Analysis of Research Methodologies for Neurorehabilitation

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ABSTRACT

This paper analyses the research methodologies available and the choice made by the researchers in choosing a methodology for neurorehabilitation. Medical personnel find it hard to establish the appropriate medical classification with this group of disabled patients. This further complicates matters in performing research with such participants, since it is not known if some of these people are aware but unable to respond, or unable to comprehend and respond appropriately to the requests made by the communications around them. This paper describes the methods and methodologies available for neurorehabilitation and concludes by describing three examples of research approaches used by the authors.

1.0 Introduction

The definition for methodology according to Kaplan (1973) is as follows: "Methodology is to describe and analyse these methods throwing light in the limitations and resources of methods, clarifying their presuppositions and consequences, relating their potentialities to the twighlight zone at the frontiers of knowledge". It is a mission overview from the success of particular techniques, signifying new applications, and new logical ideas beyond ordinary principles of problem solving (Kaplan, 1973). Methodologies refer to the theoretical analysis of the methods appropriate to a field of study. This paper describes the challenges involved in analysing research methodologies for neurorehabilitation. The usual methodologies such as waterfall, spiral, Jackson, etc. cannot be easily used when choosing methodologies for this group of individuals. Many scientific methodologies can be applied to the study of computer tools and how humans interact with these tools (e.g., Hawthorn, 2000, Höök, 2000, MacKenzie *et al.*, 2001). Research development methods can draw on engineering design approaches to optimise designs, but the broader design context in HCI must embrace usability issues (Nielsen, 1993). One such approach of particular relevance would be Gould and Lewis's (1985) three principles of system design: early focus on users and tasks, empirical measurement and iterative design whereby the interface is

modified, tested, modified again, tested again, and the cycle is repeated again and again.

Many experimental psychology (McCarthy, 1995) and scientific methodologies can be applied to the study of computer tools and how humans interact with tools (Hawthorn, 2000, MacKenzie *et al.*, 2001). There are various models and techniques for specifying user interfaces such as psychological and soft computer science notations, user models, graphical/diagrammatic approaches, abstract mathematical models and user interface management systems (Abowd *et al.*, 1989).

2.0 Challenges when working with neurorehabilitation

Various challenges need to be addressed when choosing methods and methodologies for neurorehabilitation. Firstly the challenge of access to neuro-impaired individual needed to be addressed. Permissions and informed consents from the rehabilitation institutions, participants and/or their parents or guardians had to be obtained before research began (Friedman & Kahn, 2003, p.1189). A medical practitioner would be needed to assess each disabled participant for suitability for this research. The ethics boards at each institution had to approve this research. The validity and usefulness of this research had to be emphasised.

There could be various problems associated when working with this group of participants such as:

- Individual disabilities and abilities;
- Effect of medication on individual participants (or change of medication in the middle of the investigation);
- The best time for visiting a participant (e.g. ‘night person’ or ‘morning person’);
- Attention span of an individual;
- Emotions and frustrations when research is being carried out. Will this research bring back any flash backs from the past that could effect an individual?
- Medical assessments further to existing ones will have to be carried out. Organs such as eyes might be functioning, but the brain might not process any information from the eyes;
- Can a universal access (Stephanidis, 2001) interface be developed? If not, can we identify similarities to see whether group interfaces could be developed according the classification of the brain injury, e.g. one for cerebro vascular accident (stroke), another one for locked in syndrome etc,. From initial experience of various categories of brain injury, this study considered developing interfaces to cater for specific disability groups;

- If neither universal nor group interfaces can be developed, can we design a personalised interface to cater for each neuro-impaired participant?
- Should personalisation involve choice from a group of novel interaction paradigms, or one novel interaction paradigm that can be personalised?

3 Methods and Methodologies that can be used for neurorehabilitation

There are methodologies and methods from many areas that can be used for neurorehabilitation. This includes areas such as special needs education, developmental psychology, disabilities, designing interfaces, etc. There are various models and techniques for specifying user interfaces such as psychological and soft computer science notations, user models, graphical/diagrammatic approaches, abstract mathematical models, user interface management systems, etc., (Abowd, 1989). This section looks into the various methodologies and the methods within the methodologies that could be employed in neurorehabilitation. This section describes the chosen methodologies and then goes onto to describe the chosen methods within the methodologies.

3.1 Human-Centered design (HCD)

Human-Centered design (HCD) is a process of product development that starts with users and their needs rather than with technology. Its goal is to develop a technology that serves the user, where the technology fits the task, and the complexity is that of the task, not of the tool. Human-centered product development requires developers who understand people and the tasks they wish to achieve. This method is used extensively by interface researchers (Limbourg, *et al.*, 2001, Bevan, 2003). The interface designed would be human centred and HCD will be a methodology that will be used during the literature search process to specify the design criteria.

3.2 Model Based Approach

Below are some examples of task models in Model-Based Approach used in interfaces research (Stone, *et al.*, 2005, Limbourg, *et al.*, 2001):

- Mental or User Models – The model of the human head that is formed through experiences, training and instructions that enables us to negotiate unfamiliar situations.
- The Goals, Operators, Methods and Selection (GOMS) Model – A model for predicting human performance while interacting with a system
- GroupWare Task Analysis (GTA) Model – A model for complex tasks in a cooperative environment

- Concur Task Trees (CTT) – Uses a tool for editing task models to specify tasks, roles and objects and also the task hierarchy
- The " Méthode Analytique de Description de tâches" (MAD) Model - provides object oriented task specifications to support design
- The Task Knowledge Structure (TSK) model – uses the conceptual representation of the knowledge a person has stored in memory about a particular task where each person is an agent who carries out the task.
- The DIANE+ Model – models a task with three concepts: Operation, sequencing and decomposition.

Mental models will be created during the requirement specification for the high fidelity prototyping. This is a non-scientific method that enables users to reason without a system and also enables users to use it with their subconscious mental model of actions (Stone, *et al.*, 2005).

3.3 Contextual Inquiry and Design

Contextual Inquiry and Design is a user-centred approach to any environment that shows how data gathered from people while they work can drive the definition of a product or process while supporting the needs of teams and their organizations. Contextual Design enables researchers to gather detailed data about how people work and use systems, generate systems designs from knowledge of customer work (Beyer and Holtzblatt, 1998). The Webster's dictionary definition of context is "whole situation, background or environment relevant to some happening or personality". Greenberg (2001), argues that context is dynamic when viewed over a period of time while universal access creates a unified user interface, defined as an interactive system which comprises a single (i.e., unified) interface specification, targeted to potentially all user categories and contexts of use (Stephanidis, 2001). In other words, universal access approach has user interfaces accommodating the interaction requirements of the broadest possible end-users. Contextual inquiry and design will be used during the process of participant observation, as this is a user-centred design.

3.4 The Layered Approach

The layered approach methodology supports a developing interface that does not factor out common parts while putting aside uncommon parts. It has three layers: conceptual layer, logical layer and physical layer (Furtado *et al.*, 2003). The layered approach is ideal for a universal or wider target group. This methodology deals with both common and uncommon components of an interface unlike Inductive-Consensual Enquiry or Analytic-Deductive Enquiry that require one definite conclusion. Inductive-Consensual Enquiry is a methodology that is used to create estimation for new developments for information systems (Leading Edge International Research Group, 2006) while the main problem in Analytic-

Deductive Enquiry is knowing what question should be asked for the purpose of the methodology formation (Leading Edge International Research Group, 2006). Deriving from the above it was decided that the layered approach may become useful in the second phase during the process of creating widgets (refer to 3.4) for customisation.

3.5 Usability

Another field to influence interfaces research is "Usability". Usability means making products and systems easier to use, and matching them more closely to user needs and requirements. Usability is about, effectiveness, efficiency, satisfaction. The users, their goals and the usage context influence usability. Usability should not be confused with 'functionality', however, as this is purely concerned with the functions and features of the product and has no bearing on whether users are able to use them or not. Increased functionality does not mean improved usability (Anderson, 1994, Borchers, 2001, p.59). To improve the usability of an application it is important to have a well designed interface. Shneiderman's "Eight Golden Rules of Interface Design" are a guide to good interaction design (Shneiderman, 1998). Usability, being a basic and obvious consideration of any interface design, would be implemented at the early stage of designing of low fidelity prototyping. Although the guidelines for usability will be followed the life cycle of usability will not be followed.

3.6 Conceptual Design

This is the process of establishing the underlying organization and the structure of a user interface (UI). This helps make sense of screen layouts preceding the functionality decisions (Stone, *et al.*, 2005). Content diagrams comprise of containers with task objects, attributes and actions which are laid out in tables and diagrams. This process is carried out before dealing with design guidelines, standards and rules. Conceptual design will be used in creating prototypes to enhance design decisions. During this process content diagrams will be created using tables and tree diagrams. This methodology would be suitable for both proposed phases of this research.

3.7 Widgets

The mixture of menus, tool bars and command buttons displayed as dialog boxes that create a graphical user interface (GUI) are known as widgets (Stone, *et al.*, 2005). The layered approach will be used in the designing of widgets (refer to 3.4). Content diagrams will be used for basic interface followed by interactivity. They allow the facility of typing commands, choosing from existing menu and checking boxes. This is an invaluable tool for customisation. Following the designing of the

basic interface during phase one, widgets would be designed during the designing of interactivity.

3.8 Qualitative or Formative evaluation

This method is based on scientific knowledge based on application of logic and reasoning. It produces information that can be used to improve a program while it is in progress. Qualitative approaches are based on the belief that reality based on perceptions is different for each person. Qualitative research has to be systematic and subjective, indicating the experience of individual users (Burns and Grove, 1997). This research requires an open-minded approach and it is also not possible to have any set of rules for evaluation, as each disabled child would be unique. As a result Heuristic Evaluation, which involves having a product analysed independently by multiple evaluators who understand the product's goals and have good knowledge of established usability guidelines, will not be appropriate (Baker *et al.*, 2002, Kleinig and Witt, 2000). The chosen methods involved in qualitative evaluation are outlined below.

3.8.1 Ethnomethodological Approach

This is a methodology that was thought up by Harold Garfinkel (1967) and is based on the availability of common sense knowledge of society. The purpose of this methodology is to discover the expectancies and codes that lie behind everyday behavior. This could either be for pure research used for everyday life or an applied research dealing with communication (Berger, 2000).
Ethnomethodological research would be adopted during the observation process by way of interviewing. Participants would give opinions and use interfaces of their common sense knowledge. They are not expected to be experts in any relevant field. This method would be carried during both low and high fidelity prototyping. The components of this approach are given below.

3.8.1.1 Participant observation

This is a method in which research could be carried out in a natural setting to find out what participants do, instead of what they say they do (Berger, 2000). The setting, participants, nature and purpose of group, behaviour of people in group, frequencies and durations of behaviour in group and recording for observation are significant considerations while carrying out this method. Videos taken while children use the application can be compiled into a language transcript using Systematic Analysis of Language Transcripts (SALT) (Miller and Chapman, 1985), a method used to aid participant observation. Multimodality has also been invaluable in assessing the various aspects and processes of individuals using

augmentative and alternative communication (AAC) (Loncke, *et al.*, 2006). This method will be used throughout the research in various evaluation stages.

3.8.1.2 Interviews

An interview is defined as a conversation with an individual who is interested in the topic of the researcher's interest. These interviews can be conducted informally, in an unstructured, semi structured or fully structured manner according to the purpose of interview and the interviewer's skills (Creswell, 2003). This method will be extensively used for information gathering in this research.

3.8.2 Grounded theory

Grounded theory is a general method used for developing findings grounded in data, which are systematically gathered and analysed (Mills *et al.*, 2006). This generation of theory consists of plausible relationships proposed among concepts and sets of concepts. This method also represents and meets the four central ideas. These are: fitting the substantive data, comprehensibility to all areas, and generality in a variety of contests and control towards the phenomenon. Participants will be observed, interviewed and analysed using Grounded theory as it meets the four central criteria of design. This method would be carried out during various stages of the research.

3.8.3 Case studies

This research method contributes to understanding complex issues/subjects and adds strength to existing knowledge (Soy, 1997). This can be used both as a quantitative and qualitative approach. It will be used as part of requirement gathering to complement, and add strength to existing knowledge.

3.8.4 Phenomenology

This is both a qualitative and quantitative approach used to illuminate and identify specific phenomena by understanding how the actors in a situation perceive them. This involves the processes of gathering of information and presenting in the perspective of the researcher. This method gives validity to the researcher's opinions (Lester, 1999). Phenomenology will be used for the benefit of the researcher during both low and high fidelity prototyping.

3.8.5 Narrative research

This is the understanding of information from the perspective of time and space. This may include cultural and demographic issues that have influence on

perception (Dino, 2002). This method may be used to understand information in the perspective of the user.

3.8.6 Historical analysis

This is a fact based study on the chosen topic that is used to systematise the stages of data gathering and collection. These could be based on biographies, movement or idea, regions, institutions, settings or events, selection of elements and editorials (Berger, 2000). Historical analysis based on institutions will be undertaken during the requirement gathering process. The above methods that are part of Qualitative or Formative evaluation can be adopted during the development and evaluation of research in the perspectives of the user, researcher, time and space. This methodology could be extensively used in this research evaluating the various interfaces.

3.9 Quantitative or Summative evaluation

Research is conducted to describe and examine variables in order to test theories (Burns and Grove, 1997). This method is based on conceptualising the project, planning, implementing and communicating the results. A summative method involves precise measurement, representative samples and controlled experiments. Results obtained in quantitative methods should be tested using statistical methods, statistical significance, hypothesis validation, null hypothesis etc., (Kazdin, 2003). Some of quantitative methods that may be used during the various stages of the research are set out below.

3.9.1 Experiments

Experiments are carried out in order to demonstrate that something is true, examining the value of a hypothesis or attempting to discover new information. This is usually conducted with both an experimental group and a control group using both dependant and independent variables (Green, *et al.*, 1989). This method will be used extensively to measure the performance of participants.

3.9.2 Surveys

Surveys can be both analytic and descriptive. This method is used to collect and analyse social data through interviews or questionnaires. These are often highly structured and detailed. Information can be obtained from large numbers of respondents using this method. While undertaking this method you presume the participant to be a representative of your target population (Berger, 2000). Surveys will be used at the information gathering stage of the research to analyse the number and types interfaces used in proving therapy for speech impairments.

3.9.3 Action research

This is a methodology that intends to produce both understanding and change (Dick, 2001) by observing the responses in relation to the changes made. This may be used in experiments to measure performance of participants.

3.9.4 Content Analysis

This approach is giving a perspective to factual information in order to analyse them either historically or comparatively (Berger, 2000). This method also need definite numbers and not use terms such as "a lot", "few", "little", etc. All terms should be defined operationally[1]. This method can be used during the information gathering process to analyse the various texts in the light of this research. This approach would be used depending on the size of the sample. Quantitative or Summative evaluation is used to assess and summarise the value of a design during the iterative process. This methodology will be extensively used in this research evaluating the various interfaces.

3.10 Iterative prototyping

Iteration or prototyping driven by phenomenological qualitative and quantitative evaluations (Munhill,1989 and Omery, 1987), gives the opportunity for building artefacts that can evolve into refined, tried and tested end products when developing artefacts (Abowd, *et al.*, 1989). Qualitative and quantitative methods will be used to generate different types of data that can be used when developing interfaces. The iterative development method is also useful where initial data is collected from able participants before being tested with disabled participants. Iteration will be used to build artefacts in the research. Iteration will include various methods and methodologies including low fidelity (sketches and screen mock-ups) and high fidelity (using a graphical user interface).

3.11 Iterative Development

Iteration in computing is the repetition of a process within a computer program. It can be used both as a general term, synonymous with repetition, and to describe a specific form of repetition (Larman, 2003).

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[1] Meanings of words defined in the perspective of the research

3.12 HCI approaches

Some of the approaches used by Rogers (Rogers, 2004):

- The ecological approach – the study of the interaction between the humans and its environment;
- The Activity Theory Approach - the study of actions and interactions with artefacts within a historical and cultural context;
- The external cognition approach – the study of interaction between internal and external representations when performing cognitive tasks;
- The distributed cognition approach - the study of identifying problems, breakdowns and distributed problem solving;
- The situation action approach – to study the relationship between structures of action and the resources and constraints afforded by physical and social circumstance;
- Hybrid and overarching theoretical approaches – to synthesise concepts from different theories and disciplines.

These methodologies may be used to support Human Computer Interaction issues of the interface design.

3.13 Textual Analysis

The following are two components of textual analysis, which are to be used in this research. Ideological Criticism and Psychoanalytic Criticism are also part of textual analysis but irrelevant to the target group of this research as this deals with a system of ideas and ideals that form the basis of a theory or policy exp. Feminism, Marxism, Capitalism, etc (Berger, 2000).

3.13.1.1 Semiotics Analysis

Semiotics is concerned with everything that can be taken as a sign (Berger, 2000). Semiotics can be divided into a trichotomy of icon, index and symbol. Icons are signified by resemblance, indexes by cause and effect and symbols on the basis of convention. This could also be an imperialistic science[2] (Berger, 2000). Some of the concepts used the analysis of semiotics could be:

- Detonation – literal meaning of a term or objects;
- Connotation – cultural meaning that becomes attached to terms;
- Simile – based on similarity;
- Metonymy – communicating by association;
- Synecdoche – a part is used to represent a whole or a whole a part;
- Intertextuality – relation between texts that is used to show how texts borrow from one another;

[2] The policy of extending the rule or influence of a country over other countries or colonies (Microsoft Dictionary)

- Codes – interpreting messages that are difficult to understand;
- Language and Speaking – social institution (Saussure, 1966, Chandler, 2006).

These above concepts would be used at the information gathering and evaluation stages of this research.

3.13.2 Rhetoric Analysis

Rhetoric analysis deals with how symbols communicate. The term 'rhetoric' when applied to media can be understood in nine ways (Medhurst & Benson, 1984).

- Intentional persuasion;
- Social values and effects of symbolic forms found in texts;
- Techniques by which the arts communicate to an audience;
- Persuasion techniques used by characters on one another in dramatic or narratives works;
- Cicerio's five rhetorical practices found in texts;
- Study of genres or types of texts;
- Implicit theories about human symbolic interaction implied by authors of symbolic works;
- An ideal for the conduct of communication among humans;
- Pragmatics.

These above concepts would be used at the information gathering and evaluation stages of this research.

Semiotics and rhetoric analysis can be used in the development stages of this research as it can relate to children unlike the other two methods based on the expectation of certain maturity in cognition to be implemented.

3.13.3 Mixed approaches

This is a procedure developed in order to fulfil a need to clarify the intent of mixing both quantitative and qualitative data in a single study and to create understandable designs out of complex data and analyses (Creswell, 2003), description of relevant approaches are given below.

3.13.4 Sequential Transformative Strategy

This method has two data collection processes but unlike the Sequential Explanatory Strategy that gives priority to quantitative data or Sequential Exploratory Strategy that gives priority to qualitative data, either method may be used and either can receive priority. The purpose of this method is to serve the theoretical perspective of the researcher (Green *et al.,* 1989). This research expects to use both qualitative and quantitative methods to back the final conclusion. In order to weigh the weaknesses against the strengths, qualitative and quantitative

methods would be done separately and compared if Concurrent Triangulation Strategy is used. This research is exploratory and is not guided by theories and hence Concurrent Transformative Strategy cannot be used. Concurrent Nested Strategy will not be used as this requires a predominant method that guides a project.

The choice of mixed methods is based on implementation, priority, integration and theoretical perspective of the research or project (Creswell, 2003). This research will have two data collection processes and although it serves the theoretical perspective of the researcher it is not guided by theories. It is also not possible to decide at this stage as to which methodology would be dominant. In the light of this, Sequential Transformative Strategy would be chosen over the other five conventional mixed methodologies.

4.0 Some examples of chosen approaches by the authors

The authors considered research methodologies (Freeman & Tyrer, 1998, Matthews, 2002, Preece *et al.*, 2002), appropriate ones had to be chosen to deal with the challenges of this research. Neurorehabilitation is not to be a classic engineering design approach, which would not cater for usability issues (different disabilities), but an iterative HCI approach with appropriate optimisation for some iterations. It needs to combine field usage of prototypes with field evaluation, and is an example of a design research approach.

Design methods used in 1960s and 1970s did not deliver hoped methodologies for scientific standards (Cross, 2001). However, science can and does underpin design. This research thus draws on brain and behavioural sciences. The steps to be taken for this research are thus:

1. Select a research paradigm and select research methods comparable with selected paradigm;
2. Can a universal access interface be developed? If not, can we design an interface that can group disabled participants together, when developing interfaces iteratively, e.g. one for cerebro vascular accident (stroke), another one for locked in syndrome etc.?
3. If group interfaces are not possible, can we design personalised interfaces that can be compared with the group interfaces?
4. Can the final interface be an inclusive interface that can be used by any neuro-impaired user?
5. Develop interfaces that can facilitate independent usage at user's care homes;
6. To evaluate all BBIs and design controlled studies.

For step 6 above:

1. Refine methods and approaches for each study;

2. Obtain ethical approval for each study;
3. Recruit participants both able and disabled;
4. Choose participants both able and disabled;
5. Obtain optimised values for design parameters, through engineering design approaches;
6. Measure values for usage variables (time taken to reach the target, route taken to reach a target and success rate);
7. Use formative (for development) and summative (to show robustness and validity) evaluation, based on quantitative and qualitative results.

Principles from iterative user interface design thus underpin the research approach for neurorehabilitation (Gould & Lewis, 1985). This methodology uses iterative methods to refine the interface design. Lessons learnt from previous user evaluations are used for refinement in the next iteration. There examples of approaches used by the authors shown in diagrammatic form in Figures 1, 2 and 3.

Research Approach 1, is shown in diagrammatic form in figure 1. The diagram shows the three phases of the research and the iterative processes that were used to develop the paradigms. The iterative processes that were employed in the design and development of the novel interaction paradigms are shown on the left of the diagram and the other issues that influenced the processes are shown on the right side of the diagram. Iteration driven by phenomenological formative and summative evaluations (Munhall, 1989, Omery, 1987), gives the opportunity for building artefacts that can evolve into refined, tried and tested end products when developing artefacts (Abowd *et al.,* 1989). The final feedback from each phase is shown in the text boxes. One method of conducting scientific research in a new area of study with a new tool is to use the tool with a group of participants and to collect data from the performance of tasks with the tool. The data then display trends that allow other questions to be formed. These questions can be used to form a hypothesis that may be evaluated by further experiments. This method is known as Naturalistic Inquiry. Williams (1986) states "naturalistic inquiry is disciplined inquiry conducted in natural settings (in the field of interest, not in laboratories), using natural methods (observation, interviewing, thinking, reading, writing)". Naturalistic inquiry was used in this research for investigating topics of interest. Formative research methods and empirical summative methods were used to evaluate the paradigms being investigated in this research (Kerlinger 1986**,** Nogueira and Garcia, 2003). Developed prototypes were tested using able-bodied users as test subjects before being evaluated with disabled users. Iteration with able-bodied participants allowed better feedback for faster interface development and also enabled to obtain optimum settings that can be used with brain injured participants in the next phase of the research. Six versions of the interface program were developed to get the final artefact.

Summative evaluation was used to assess and summarise the value of completed activities. Research was conducted to describe and examine variables in order to test theory. This evaluation was based on conceptualising the project, planning,

implementing and communicating the results. The summative evaluation involved precise measurement, representative samples and controlled experiments (Burns and Grove, 1997). Results obtained from summative evaluation was tested using T-Tests, Chi-squared Tests, Marascuilo Procedure and Survival Analysis (Kazdin, 2003).

Formative evaluation can be conducted during the planning and delivery of research. This evaluation is based on scientific knowledge based on application of logic and reasoning. It produces information that is used to improve a program while it is in progress. Formative approaches are based on the worldview belief that reality based on perceptions is different for each person. Formative research has to be systematic and subjective, indicating the experience of individual users (Burns and Grove, 1997). Formative and summative evaluations compliment each other since they generate different types of data that can be used when developing interfaces. The iterative development method is a useful approach when initial data is collected from able participants before being tested with disabled participants.
Figure 2 (Research Approach 2), shows an oval shape with an inner and outer area. The inner shows initial development and evaluation process carried out with able-bodied participants, while the outer shows the main evaluation process carried out with disabled participants. Evaluating with able-bodied participants could give data for optimising interfaces before they are used with the disabled participants. It also enabled optimising the settings for each novel interaction paradigm before it can be used with neuro-impaired participants. These optimised settings were used as the starting point when experiments were concluded with the disabled participants. Iteration drove the formative and summative evaluations (Munhall, 1989, Omery, 1987). Iteration also gave the opportunity for building artefacts that evolved into refined, tried and tested prototypes (Abowd *et al.*, 1989).

Formative and summative methodologies were chosen to evaluate the paradigms being developed in this research (Kerlinger, 1986**,** Nogueira & Garcia, 2003). Formative evaluation is to be conducted before summative evaluation at each phase of research (Figure 2). Prototypes to be formatively evaluated based on users' preferences and its implications for interface design, which could suggest possible re-designs. The participants for the formative evaluations are to be medical professionals, attending personnel and relatives of brain injured individuals. Focus groups are also expected to be setup for formative and summative evaluations during the development stages of the research. Summative evaluation is to be used to assess the interface designs refined through formative evaluation. Formative and summative evaluations are to complement each other when developing interaction paradigms.

The methodologies and methods used in Research Approach 3 (Figure 3) are listed below.

4.1 Phase One

The use of interfaces in therapeutic and training of speech (articulation and phonology) would be explored. Following the gathering of requirements and writing up the specifications. A prototype would be designed, for three dimensional model interfaces to facilitate pronunciation skills. It will be developed and evaluated using various methods and methodologies methods.

4.1.1 Requirement Gathering

Initially the requirements for the interface need to be defined. This observation can be carried out either directly or via video recording. Participants could be both the children with speech impairments and their support workers or parents.

4.1.2 Requirement Specification

The users' characteristics should be defined based on physical and mental limitations keeping in mind usability issues.

4.1.3 Conceptual Design

A content diagram would be created identifying task objects, their attributes and actions (Stone, *et al.*, 2005). It is during this process that design decisions need to be recorded. Mental models will be created keeping in mind the goals, tasks and actions (Stone, *et al.*, 2005). Actions and related system responses should be defined as accurately as possible. User and environmental characteristics would be defined. Any additional artefacts necessary should be listed and described. This would include tables, diagrams, equations etc.

4.1.4 Low fidelity Prototyping

Low fidelity prototyping is the creation of manual sketches and screen mock-ups for the user interface. This is carried out before creating the interface on the computer or programming it. This would be evaluated using qualitative methods such as ethnography, narrative research and phenomenology (Stone *et al.*, 2005).

4.1.5 Interaction design

Interaction would be added based on the mental models created in order to identify the different stages of actions and tasks. These models would be defined to influence the design process in a customisable.

4.1.6 Interface properties

Text: A legible typeface should be used. It is also important that included text is brief and straightforward. It is important that due attention is paid to kerning, leading and justifications.
Colour: Use appropriate colour to draw attention to the appropriate area to make the meaning clearer. Enhance the look and feel of the display. It is also possible to reveal the status, using colour.
Images: Appropriate and suitable images can be used to help overcome language barriers, motivate and attract attention and to help interaction.
Moving Images: Animations and video clips can be used to achieve visual dynamic, to convey human emotions and to motivate.
Sound: Helps keep the user alert while user deals without visuals. This keeps the user under control and deals with visually impaired as well.

4.1.7 High Fidelity Prototyping

The previous stage (interface properties) would be followed by high fidelity prototyping derived from the low fidelity prototype's evaluation, which would give a better idea of usability issues.

4.2 Phase Two

All methodology and methods from phase one would be carried out right up to the high fidelity prototyping, keeping mind that this would be an interface which enable customisation for users according to level of disability, environment and any other usability issues.

In this level Widgets (Stone, *et al.*, 2005) would be used to create this facility. Customisation needs would be listed and Widgets will be designed to enable customisation of interface.

Quantitative method is used to assess and summarise the value of a completed activity or program. Research is conducted to describe and examine variables in order to test theory. This method is based on conceptualising the project, planning, implementing and communicating the results.

5.0 Ethical Considerations

It is important to speak to the relevant participants before actually carrying out the research. It is always important that all permissions for access and research are obtained in written format. For participants to feel secure it is important to be honest about the research but not make it awkward for the participants by giving

the feeling that they are being observed and analysed (Friedman and Kahn, 2003, p.1189).

The researcher will obtain all permissions and informed consents from the institutions, participants and/or their guardians before research begins. Researchers will make no commercial gain and the participants would be able to leave the program at any time if he or she chooses to do so. The information obtained from this research will be used to improve related devices only.

Permission for research to be carried out in the premises will be completed after obtaining individual consent from each participant and their legal guardians. No results will be published including personal details.

6.0 Summary and Conclusions

This paper highlighted the challenges involved in this investigation, and the approach chosen to possibly deal with the challenges. Various methodologies were considered before a final selection was made. The chosen methodology is a design research paradigm, guided by principles from HCI research and practice, including engineering design approaches based on psychology research methods (called Human Factors Engineering in North America). A two level research framework uses able-bodied, then neuro-impaired participants. The methodology addresses known challenges to develop an appropriate interface needed for severely neuro-impaired individuals to communicate during their daily routines. The chosen methodology combines elements of engineering design and design science to create novel interaction paradigm and to evaluate their effectiveness.

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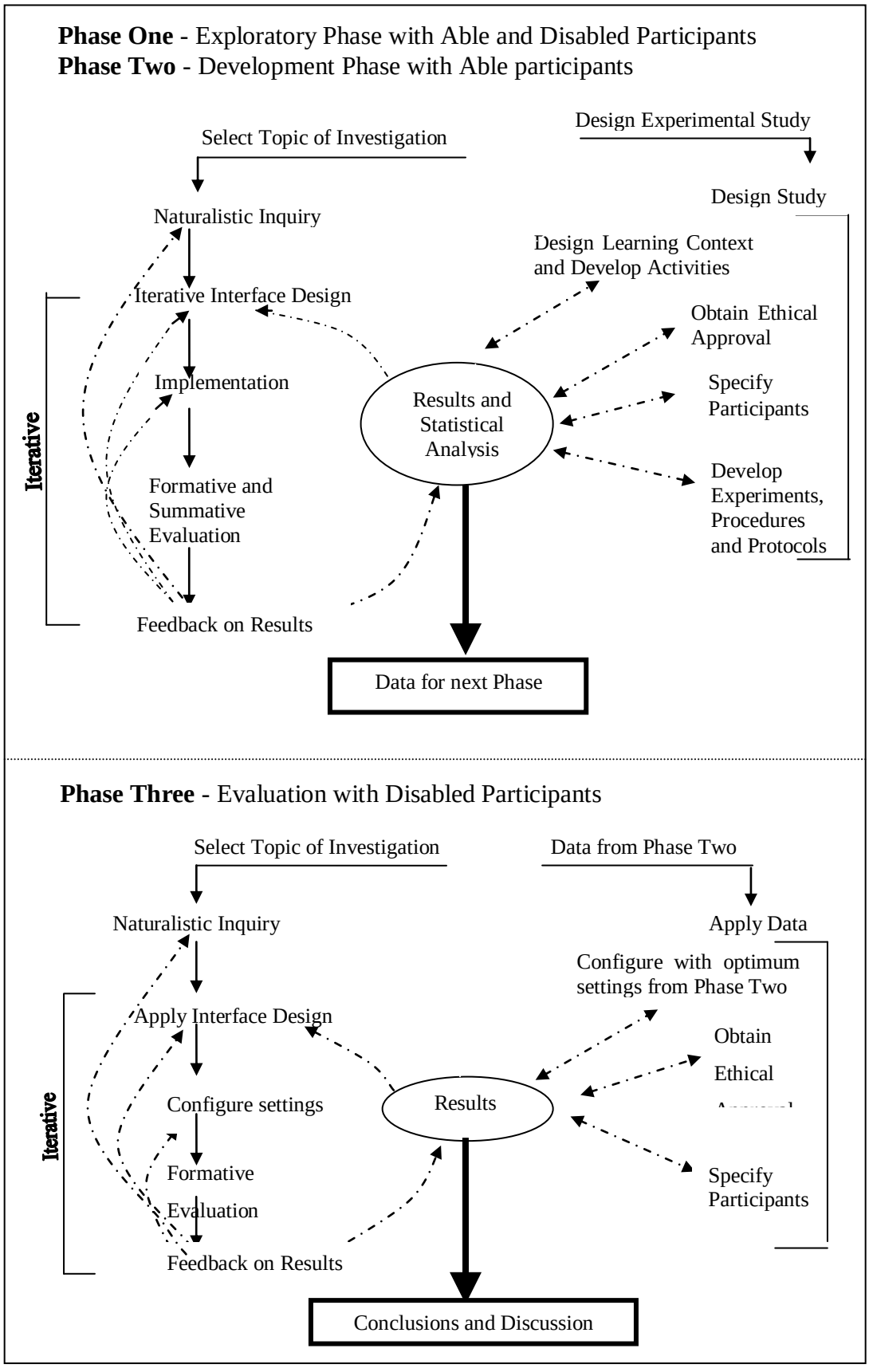
Figure 1 *Research Approach 1*



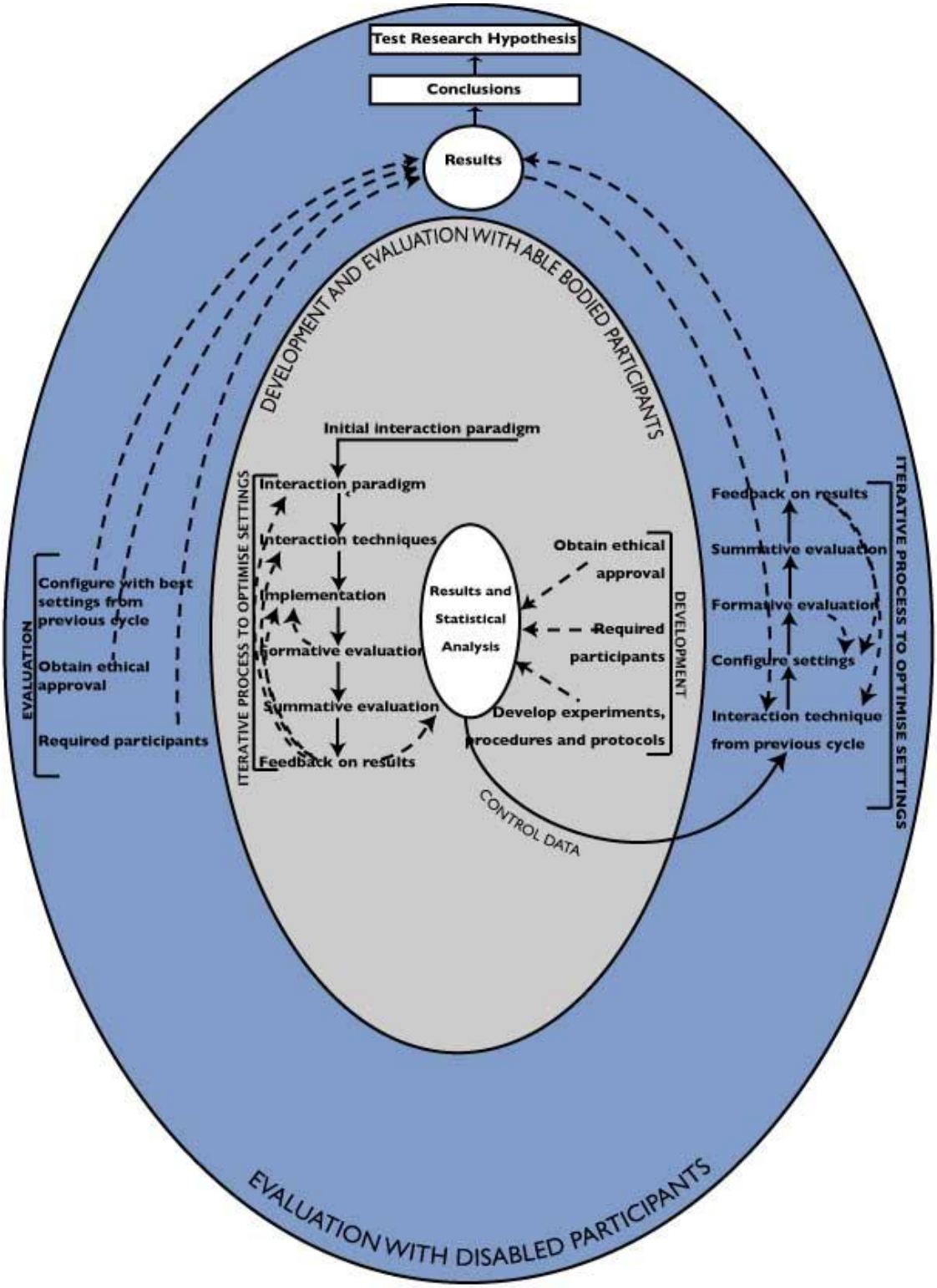

Test Research Hypothesis
Conclusions
Results
DEVELOPMENT AND EVALUATION WITH ABLE BODIED PARTICIPANTS
Initial interaction paradigm
Interaction paradigm
Interaction techniques
Implementation
Formative evaluation
Summative evaluation
Feedback on results
ITERATIVE PROCESS TO OPTIMISE SETTINGS
Results and Statistical Analysis
Obtain ethical approval
Required participants
Develop experiments, procedures and protocols
DEVELOPMENT
CONTROL DATA
EVALUATION
Configure with best settings from previous cycle
Obtain ethical approval
Required participants
Feedback on results
Summative evaluation
Formative evaluation
Configure settings
Interaction technique from previous cycle
ITERATIVE PROCESS TO OPTIMISE SETTINGS
EVALUATION WITH DISABLED PARTICIPANTS

Figure 3 *Research Approach 3*