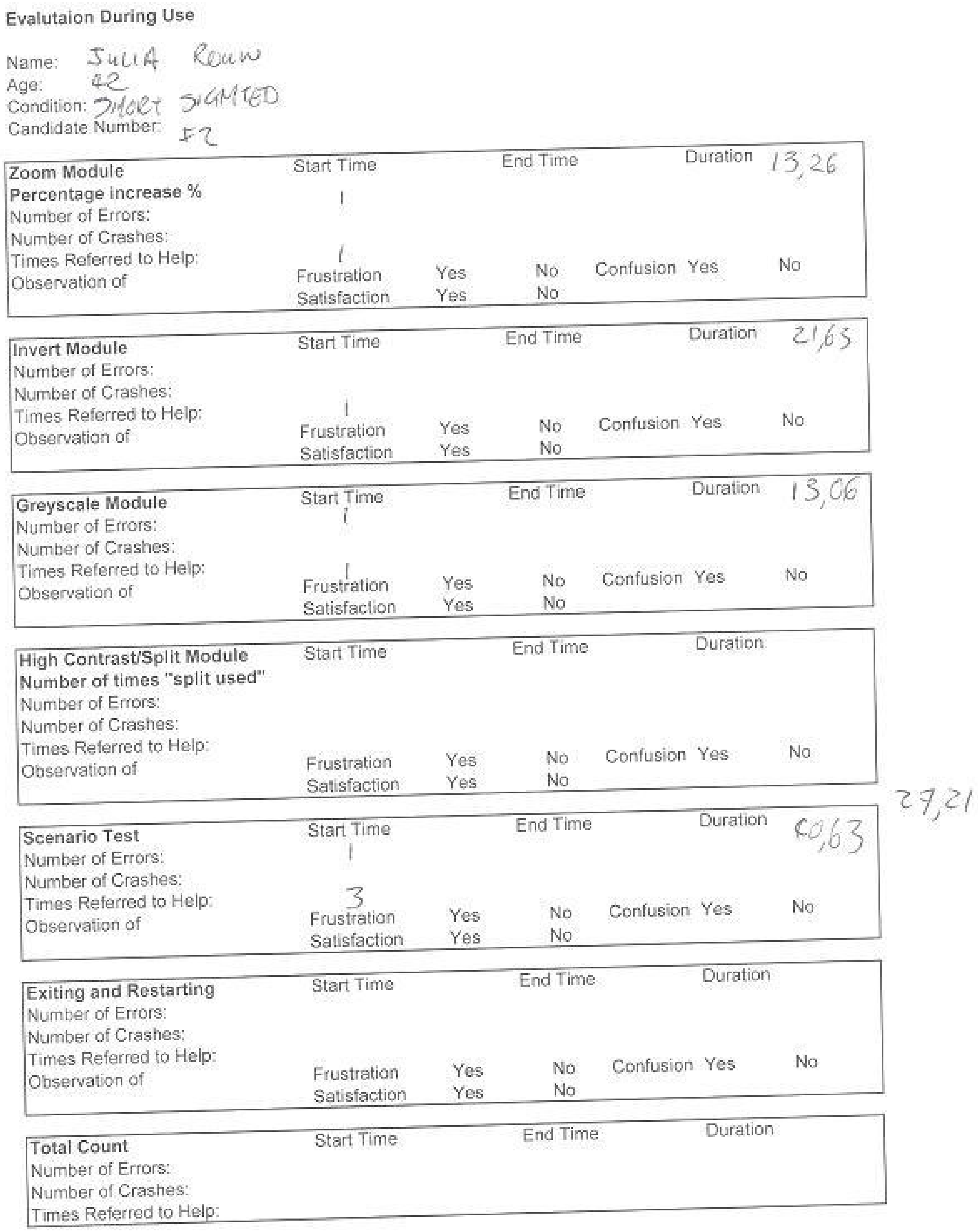
Greyscale Module Start Time End Time Duration 7,65.
Number of Errors:
Number of Crashes: 1
Times Referred to Help: 2
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

High Contrast/Split Module Start Time End Time Duration 12,34.
Number of times "split used"
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Scenario Test Start Time End Time Duration 24,22
Number of Errors: 2
Number of Crashes: 1
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration
Number of Errors:
Number of Crashes: 15
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evalutaion During Use

Name: JULIA ROUW
Age: 42
Condition: SHORT SIGHTED
Candidate Number: F2

Zoom Module Start Time End Time Duration 13,26
Percentage increase % 1
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Invert Module Start Time End Time Duration 21,63
Number of Errors:
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Greyscale Module Start Time End Time Duration 13,06
Number of Errors: 1
Number of Crashes:
Times Referred to Help: 1
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

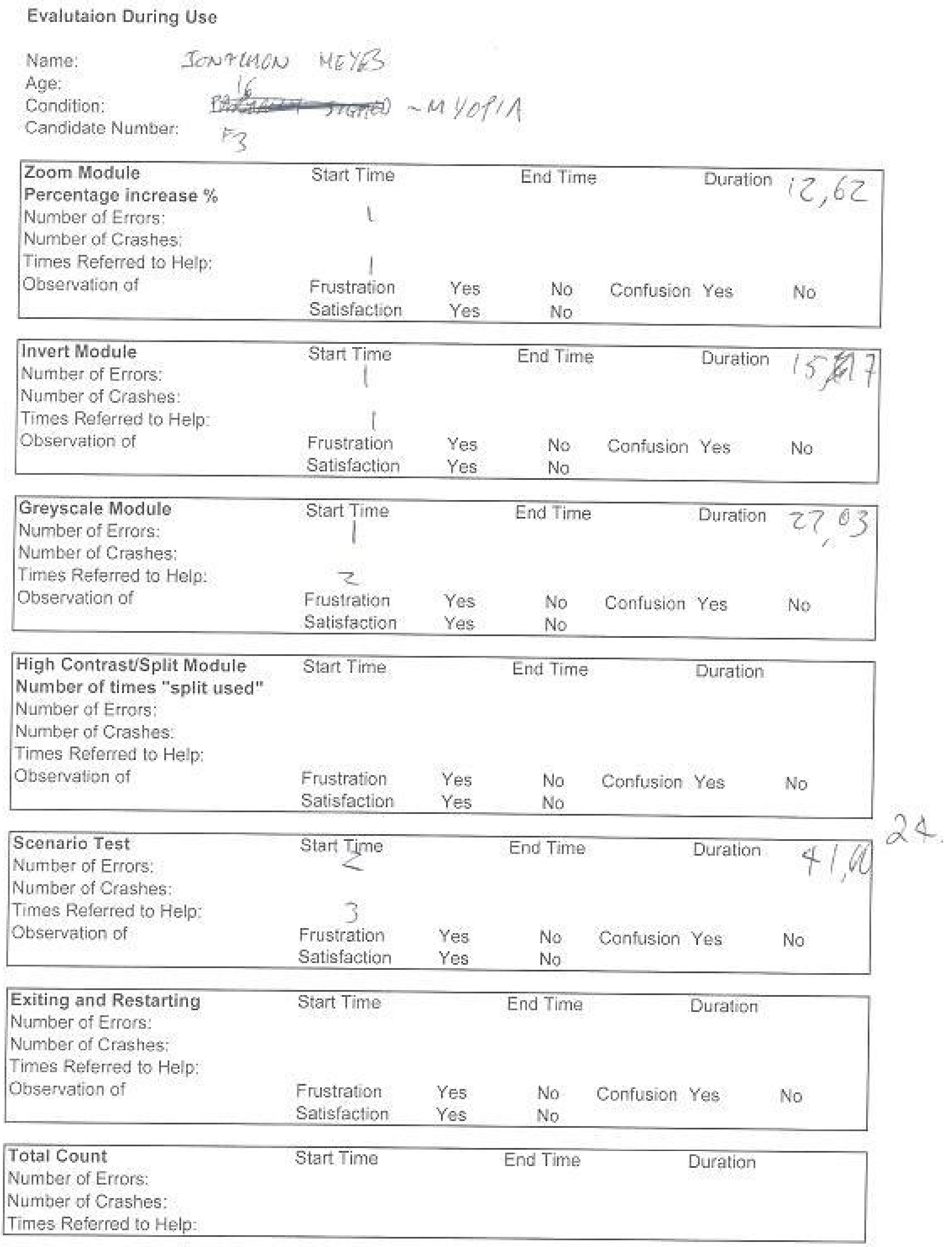
High Contrast/Split Module Start Time End Time Duration
Number of times "split used"
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

27,21

Scenario Test Start Time End Time Duration 60,63
Number of Errors: 1
Number of Crashes:
Times Referred to Help: 3
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Exiting and Restarting Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:
Observation of Frustration Yes No Confusion Yes No
Satisfaction Yes No

Total Count Start Time End Time Duration
Number of Errors:
Number of Crashes:
Times Referred to Help:



Evalutaion During Use

Name: JONTHON MEYES
Age: 16
Condition: ~~[illegible] SIGNED)~~ ~MYOPIA
Candidate Number: F3

Zoom Module	Start Time		End Time		Duration	12,62
Percentage increase %						
Number of Errors:	1					
Number of Crashes:						
Times Referred to Help:	1					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Invert Module	Start Time		End Time		Duration	15,~~[illegible]~~7
Number of Errors:	1					
Number of Crashes:						
Times Referred to Help:	1					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Greyscale Module	Start Time		End Time		Duration	27,03
Number of Errors:	1					
Number of Crashes:						
Times Referred to Help:	2					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

High Contrast/Split Module	Start Time		End Time		Duration	
Number of times "split used"						
Number of Errors:						
Number of Crashes:						
Times Referred to Help:						
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

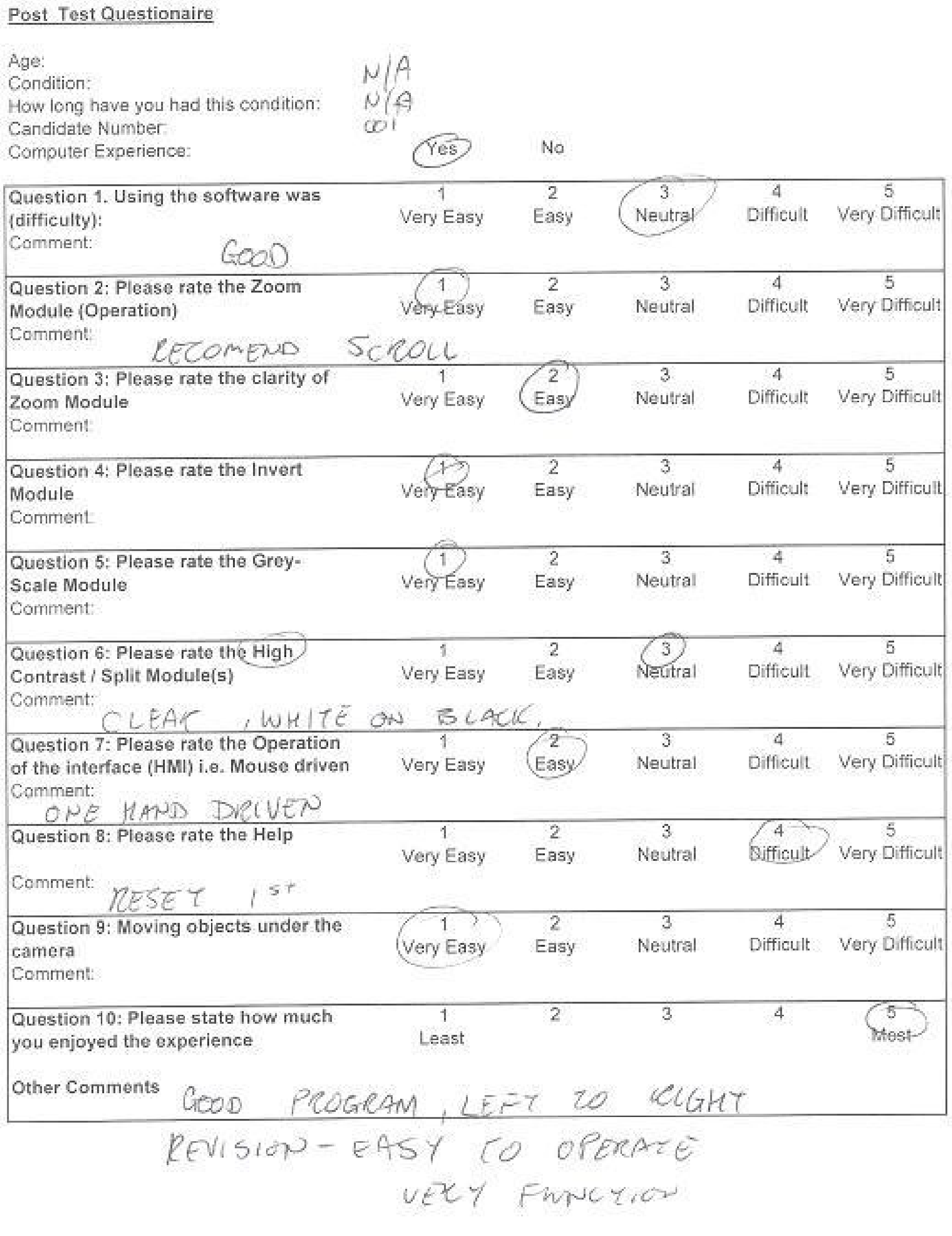
24.

Scenario Test	Start Time		End Time		Duration	41,0
Number of Errors:	2					
Number of Crashes:						
Times Referred to Help:	3					
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Exiting and Restarting	Start Time		End Time		Duration	
Number of Errors:						
Number of Crashes:						
Times Referred to Help:						
Observation of	Frustration	Yes	No	Confusion	Yes	No
	Satisfaction	Yes	No			

Total Count	Start Time	End Time	Duration
Number of Errors:			
Number of Crashes:			
Times Referred to Help:			

Appendix E.5. Posttest Questionaire Sheets

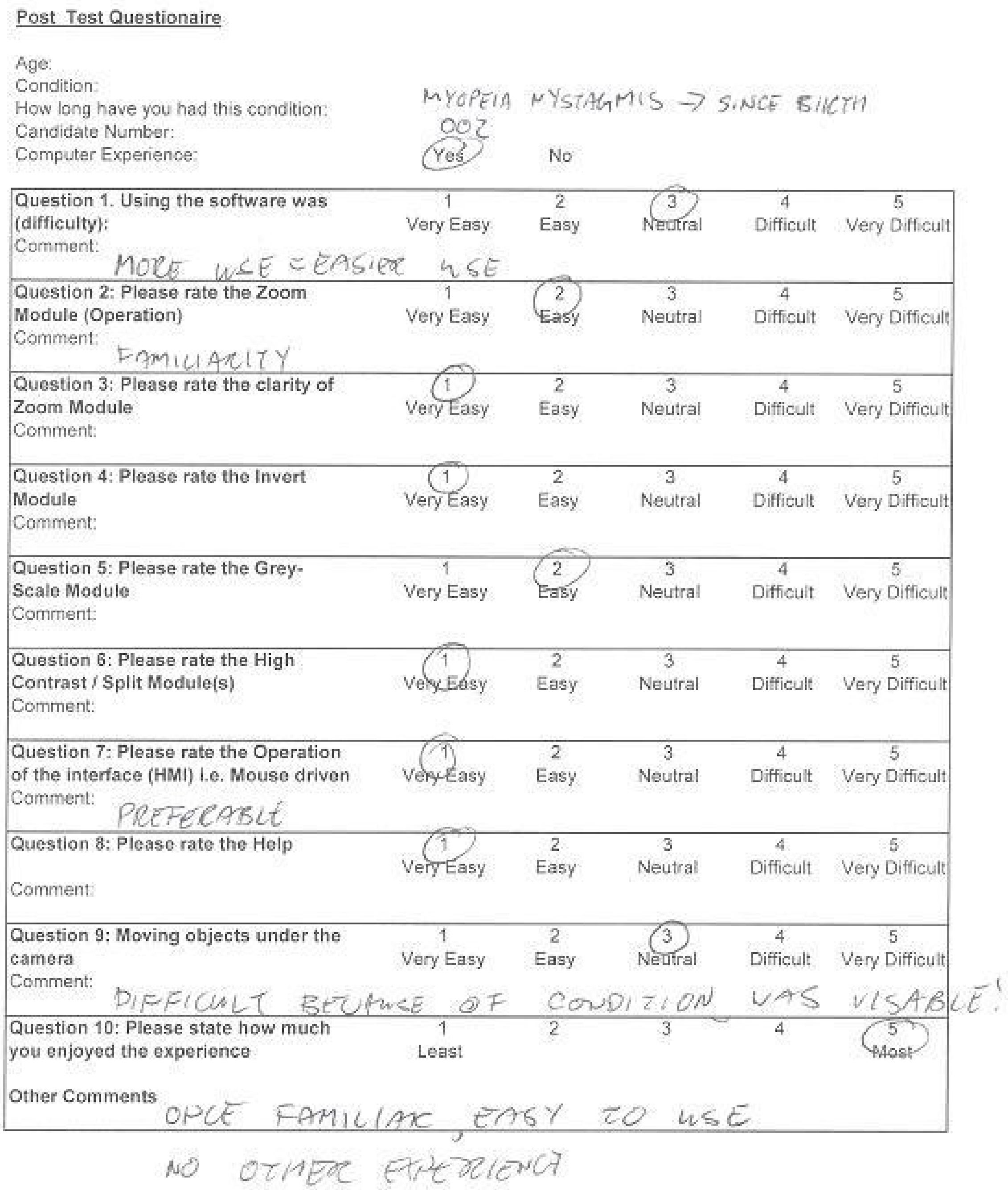


Post Test Questionaire

Age: N/A
Condition:
How long have you had this condition: N/A
Candidate Number: 001
Computer Experience: [✓ Yes] No

Question 1. Using the software was (difficulty): Comment: GOOD	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment: RECOMEND SCROLL	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment: CLEAR, WHITE ON BLACK,	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment: ONE HAND DRIVEN	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment: RESET 1st	1 Very Easy	2 Easy	3 Neutral	[✓ 4 Difficult]	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience	1 Least	2	3	4	[✓ 5 Most]

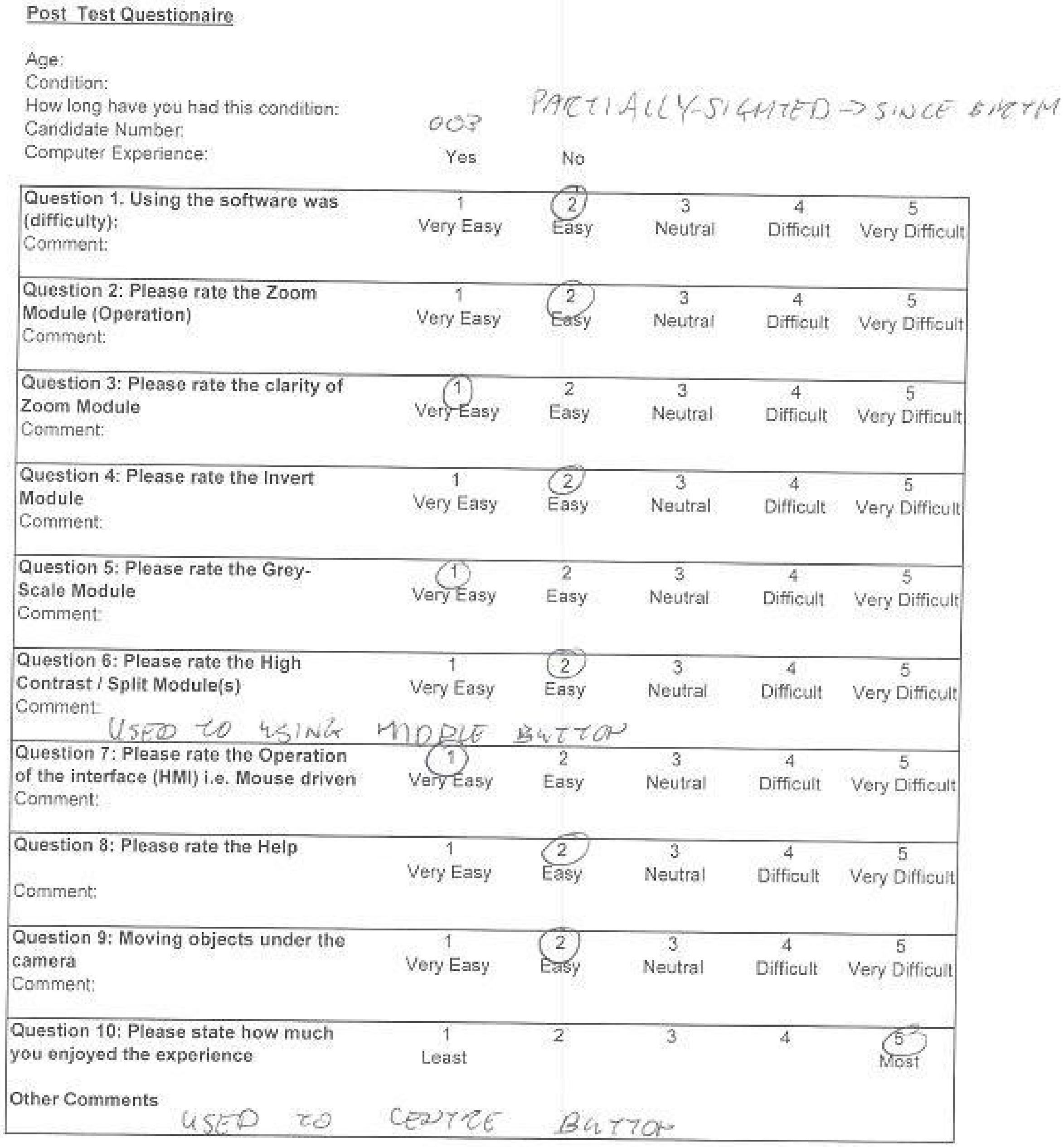
Other Comments GOOD PROGRAM, LEFT TO RIGHT REVISION - EASY TO OPERATE VERY FUNCTION



Post Test Questionaire

Age:
Condition: MYOPEIA NYSTAGMIS → SINCE BIRTH
How long have you had this condition:
Candidate Number: 002
Computer Experience: [✓ Yes] No

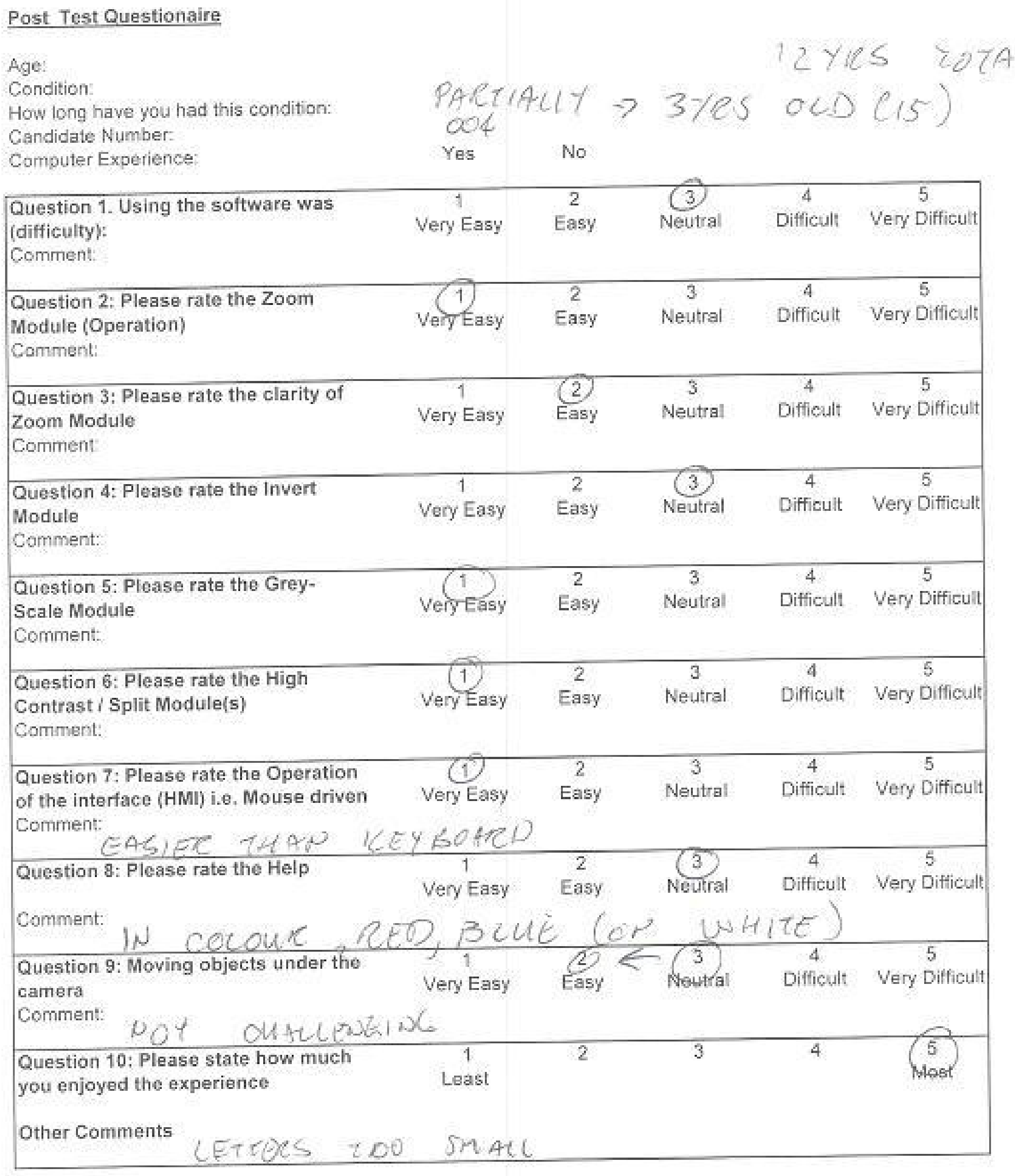
Question 1. Using the software was (difficulty): Comment: MORE USE = EASIER USE	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment: FAMILIARITY	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment: PREFERABLE	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment: DIFFICULT BECAUSE OF CONDITION WAS VISABLE!	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience	1 Least	2	3	4	[✓ 5 Most]
Other Comments ONCE FAMILIAR, EASY TO USE NO OTHER EXPERIENCE					



Post Test Questionaire

Age:
Condition: PARTIALLY-SIGHTED → SINCE BIRTH
How long have you had this condition:
Candidate Number: 003
Computer Experience: Yes No

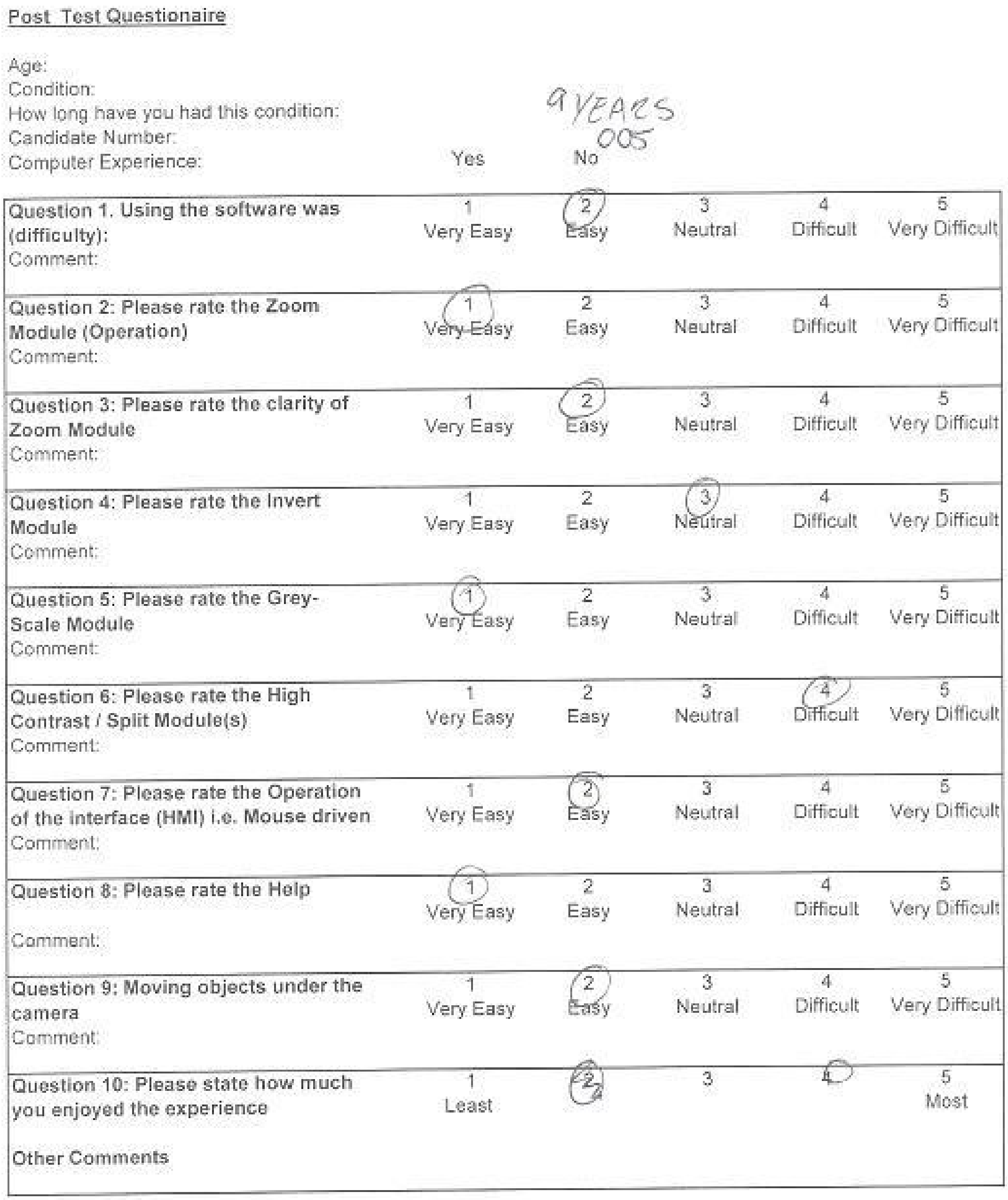
Question 1. Using the software was (difficulty): Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment: USED TO USING MIDDLE BUTTON	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments** USED TO CENTRE BUTTON	1 Least	2	3	4	[✓ 5 Most]



Post Test Questionaire

Age: 12 YRS TOTAL
Condition: PARTIALLY → 3YRS OLD (15)
How long have you had this condition:
Candidate Number: 004
Computer Experience: Yes No

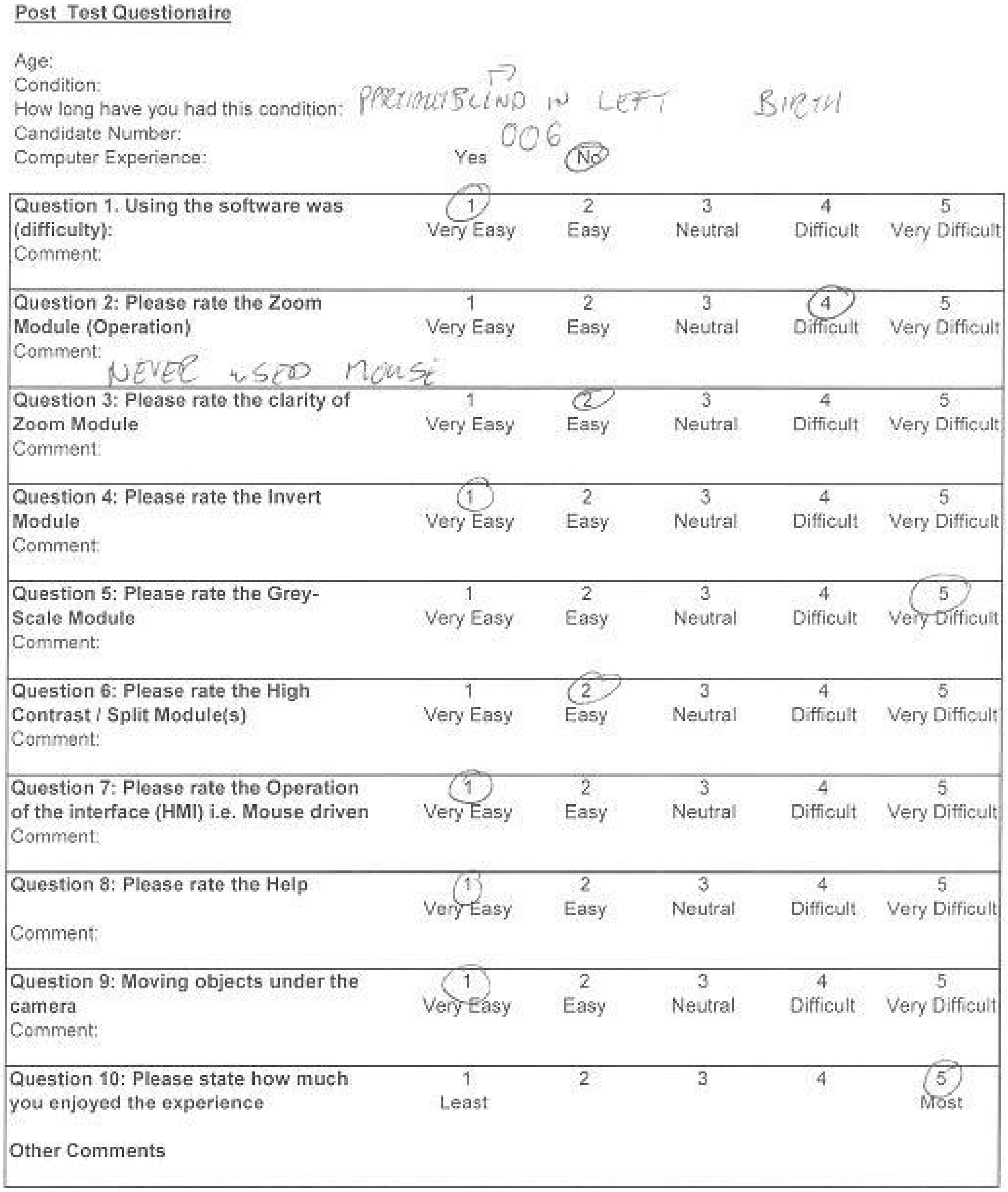
Question 1. Using the software was (difficulty): Comment:	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment: EASIER THAN KEYBOARD	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment: IN COLOUR, RED, BLUE (OR WHITE)	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment: NOT CHALLENGING	1 Very Easy	[✓ 2 Easy] ←	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience	1 Least	2	3	4	[✓ 5 Most]
Other Comments LETTERS TOO SMALL					



Post Test Questionaire

Age:
Condition:
How long have you had this condition: 9 YEARS
Candidate Number: 005
Computer Experience: Yes No

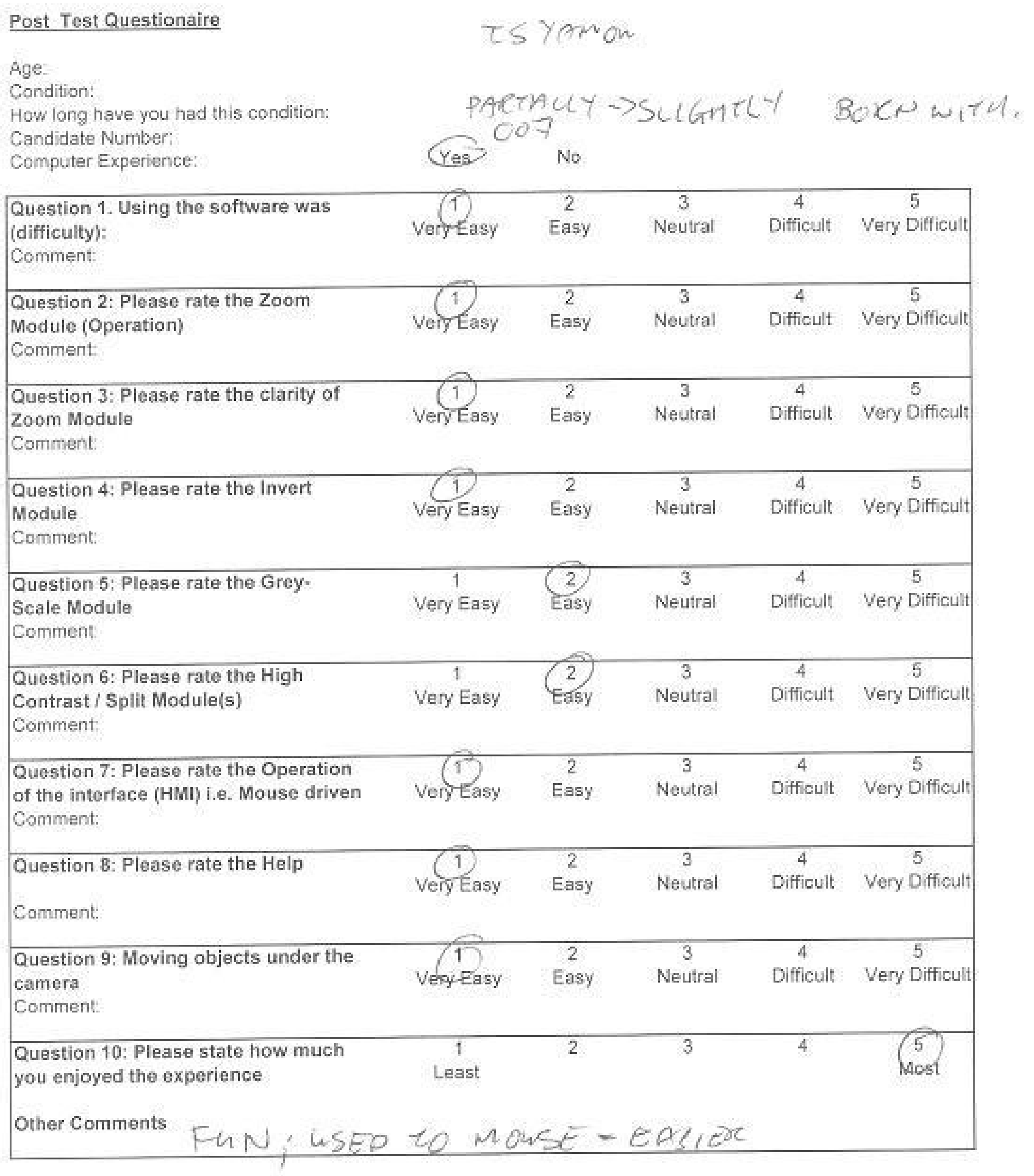
Question 1. Using the software was (difficulty): Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	2 Easy	3 Neutral	[✓ 4] Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	1 Least	[✓ 2]	3	[✓ 4]	5 Most



Post Test Questionaire

Age:
Condition: PARTIALLY BLIND IN LEFT
How long have you had this condition: BIRTH
Candidate Number: 006
Computer Experience: Yes [✓ No]

Question 1. Using the software was (difficulty): Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment: NEVER USED MOUSE	1 Very Easy	2 Easy	3 Neutral	[✓ 4] Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	2 Easy	3 Neutral	4 Difficult	[✓ 5] Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	1 Least	2	3	4	[✓ 5] Most

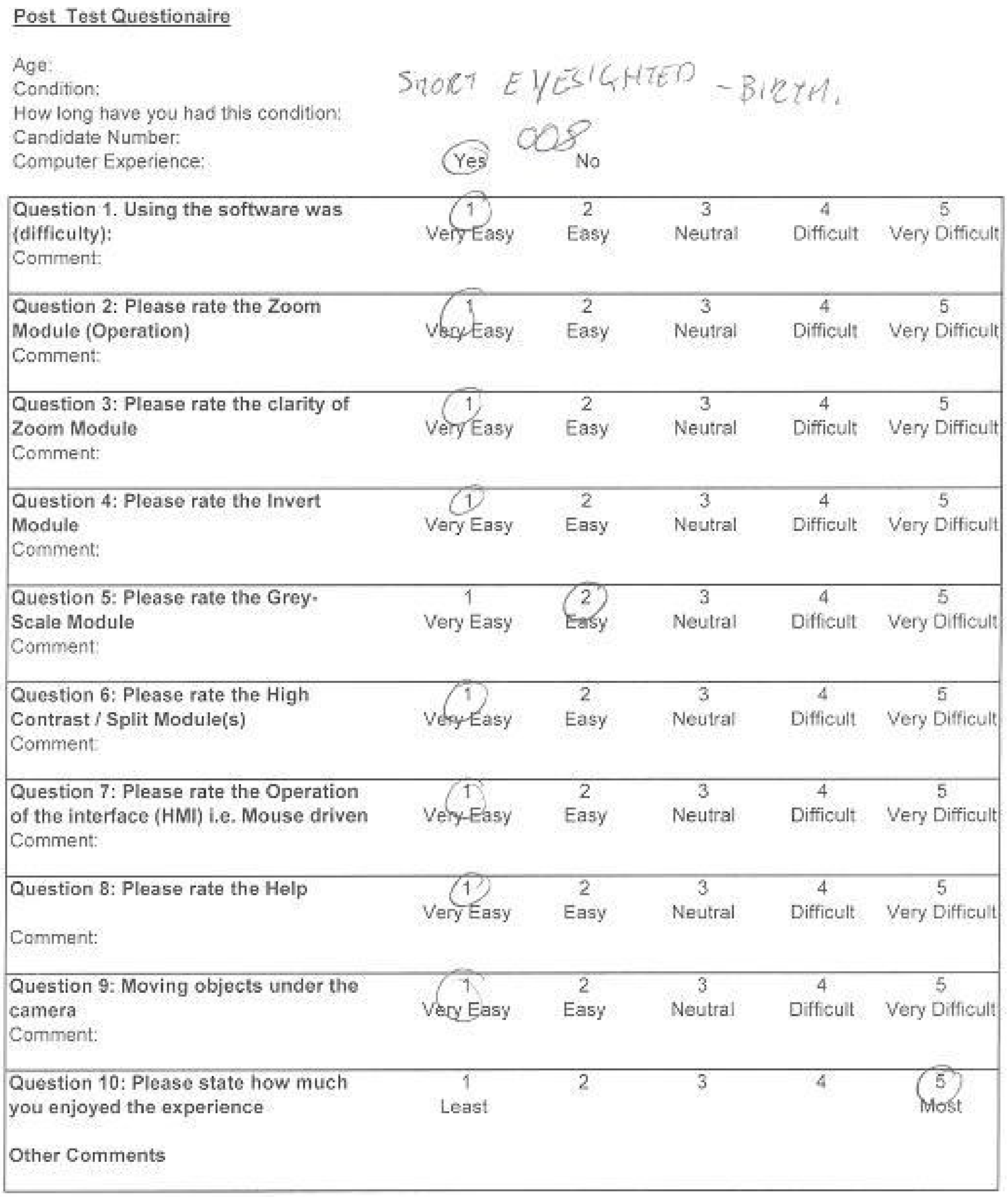


Post Test Questionaire

TS YAMON

Age:
Condition: PARTIALLY ->SLIGHTLY
How long have you had this condition: BORN WITH.
Candidate Number: 007
Computer Experience: [✓ Yes] No

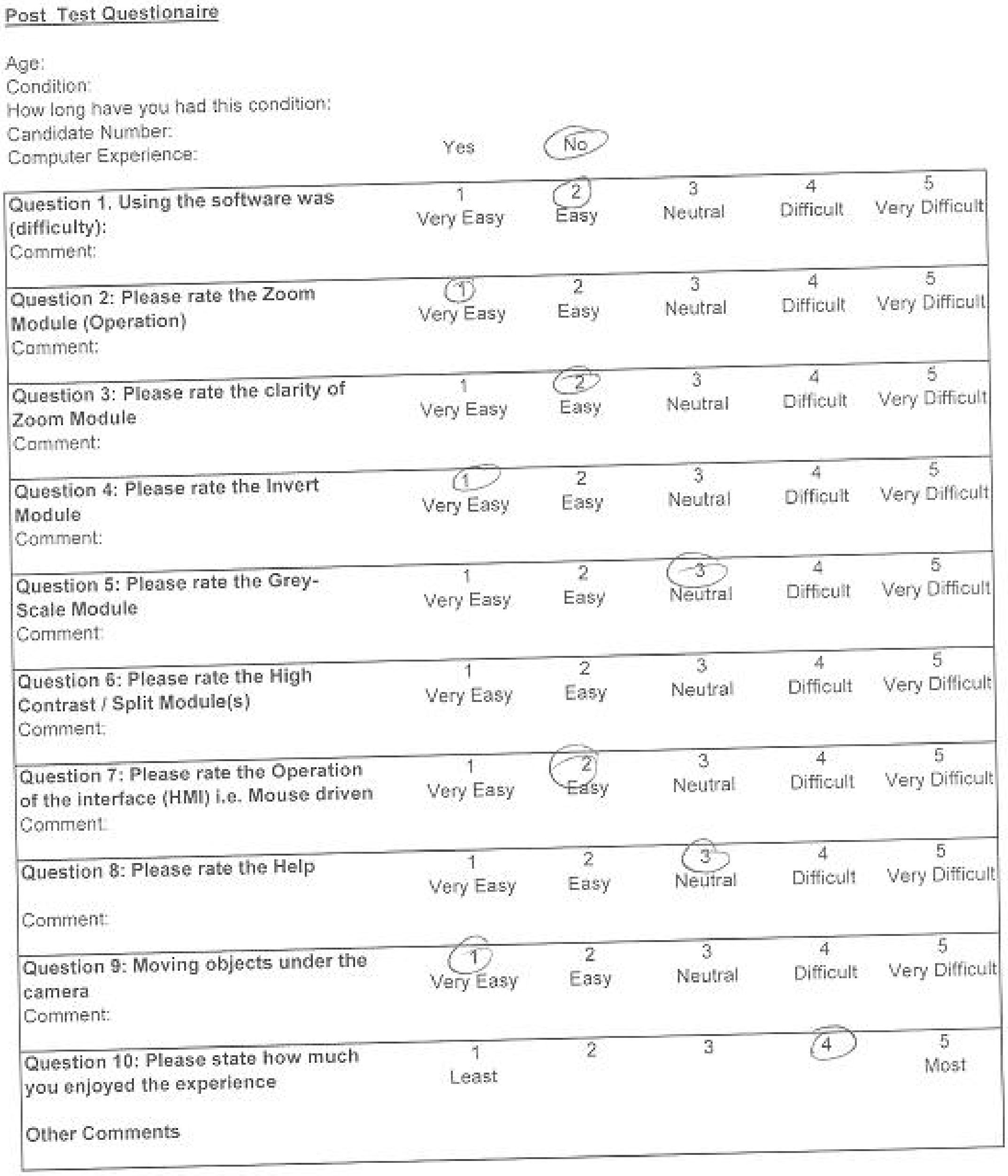
Question 1. Using the software was (difficulty): Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience	1 Least	2	3	4	[✓ 5 Most]
Other Comments FUN; USED TO MOUSE - EASIER					



Post Test Questionaire

Age:
Condition: SHORT EYESIGHTED - BIRTH.
How long have you had this condition:
Candidate Number: 008
Computer Experience: [✓ Yes] No

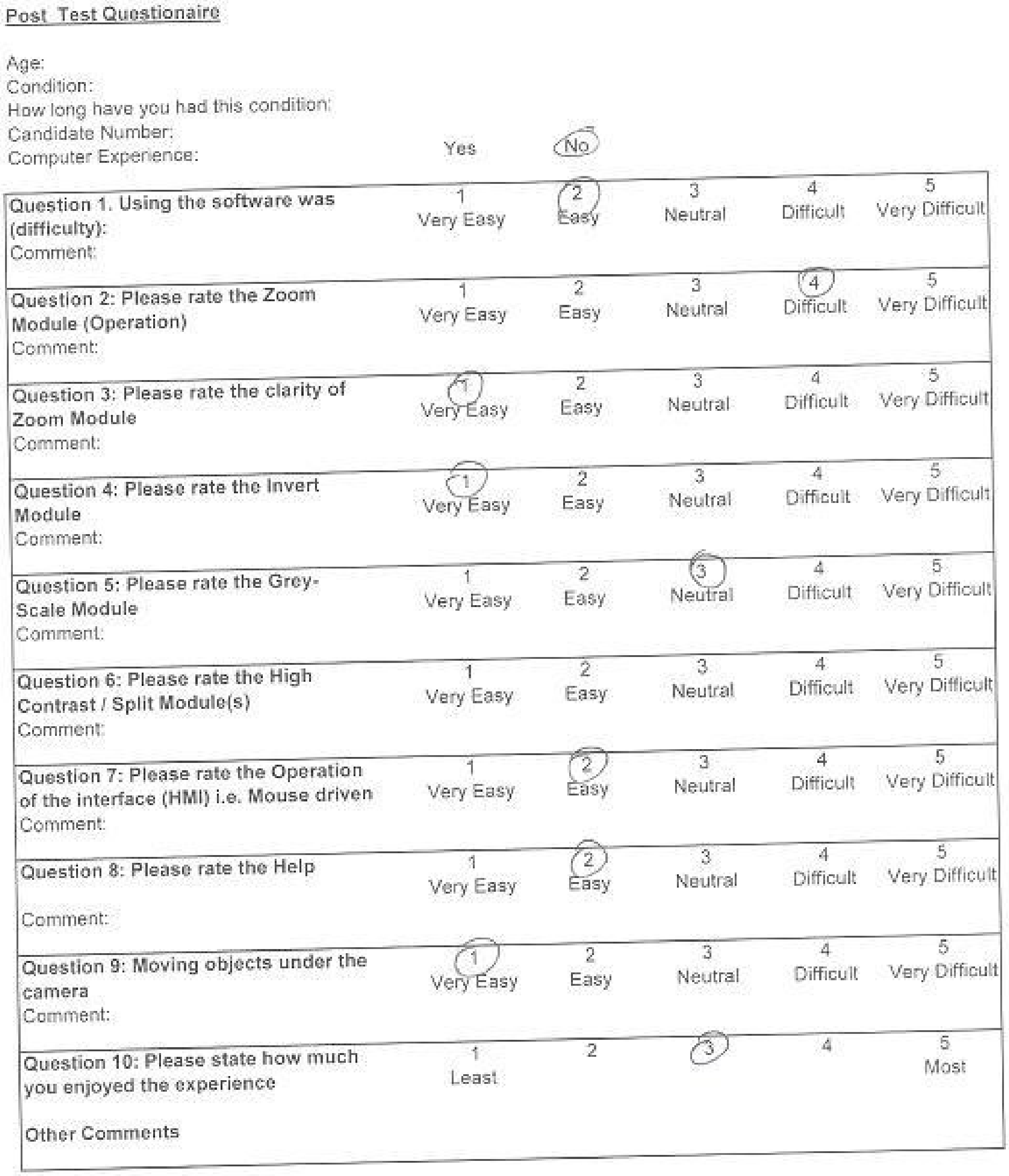
Question 1. Using the software was (difficulty): Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	1 Least	2	3	4	[✓ 5 Most]



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes [✓ No]

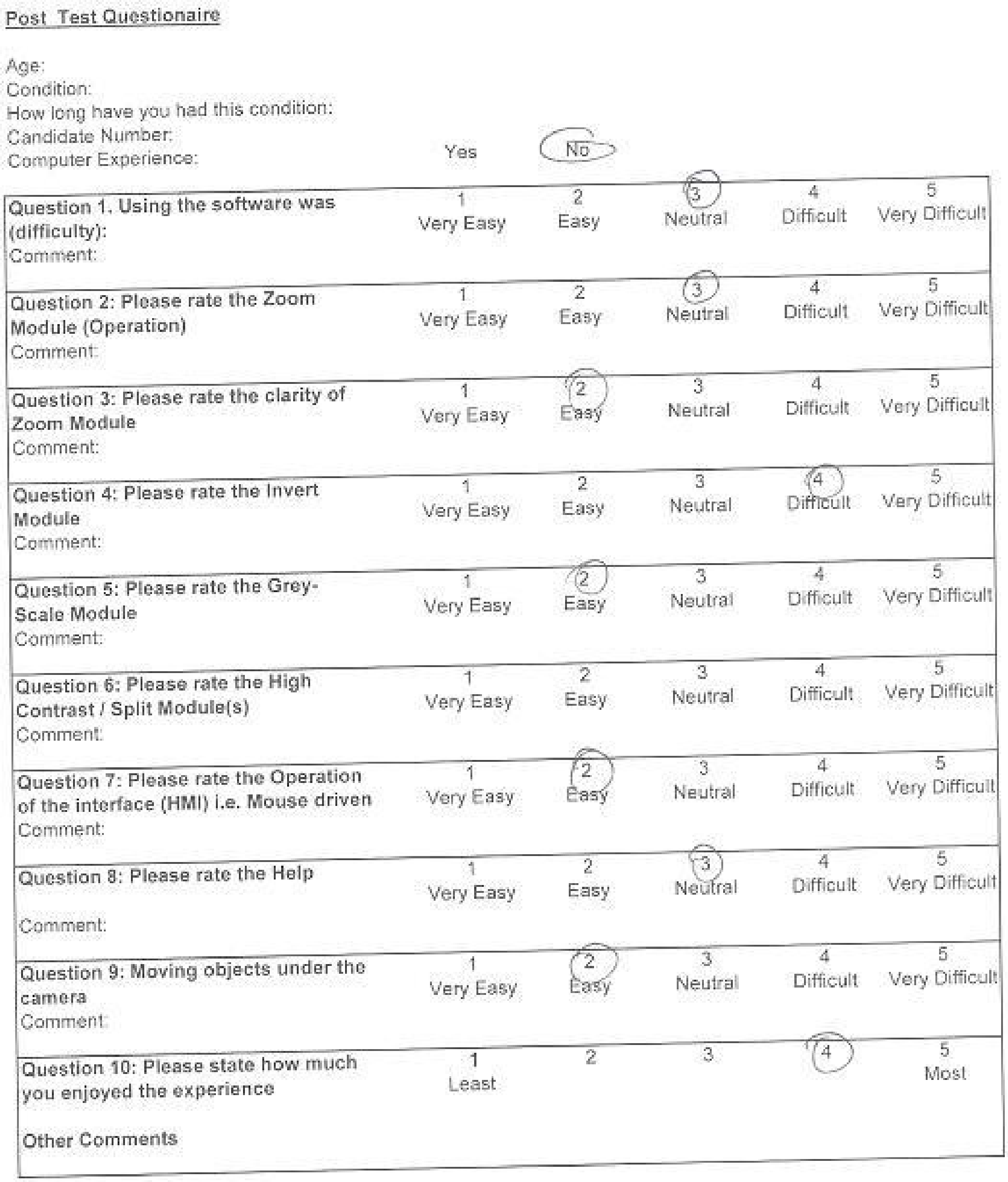
Question 1. Using the software was (difficulty): Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	1 Least	2	3	[✓ 4]	5 Most



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes [✓ No]

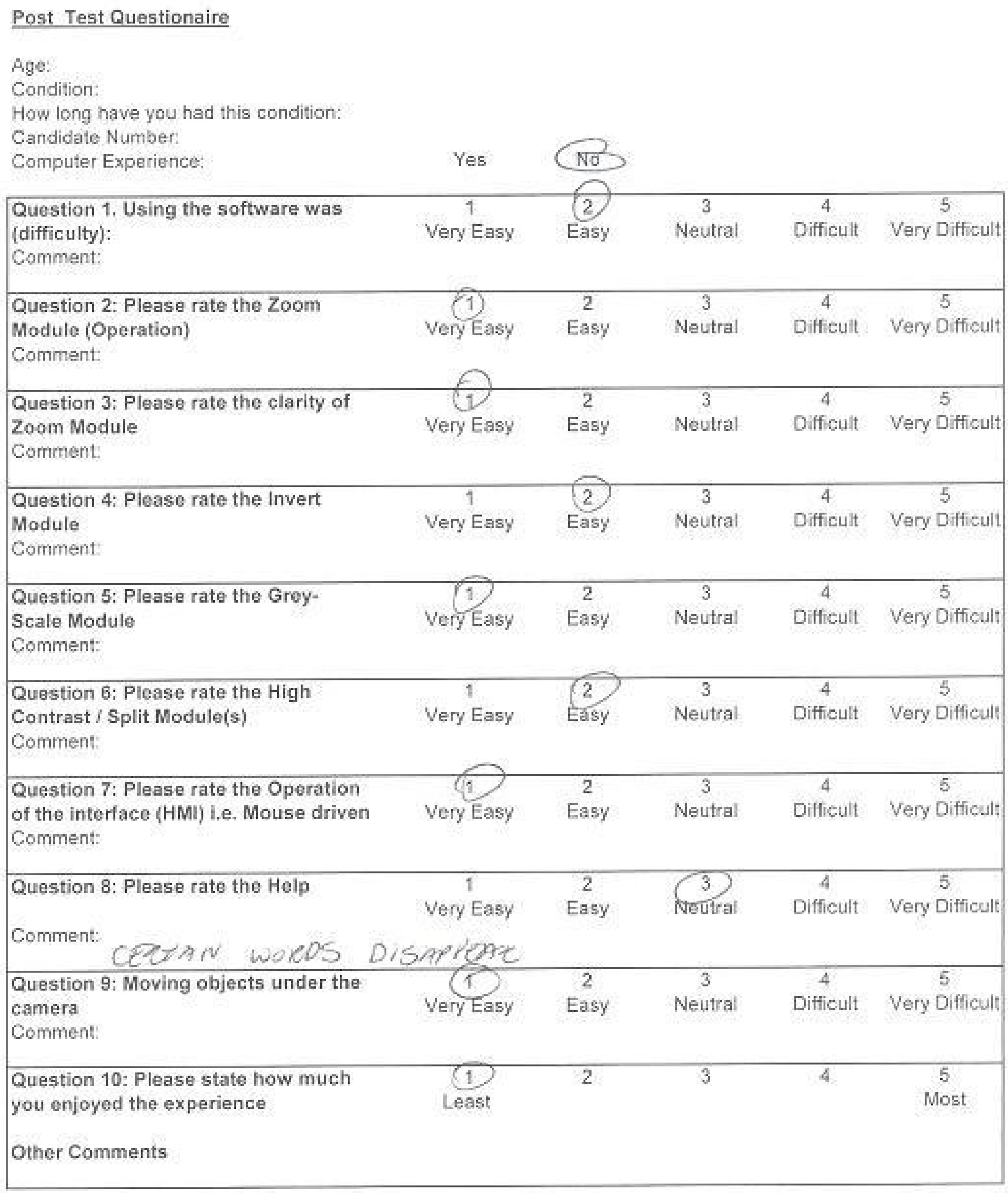
Question 1. Using the software was (difficulty): Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	2 Easy	3 Neutral	[✓ 4] Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	1 Least	2	[✓ 3]	4	5 Most



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes [✓ No]

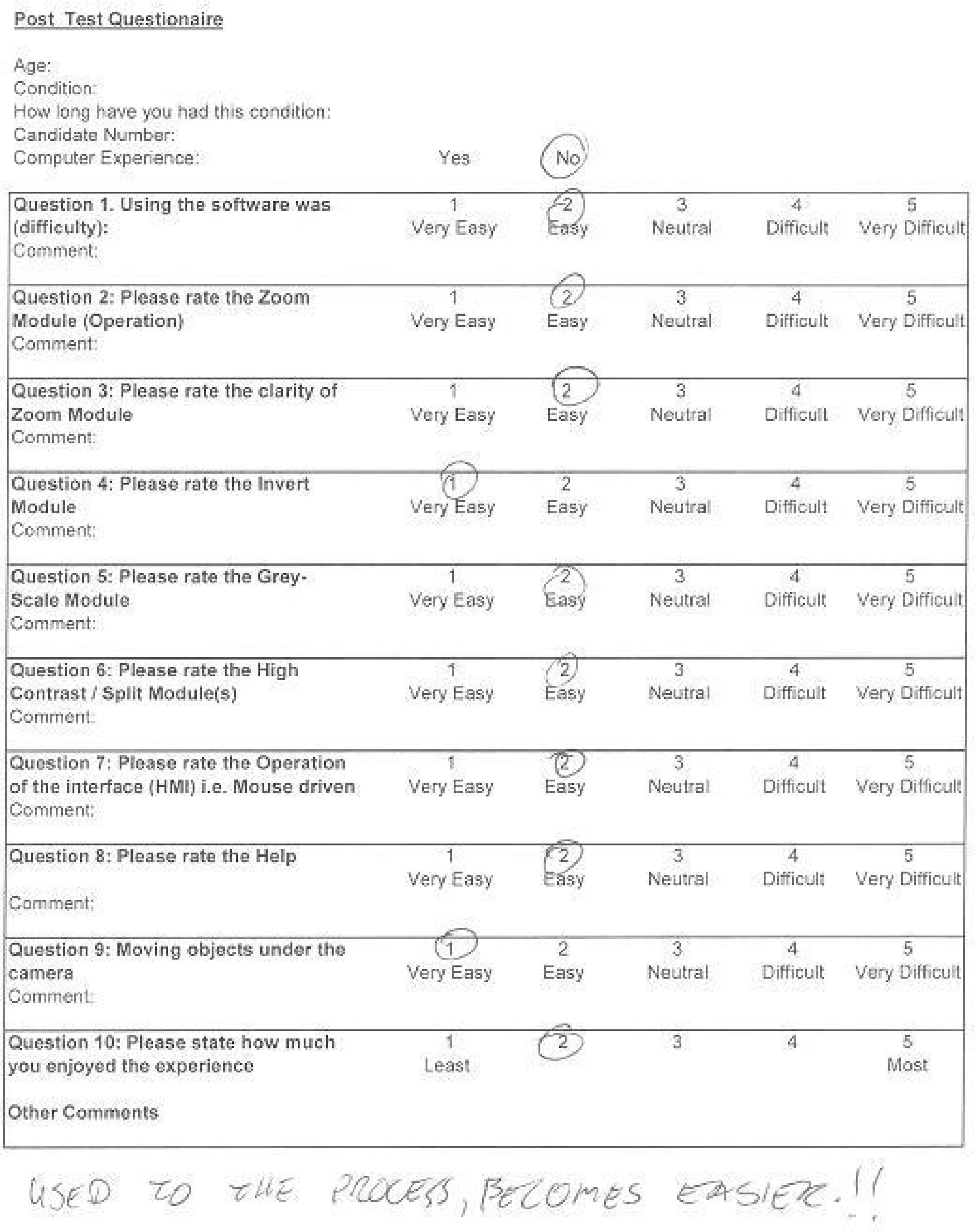
Question 1. Using the software was (difficulty): Comment:	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	1 Very Easy	2 Easy	3 Neutral	[✓ 4 Difficult]	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	1 Very Easy	2 Easy	[✓ 3 Neutral]	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	1 Least	2	3	[✓ 4]	5 Most



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes [✓ No]

Question 1. Using the software was (difficulty): Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment: CERTAIN WORDS DISAPPEAR	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	[✓ 1] Least	2	3	4	5 Most

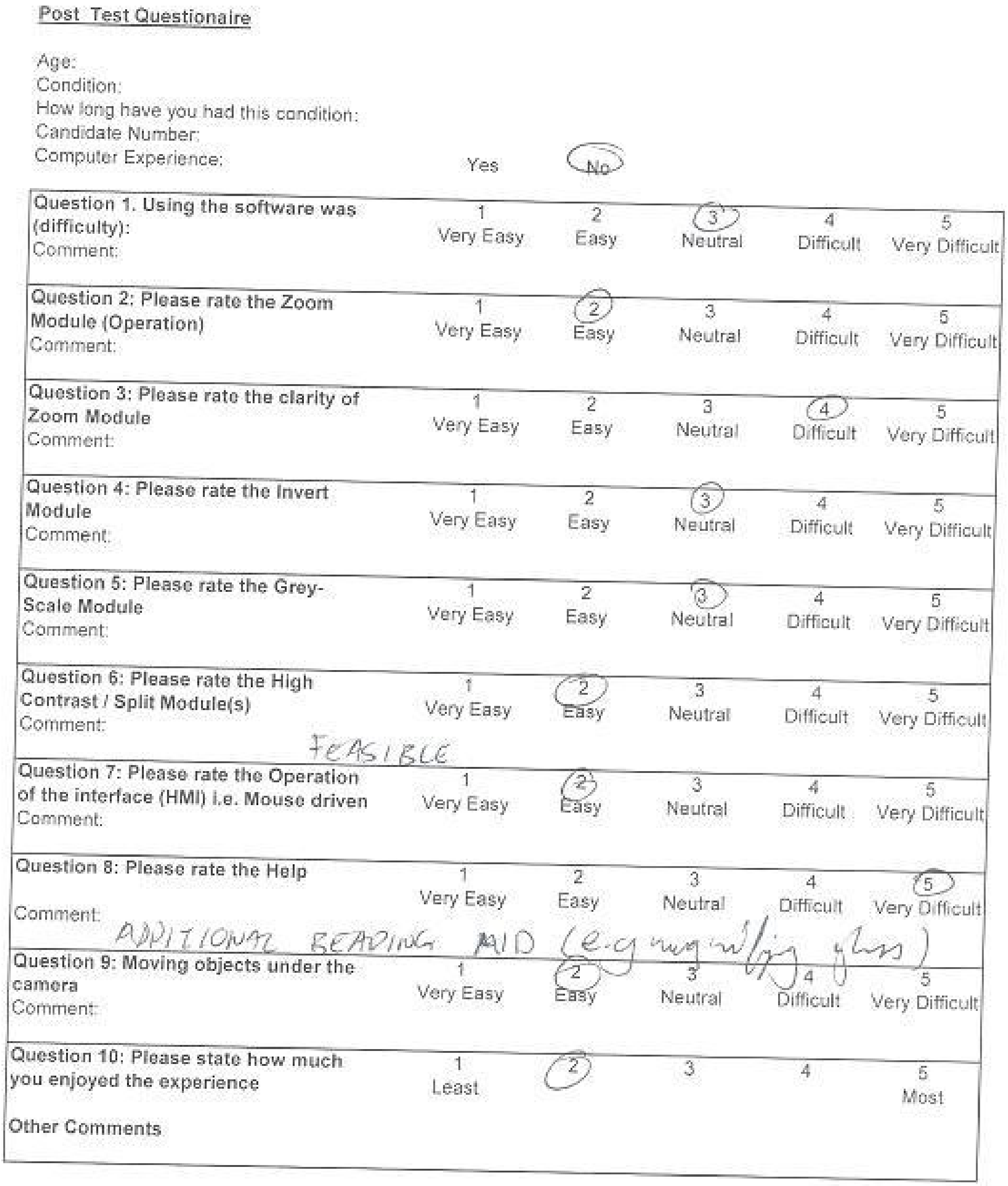


Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes [✓ No]

Question 1. Using the software was (difficulty): Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	1 Least	[✓ 2]	3	4	5 Most

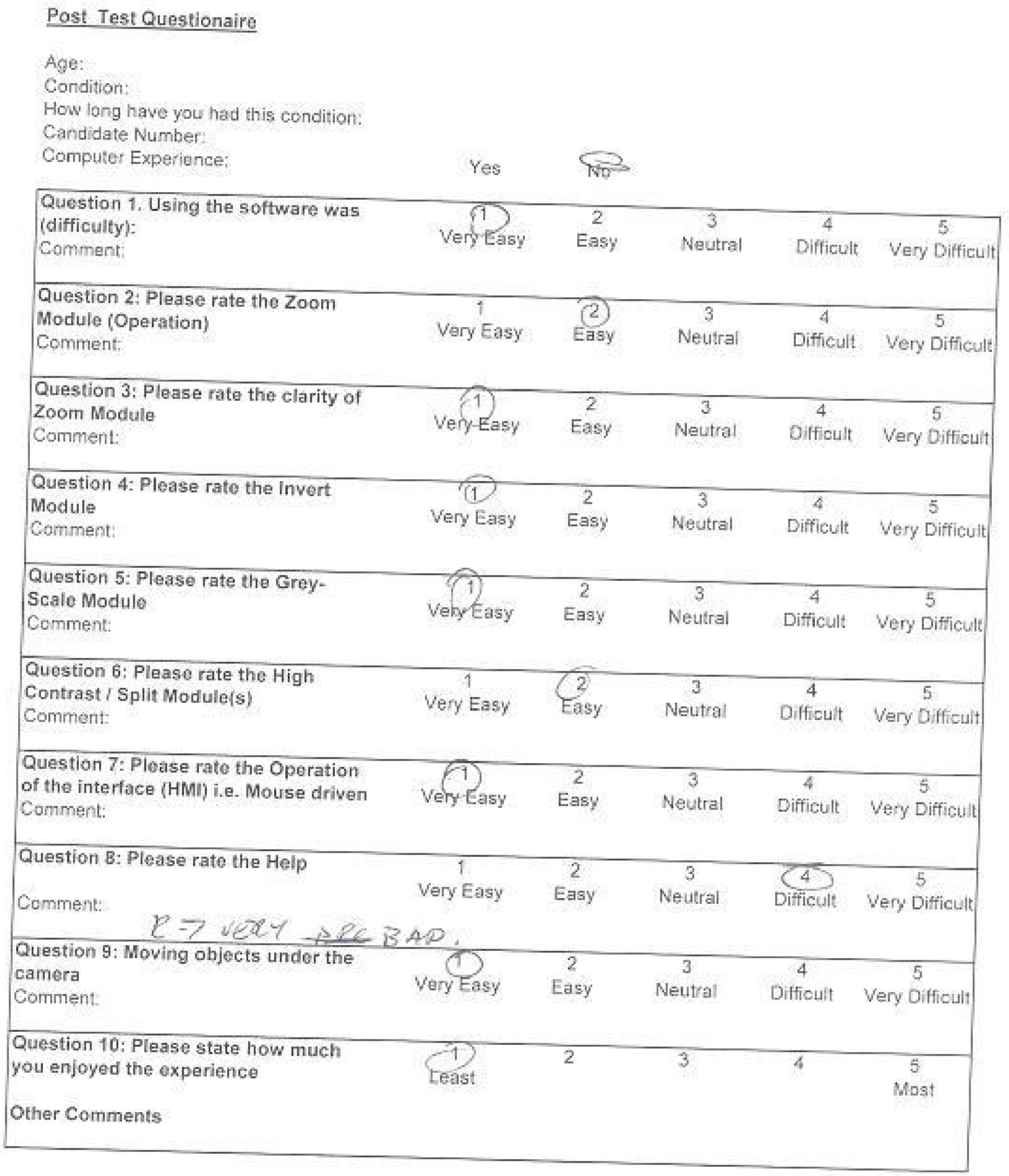
USED TO THE PROCESS, BECOMES EASIER.!!



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes [✓ No]

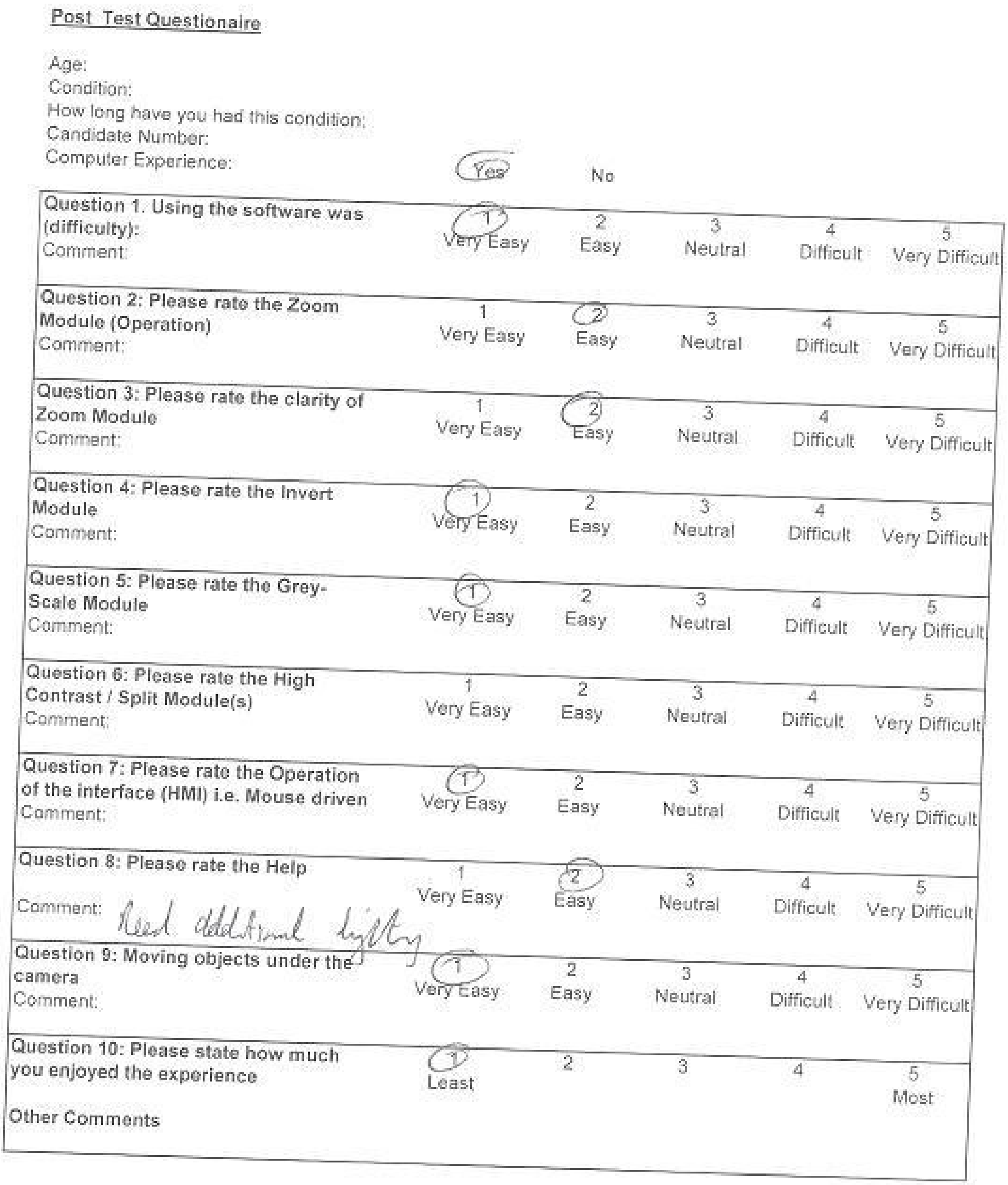
Question 1. Using the software was (difficulty): Comment:	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	2 Easy	3 Neutral	[✓ 4] Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	1 Very Easy	2 Easy	[✓ 3] Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment: FEASIBLE	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment: ADDITIONAL READING AID (e.g. magnifying glass)	1 Very Easy	2 Easy	3 Neutral	4 Difficult	[✓ 5] Very Difficult
Question 9: Moving objects under the camera Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience	1 Least	[✓ 2]	3	4	5 Most
Other Comments					



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes [✓ No]

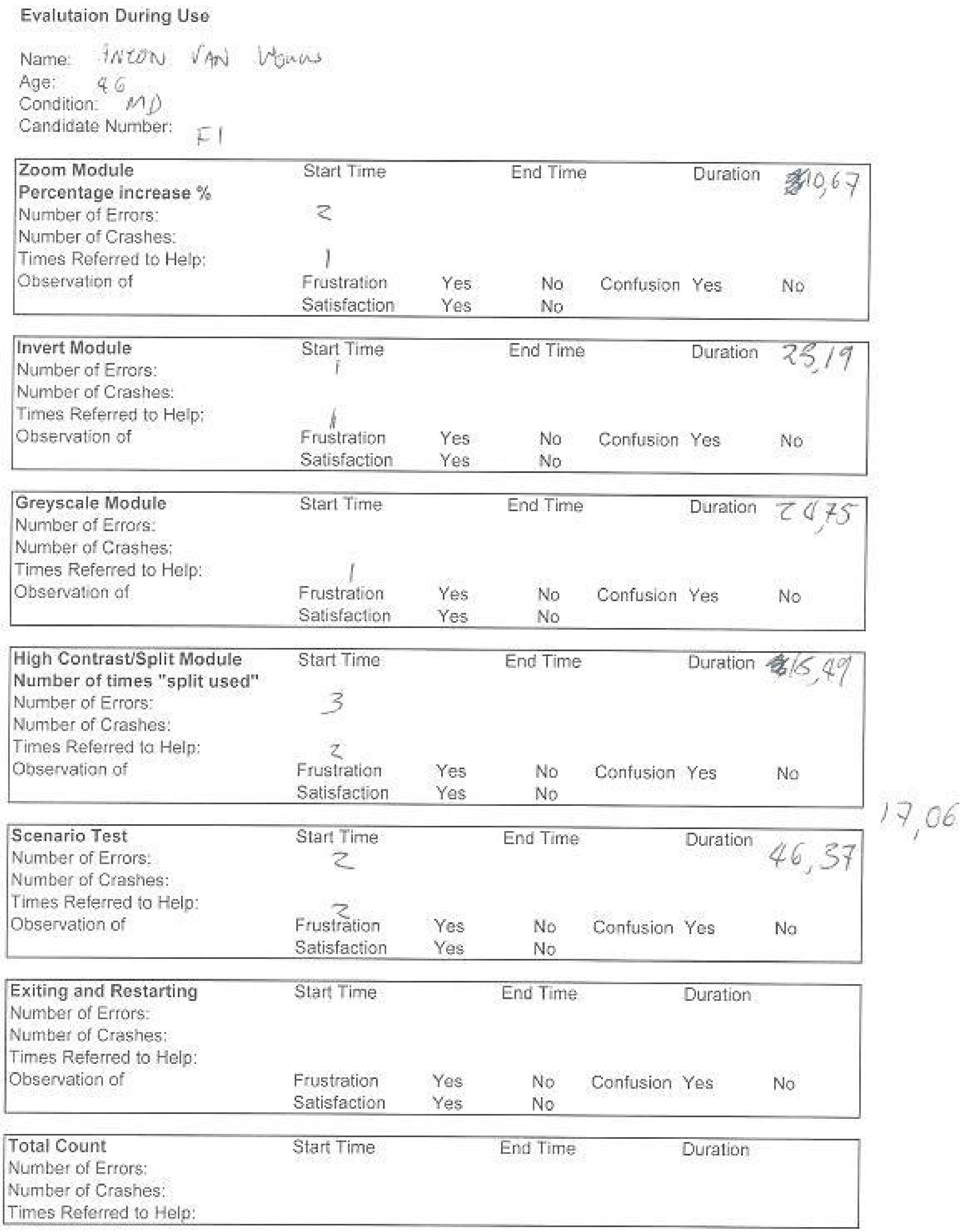
Question 1. Using the software was (difficulty): Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment: R-7 VERY ~~ARE~~ BAD.	1 Very Easy	2 Easy	3 Neutral	[✓ 4 Difficult]	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience	[✓ 1 Least]	2	3	4	5 Most
Other Comments					



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: [✓ Yes] No

Question 1. Using the software was (difficulty): Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment: Need additional lighting	1 Very Easy	[✓ 2] Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1] Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	[✓ 1] Least	2	3	4	5 Most



Evalutaion During Use

Name: ANTON VAN [illegible]
Age: 46
Condition: MD
Candidate Number: F1

Zoom Module	Start Time		End Time	Duration	10,67
Percentage increase %					
Number of Errors:	2				
Number of Crashes:					
Times Referred to Help:	1				
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Invert Module	Start Time		End Time	Duration	23,19
Number of Errors:	1				
Number of Crashes:					
Times Referred to Help:	1				
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Greyscale Module	Start Time		End Time	Duration	24,75
Number of Errors:					
Number of Crashes:					
Times Referred to Help:	1				
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

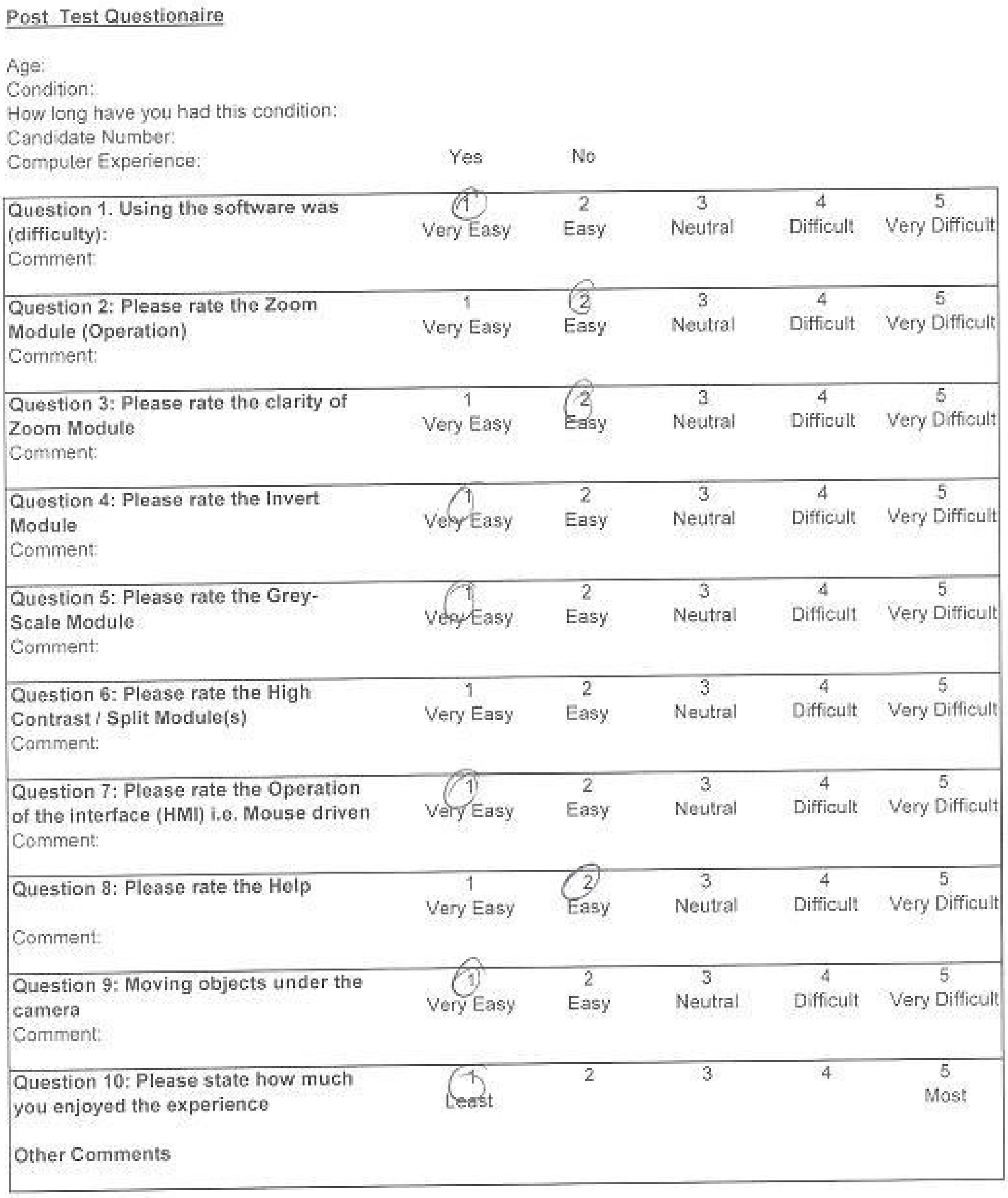
High Contrast/Split Module	Start Time		End Time	Duration	15,49
Number of times "split used"					
Number of Errors:	3				
Number of Crashes:					
Times Referred to Help:	2				
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

17,06

Scenario Test	Start Time		End Time	Duration	46,37
Number of Errors:	2				
Number of Crashes:					
Times Referred to Help:	2				
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Exiting and Restarting	Start Time		End Time	Duration	
Number of Errors:					
Number of Crashes:					
Times Referred to Help:					
Observation of	Frustration	Yes	No	Confusion Yes	No
	Satisfaction	Yes	No		

Total Count	Start Time	End Time	Duration
Number of Errors:			
Number of Crashes:			
Times Referred to Help:			



Post Test Questionaire

Age:
Condition:
How long have you had this condition:
Candidate Number:
Computer Experience: Yes No

Question 1. Using the software was (difficulty): Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 2: Please rate the Zoom Module (Operation) Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 3: Please rate the clarity of Zoom Module Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 4: Please rate the Invert Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 5: Please rate the Grey-Scale Module Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 6: Please rate the High Contrast / Split Module(s) Comment:	1 Very Easy	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 7: Please rate the Operation of the interface (HMI) i.e. Mouse driven Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 8: Please rate the Help Comment:	1 Very Easy	[✓ 2 Easy]	3 Neutral	4 Difficult	5 Very Difficult
Question 9: Moving objects under the camera Comment:	[✓ 1 Very Easy]	2 Easy	3 Neutral	4 Difficult	5 Very Difficult
Question 10: Please state how much you enjoyed the experience **Other Comments**	[✓ 1 Least]	2	3	4	5 Most

Appendix E.6. Data Analysis

Candidate	**Number**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Avg**	**Variance**	**Standard Deviation**	**Median**	**Tolerence Low (-20%)**	**Tolerence High (+20%)**
Zoom Module	Time to Complete	4.2	9.02	3.12	11.5	3.56	14	32	12.6	11.25875		9.411986943	10.275	9.007	13.5105
	Help Referals	1	1	1	1	1	1	1	1	1	0	0	1	0.8	1.2
	Errors							4	1	2.5			2.5	2	3
	Crashes				**1**		**1**				0	0	1	0	0
Invert Module	Time to Complete	5.21	36.2	22.1	64.5	21.1	17.2	42.3	15.2	27.975		18.84266663	21.61	22.38	33.57
	Help Referals	1	3	1	1	1	1	1	1	1.25	0.5	0.707106781	1	1	1.5
	Errors					2		3	1	2	1	1	2	1.6	2.4
	Crashes														
Greyscale	Time to Complete	54.1	4.01	4.02	62.1	48.3	33.7	20	22	31.03875		22.25389946	27.875	24.831	37.2465
	Help Referals	3	2	1	3	1	3	1		2	1	1	2	1.6	2.4
	Errors	3	1		5	4	4	4		3.5	1.9	1.378404875	4	2.8	4.2
	Crashes														
High Contrast	Time to Complete	45.2	2.45	65.2	56.2	26.3	16.2	32.2		34.82857		22.21939575	32.21	27.8628571	41.7942857
	Help Referals	1	1	1	2	3	2	2		1.714286	0.571429	0.755928946	2	1.37142857	2.05714286
	Errors	3		1	2	2	1	2		1.833333	0.566667	0.752772653	2	1.46666667	2.2
	Crashes												#NUM!		
Block Test	Time to Complete	26	21	20	62.1	27.2	27.2	19.8	24	28.4125		13.9580389	25	22.73	34.095
Scenario Test	Time to Complete	37.1	65	39.4	68.1	26.2	47	110	41.6	54.30375		26.52822213	44.3	43.443	65.1645
	Help Referals	3	2	2	4	2	3	3	2	2.625	0.553571	0.744023809	2.5	2.1	3.15
	Errors	1	4	3			2	3	3	2.666667	1.066667	1.032795559	3	2.13333333	3.2
	Crashes							**1**					1		
Exit / Restart	Time to Complete	71.1	18	48.1	73.2	10	18			39.73333		28.28901247	33.065	31.7866667	47.68
	Help Referals	2	1		2	1				1.5	0.333333	0.577350269	1.5	1.2	1.8
	Errors	1		1	2					1.333333	0.333333	0.577350269	1	1.06666667	1.6
	Crashes														
Total Analysis	Time to Complete	243	156	202	398	163	173	217	69.4	202.5338		94.33467821	187.7	162.027	243.0405
	Help Referals	11	10	6	13	9	10	8	4	8.875	8.125	2.850438563	9.5	7.1	10.65
	Errors	8	5	5	9	8	7	16	5	7.875	13.26786	3.642506986	7.5	6.3	9.45
	Crashes	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**0**	0.375	0.267857	0.51754917	0	0.3	0.45
	Total Crashes	3													