Human Computer Interaction and Theories

Jennifer C George[1] and Paul Gnanayutham[2]

[1] SAE Institute, 297 Kingsland Road, London, E8 4DD, United Kingdom,
+44 (0) 20 7923 9159, jennifer.george@sae.edu

[2] School of Computing, University of Portsmouth, Buckingham Building,
Lion Terrace, Portsmouth, PO1 3HE, United Kingdom, +44 (0) 23 9284 6404,
paul.gnanayutham@port.ac.uk

Abstract

This paper reviews the theories that were used for designing interfaces for facilitating pronunciation skills for children with severe speech impairments using multimedia based interfaces. Theories were surveyed from educational, psychological multimedia and social perspectives. The chosen theories were structured to support the chosen methodology used in this research.

1. Introduction

"A theory is a set of interrelated constructs (variables), definitions, and propositions that presents a systematic view of phenomena by specifying relations among variables with the purpose of explaining natural phenomena" – Kerlinger, 1979

Theories are used to describe various aspects of interactive interfaces. They can be explanatory or predictive (Shneiderman, 1998).

This document reviews several theories and criticises them in the light of the methodology of a case study. This paper analyses the possible theories that could be used for designing interfaces for facilitating pronunciation skills for children with severe speech impairments using multimedia. These theories will be analysed using educational, psychological multimedia and social perspectives. Then the paper will go onto show how the chosen theories were mapped on to the methodology.

2. The Case Study

The research question posed in this case study is, *should there be a group of interaction paradigms or one novel interaction paradigm that can be personalised, to enhance the performance of pronunciation skills for children with speech impairments?*

The investigation to answer the research question was carried out using audio visual two and three dimensional interfaces and then evaluated with groups and

individual participants with speech impairments. The end product was a CD-ROM containing the interface program. For the purpose of designing the interfaces, various theories were studied and appropriate theories were chosen for the research while others were excluded by including. Figure 1 shows the methodology used for the development of the interfaces which was followed for the identification of appropriate theories.

   A literature map was created by way of categorisation of information found during the search (figure 2).
   Educational, Psychological, Multimedia and Social Theories were identified as a part of literature search for this research. The next section discusses the chosen theories after they were filtered.

3.   Chosen Theories

3.1.   Educational Theories

3.1.1.   Cognitive Load Theory
Cognitive load theory is based upon a model of mental processes, or 'cognitive architecture', that is made up of a limited working memory, with processing units for visual and audio information which are partly independent and which interact with an unlimited long-term memory (Kirschner 2002). Experiments suggest that working memory can only hold 5-9 'chunks' of information at any one time (Miller 1956).
   As this research deals with children with learning disabilities, extra care should be taken as to how much information is presented or given during one particular task. A typically developing child may be able to hold in short term memory 5-9 words at a time but in this case it may be even one word every few weeks. This theory is likely to be used during the designing of the content diagram as part of the conceptual design.

3.1.2.   Dual Coding Theory and Constructivist Learning
According to dual coding theory, mental representations of the information loaded into working memory are associated with distinct verbal and non-verbal modes which keep in memory those properties of the actual sensory events upon which they were originally built. This means that there is firstly a distinct verbal system which deals with "word-like" codes whether they are presented visually in the form of text, auditorily in the form of speech or articulatory in the form of gestures, which represent objects, events and abstract ideas. Conversely, there is a nonverbal system of modality which deals specifically with images for shapes, sounds, actions and other nonverbal objects and events (Clark and Paivio 1991).
   During multimedia learning, an active learner will pay attention to verbal and nonverbal information, will mentally build referential connections between the

two and integrate this with prior knowledge (Mayer and Moreno 2002). In learning with multimedia, constructivist learning is the active process of selecting verbal and nonverbal material, organising and building internal connections, integrating them with one another and with prior knowledge from long-term memory (Mayer *et al.* 1999).

As this research does not require the participants to possess any previous knowledge or ability it is essential that each task is communicated as clear as possible using both verbal and no-verbal communication including animations where necessary. This theory will be practiced during the development of mental models prior to creating the prototypes.

3.1.3. Split Attention Effects

Multimedia incorporates animations and text on screen, this presents the learner with material for concurrent verbal and nonverbal processing. If the learner focuses attention on the animation images, they may miss some of the important being presented on the screen. Similarly if the learner reads the text first, taking attention away from the images, they may miss important aspects of the animation sequence. This is known as a split-attention effect. In experiments designed to test the impact of presenting verbal information accompanying animations either auditorily via speech or visually via text Mayer and Moreno (1998) demonstrated that learners can integrate words and pictures more easily when the words are presented auditorily rather than visually.

This is an interface that includes audio and visual elements and this theory would be used during the interaction design with care especially as these children have learning disabilities.

3.1.4. Emotional Intelligence

This theory states that academic intelligence measured by IQ tests in educational environment offers virtually no preparation for life. There are other characteristics such as "being able to motivate oneself and persist in the face of frustration; to control impulse and delay gratification; to regulate one's moods and keep distress from swamping the ability to think; to empathize and to hope" (Kristjansson 2006).

From the psychological point of view, doubts still remain as to the usefulness of this theory since it needs depth and cannot be justified be successfully for every participant. But this theory will be considered during the information gathering process during both phases as children with varied intelligence levels will be used in this research. This research obtains data for initial assessment and is not expected to prepare children for life.

3.1.5. Disability Theory

Disability theories can be predominantly medical or biological while others are concerned mainly with identity or negotiations of social roles (Oliver 1996). Disability theory assumes a relationship between the individual and society and

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these two interact with each other to produce four basic theoretical positions. Positions one and two are concerned with properties of individuals, on other words 'body' and 'mind'. The third and fourth are concerned with the properties of collectives than with those of individuals, in other words, 'real' existence. Position 1 covers knowledge derived from the observation and classification of individuals. Position 2 focuses on knowledge derived form the experiences, beliefs and interpretation of individuals. Position 3 suggests that we can know about social phenomena in a real material way. Position 4 includes approaches that view social phenomena as having some objective reality beyond the individual (Priestly 1998).

Similar to the theory of emotional intelligence, this theory too would be used during the information gathering process.

3.1.6. Development of children with disabilities and the adaptation of their parents

This field has been guided by two inter-related principles: (a) An understanding of the causes and organization of both adaptive and maladaptive behaviour can be gained through the application of developmental theory and (b) knowledge of the extent to which developmental processes are universal and requires the study of a typical population (Luthar *et al.* 2000). Longitudinal studies of children with developmental disabilities have resulted in a similar pattern of findings such as cognitive levels of children with Down syndrome may be relatively high during infancy then reach low to moderate state. This does not imply that the children are losing skills but they are not making the gains at the same rate as typically developing children. This applies very much to language development. The importance of family cohesion in relation to children's development was also analysed and found harmonious interaction enhanced child development (Houser-Cram 1998).

Although this theory is not used in any particular area of the research this is one of the main motivations behind this research.

3.1.7. Vygotsky's Theory

Vygotsky proposes that one should measure two levels of psychological development. The first level of a child which involves mental functions that have been established by completed development cycles. The second level is the level of potential development. He was promoting dynamic assessments techniques as a practical contribution to the assessment repertory (Rutland and Campbell 1996).

This theory would be an awareness criterion during the evaluation and prediction processes of the research.

3.1.8. Theory of mind

Intellectual Disability is associated with impairment in social behaviour that are manifested across a range of contexts and tasks. Because these impairments can be a barrier to inclusive education it is important to identify their causes. 'Theory of mind' refers to the coherent body of knowledge about the human mind that we

typically acquire and use to predict and explain our behaviours and of others. Theory of mind is the foundation of social tasks, imaginative play, meeting information needs of a listener etc. (Abbeduto *et al.* 2004).

Theory of mind would be considered during the evaluation of both cycles of the methodology in both phases to support understanding of results obtained.

3.2.   Psychological Theories

3.2.1.   Repetitive conditioning of learner responses

The behaviourist view of learning emphasises approaches to teaching that involve "repetitive conditioning of learner responses" (Dalgarno 2001). This view and its practical manifestations in classrooms and in the design of interfaces, including repetition, reinforcement, feedback and motivation, have underpinned educational theory for many years.

This theory may be used but not at this initial stage of research. During the latter stages it may be used to condition learners depending on the outcomes.

3.2.2.   Anchored Instruction

Anchored instruction is a major paradigm for technology-based learning that has been developed by the Cognition & Technology Group at Vanderbilt (CTGV).

The initial focus of the work was on the development of interactive videodisc tools that encouraged students and teachers to pose and solve complex, realistic problems. The video materials serve as "anchors" (macro-contexts) for all subsequent learning and instruction. As explained by CTGV (1993, p52): "The design of these anchors was quite different from the design of videos that were typically used in education...our goal was to create interesting, realistic contexts that encouraged the active construction of knowledge by learners. Our anchors were stories rather than lectures and were designed to be explored by students and teachers. "The use of interactive videodisc technology makes it possible for students to easily explore the content".

The primary application of anchored instruction has been to elementary reading, language arts and mathematics skills. The principle of 'anchors' will be used during interaction planning.

3.2.3.   Cognitive Flexibility Theory

Cognitive flexibility theory focuses on the nature of learning in complex and ill-structured domains. Spiro and Jehng (1990), state: "By cognitive flexibility, we mean the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands...This is a function of both the way knowledge is represented and the processes that operate on those mental representations." The theory is largely concerned with transfer of knowledge and skills beyond their initial learning situation. The theory also asserts that effective learning is context-dependent, so instruction needs to be very

specific. In addition, the theory stresses the importance of constructed knowledge; learners must be given an opportunity to develop their own representations of information in order to properly learn.

Cognitive flexibility theory is especially formulated to support the use of interactive technology (e.g., videodisc, hypertext).Although this theory may not be used in any specific stage of the research this will remain a basic principle of the research.

3.2.4. Component Display Theory (CDT)

The theory specifies that instruction is more effective to the extent that it contains all necessary primary and secondary forms. Thus, a complete lesson would consist of objective followed by some combination of rules, examples, recall, practice, feedback, helps and mnemonics appropriate to the subject matter and learning task. Indeed, the theory suggests that for a given objective and learner, there is a unique combination of presentation forms that results in the most effective learning experience (Merrill 1987, 1994).

CDT specifies how to design instruction for any cognitive domain. CDT provided the basis for the lesson design in computer based learning system. This too like the Cognitive Flexibility Theory will be a basic principle of the research.

3.2.5. GOMS Model

GOMS is a theory of the cognitive skills involved in human-computer tasks. It is based upon an information processing framework that assumes a number of different stages or types of memory with separate perceptual, motor, and cognitive processing. According to the GOMS model, cognitive structure consists of four components: (1) a set of goals, (2) a set of operators, (3) a set of methods for achieving the goals, and (4) a set of selection rules for choosing among competing methods (Card, *et al.,* 1983, p.144). For a given task, a particular GOMS structure can be constructed and used to predict the time required to complete the task.

The primary application of the GOMS model is to text editing tasks, although it has also been applied to a wide range of computer tasks. This research explores the time taken to accomplish task and does not predict time. Although GOMS will not be used in this respect it will be used during the planning of interactivity.

3.2.6. Multiple Intelligences

The theory of multiple intelligences suggests that there are a number of distinct forms of intelligence that each individual possesses in varying degrees. Gardner proposes seven primary forms: linguistic, musical, logical-mathematical, spatial, body-kinesthetic, intrapersonal (e.g., insight, metacognition) and interpersonal (Gardner 1983, 1993a, 1993b).

The theory of multiple intelligences has been focused mostly on child development although it applies to all ages. While there is no direct empirical support for the theory, this theory will be used in phase two during the personalising of the interface.

3.2.7. Psychological Principles of Interface Design (Stone, 2005)
Four psychological principles of interface design

3.2.7.1. Users see what they expect to see
(1) The principle of consistency
(2) The principle of exploiting prior knowledge

3.2.7.2. Users have difficulty in focussing on more than one activity at a time
The everyday experience of focussing on one particular activity while switching between others has become known as the cocktail party effect (Cherry, 1953).

3.2.7.3. It is easy to perceive a structured layout
(1) The law of proximity
(2) The law of similarity
(3) The law of continuity
(4) The law of symmetry

This characteristic of perception is referred to as figure-ground segregation (Stone, *et al.,* 2005). According to Gestalt Psychology a number of laws determine the way in which we perceive the world (Koffka, 1935, or Kohler, 1947).

3.2.8. It is easy to recognise something than to recall it
Principles of recognition involves combining information that is stored in memory as is located in the world (Norman, 1998). These principles are based on both psychology and design.
(1) Visibility: What a control is used for
(2) Affordance: How a control is used
(3) Feedback: When a control has been used

All four principles will be used during the designing of interface properties.

3.3. Multimedia Theories

The addition to the multimedia theories discussed in George (2006), the following theories were considered.

3.3.1. Summary of Aids to Multimedia Learning
Based upon a cognitive theory of how learners process multimedia information, Mayer and Moreno (2002) propose some preliminary principles of instructional design for multimedia messages based upon a number of experiments into the effects of using different combinations of media. Table 1 shows the type of aid under investigation and the number of tests conducted; the effect size was statistically derived by a comparison of the results of students in problem solving transfer tests. An effect size of 1.9 is indicative of a very strong improvement in understanding (Faraday and Sutcliffe 1996, 1997a, 1997b, 1998).

This research deals with multimedia during the high fidelity stage in both phases. The choice of such would be made using the above table and the affectivity shown.

3.3.2.   Interactivity and Graphic Design

Interface design is not just about the 'look and feel' of screen components, it also encompasses the ergonomics of the user's control of the programme. This includes practical considerations such as clustering related devices close together so that users can easily swap between them. The sum total of the GUI is that it designs the user's interactions -- what they can do and how they do it. What the user sees and hears is only a manifestation of 'inter' activities (Nelson 1990).

This theory will be used during the designing of interface properties.

3.3.3.   Usability

Since 1984 usability has been dealt with by various people and many guidelines and principles have been introduced.

Bennett (1984) identified learnability, throughput, flexibility and attitude to be four concepts of usability and later made operation by Shakel (1990) to be testable aspects of the system. Since mid 1990s ISO standards in relation to systems were developed. Some of the most relevant standards include ISO 13470, 14915, 13407, 20282 and 9241 (in Stone, 2005 pg 105-107, 166).

Queensbury (2003) has proposed five dimensions with regard to usability referred to as the five E's based on ISO 9241. They are namely Effective, Efficient, Engaging, Error and Easy to learn.

3.3.4.   Design Principles

These are principles that complement both Gestalt's and Norman's principles. (Constantine and Lockwood, 1999)
(1)   Simplicity
(2)   Structure
(3)   Consistency
(4)   Tolerance

These principles would be maintained throughout the interaction design stage of the research.

3.4.   Social Theories

Social theories are used to identify social structures that may affect individuals behaviour, cognition or learning.

3.4.1.   Behaviourist Theories (Webquest, 2006)

- Principles of learning apply equally to different behaviours and to different species of animals. (Equipotentiality)

- Learning processes can be studied most objectively when the focus of study is on stimuli and responses.
- Internal cognitive processes are largely excluded from scientific study.
- Learning involves a behaviour change.
- Learning is largely the result of environmental events.

Some of these theories will be used partially at various stages. This research deals with children only and are not dealing with the biological aspects of speech therapy. And hence the first and third theories will not be used. The success of the experiment may cause the children to be more confident and outgoing and prove the fourth theory correct. The experiment will include stimuli and responses during the interaction design process to motivate children.

3.4.2.   Cognitive Theories (Webquest, 2006)
- Some learning processes may be unique to human beings.
- Cognitive processes are the focus of study.
- Objective, systematic observations of people's behaviour should be the focus of scientific inquiry, however, inferences about unobservable mental processes can often be drawn from such behaviour.
- Individuals are actively involved in the learning process.
- Learning involves the formation of mental associations that are not necessarily reflected in overt behaviour changes.
- Knowledge is organized.
- Learning is a process of relating new information to previously learned information.

All these theories will be part of the information gathering by literature search and observation.

3.4.3.   Social Learning Theory (Webquest, 2006)
- Modelling provides an alternative to shaping for teaching new behaviours.
- Teachers and parents must model appropriate behaviours and take care that they don't model inappropriate ones.
- Students must believe that they are capable of accomplishing school tasks.

This research is focussed on those who have difficulty in pronouncing by way of observation and explanation and hence does not prove the first of these theories. The rest of the theories must be strictly followed to avoid confusion for the child, during the requirement gathering processes and during the creation of mental.

4. Analysis

The Figure 3 shows the various stages of this research and the theories associated with it.

The following theories would be the basis and motivation on which the project is built:

- Development of children with disabilities and the adaptation of their parents.
- Vygotsky's Theory
- Cognitive Flexibility Theory
- Component Display Theory
- Digital game-based learning
- Social Learning Theory

In Cycle one, during the requirement gathering process Emotional Intelligence, Disability Theory, Usability, Cognitive, Social Theory would be used. This would be followed by Information processing Theory in order to specify requirements. In order to design concepts, Conceptual, semantic, syntactic and lexical models and Usability Engineering would be used. Contents would be analysed using Cognitive load theory for content diagrams and Dual Coding Theory, Organising the Display, Social Theories to create Mental models. Based on the content analysis low fidelity prototypes would be created. During this stage the eight golden rules of interface design and three principles for design would be used. The prototypes would be evaluated using Vygotsky's Theory, Theory of mind, seven stages of action model, Usability, Accessibility and Principles of Good Layout. This would be an iterative process.

During cycle two, requirement gathering would take place using Emotional Intelligence, Disability Theory, Usability, Cognitive and Social Theory and they would be specified using Information processing Theory. Interaction would be designed keeping in mind theories such as Split Attention Effects, Anchored Instruction, GOMS Model, TAGs, Interaction Design, Accessibility, Recognising Diversity, Getting the user's Attention. Properties for the Interface would be defined using Psychological Principles of Interface Design, Interactivity and Graphic Design, Accessibility, Principles of Interaction Elements, Icon Properties and Nonanthropomorphic Design. Based on these guidelines the high fidelity prototype would be created based on High fidelity prototyping: Eight Golden Rules of Interface Design, Three principles of design, Aids to Multimedia Learning. These prototypes will be evaluated using Vygotsky's Theory, Theory of mind, Seven stages of action model, Usability, Accessibility, Principles of Good Layout

During Phase two the above stages would be repeated along with the theories involved. In addition repetitive conditioning of learner responses, Constructivism, multiple intelligences and style guide of widgets theories would be used in order to create widgets to customise the application.

5. Conclusions

This report surveyed the theories associated with multimedia interfaces for children with speech impairments. They were investigated under multimedia, educations, psychological and social theories. Each theory was followed by an analysis do decide if the theory could or could not be used for the research. The chosen theories were structured according to the chosen methodology. A diagram was included for both phases in order to attempt answering the research question of 'should there be a group of interaction paradigms or one novel interaction paradigm that can be personalised to enhance the performance of pronunciation skills for children with speech impairments?' The educational theories are mainly associated with the requirement gathering, conceptual design and evaluation stages of the research. The psychological theories in addition to these stages are involved during the interaction design. Multimedia theories are used primarily during the high and low fidelity prototyping and also the evaluations. Social theories are used the least and they will be used during requirement gathering, creating mental models and interaction design.

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Figure 1 - *Methodology*
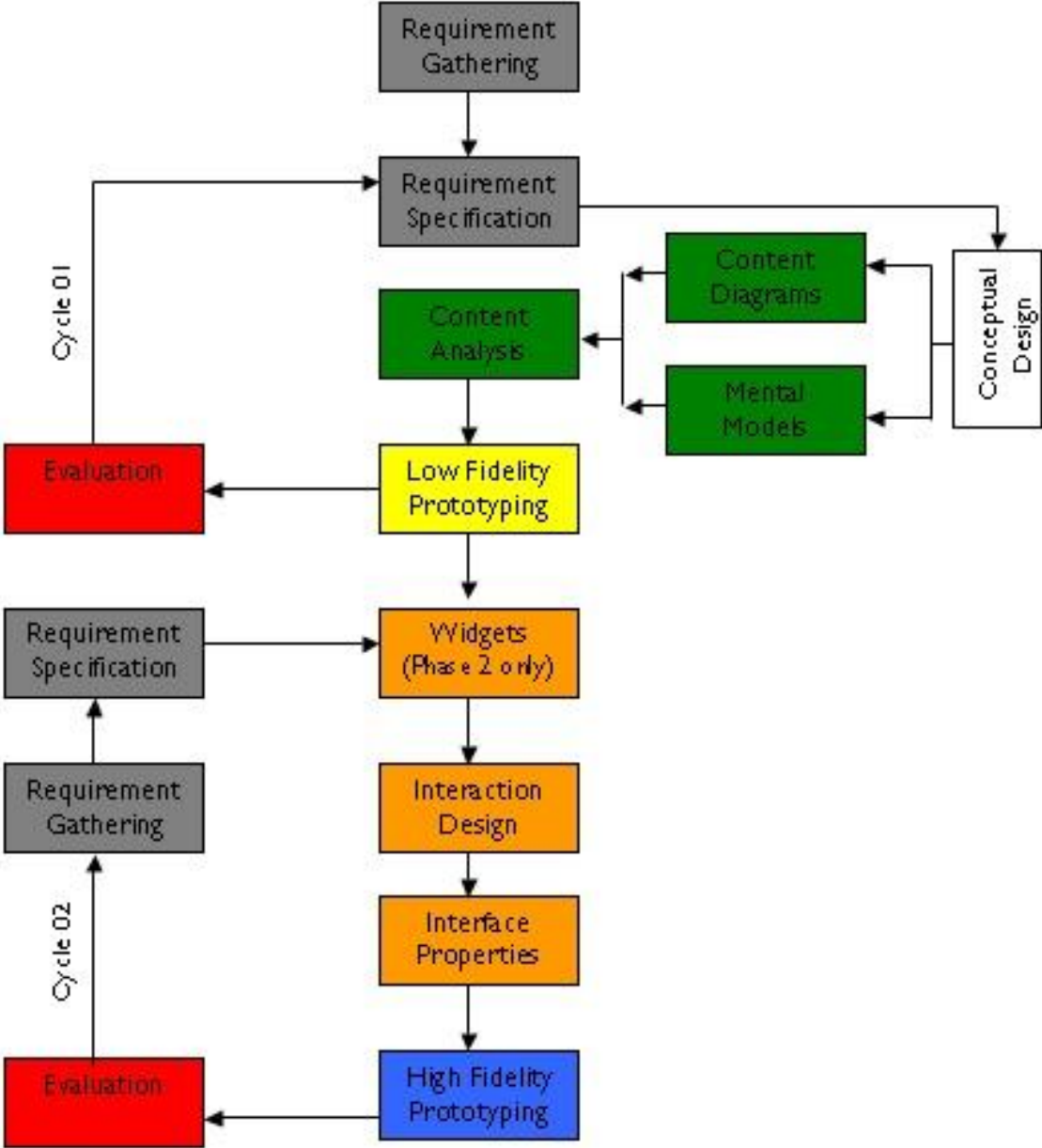
Figure 2 – *Literature Map*
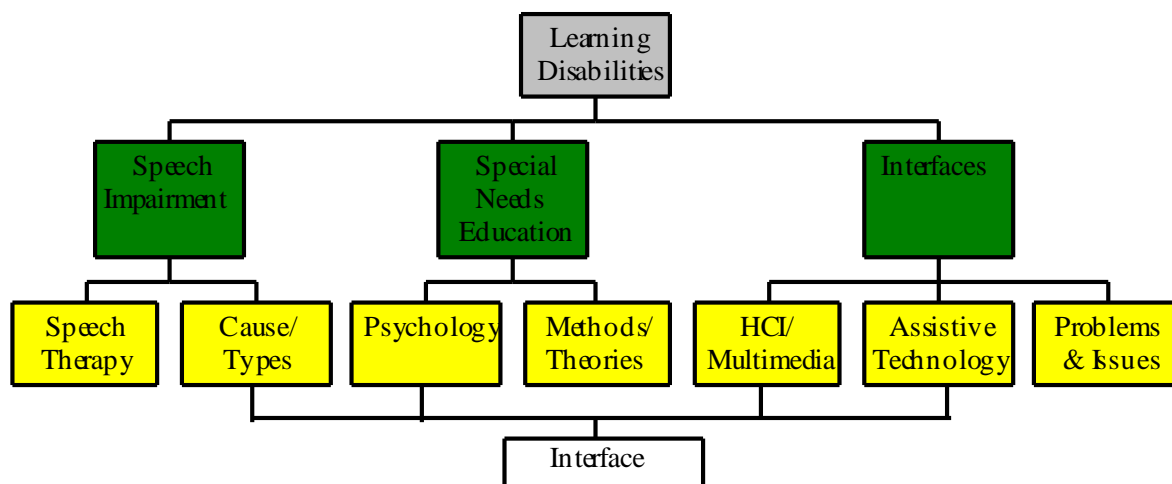
Table 1 - *Aids to Multimedia Learning (Mayer and Moreno 2002).*

Type of Aid	Description of Aid	Number of Tests	Effect Size
Multimedia aids	Use narration and animation rather than animation alone	3 of 3	1.90
Contiguity aids	Present corresponding narration and animation simultaneously rather than successively	8 of 8	1.30
Coherence aids	Eliminate unneeded words and sounds	3 of 3	0.90
Modality aids	Present words as narration rather than on-screen text	4 of 4	1.17
Redundancy aids	Present narration and animation rather than narration, animation and on-screen text	2 of 2	1.24

Figure 3 - *Chosen Theories*

Requirement Gathering
Emotional Intelligence
Disability Theory
Usability
Cognitive, Social Theory

Requirement Specification
Information processing Theory

Content Diagrams
Cognitive Load Theory

Content Analysis

Mental Models
Dual Coding Theory
Organising the Display
Social Theories

Conceptual Design

Evaluation
Vygotsky's Theory
Theory of mind
Seven stages of action models
Usability
Accessibility
Principles of Good Layout

Cycle 01

Low Fidelity Prototyping
Eight Golden Rules of Interface
Design
Three principles of design

Conceptual Design
Conceptual, semantic,
syntactic and lexical
model
Usability Engineering

Widgets
Multiple Intelligence
Style Guides to Widgets

Interaction Design
Split Attention Effects
Anchored Instruction
GOMS Model, TAGs
Interaction Design, Accessibility
Recognising Diversity
Getting the user's Attention

Requirement Specification
Information processing Theory

Requirement Gathering
Emotional Intelligence
Disability Theory
Usability
Cognitive, Social Theory

Cycle 02

Interface Properties
Psychological Principles of
Interface Design
Interactivity and Graphic Design
Accessibility
Principles of Interaction Elements
Icon Properties
Nonanthropomorphic Design

Evaluation
Vygotsky's Theory
Theory of mind
Seven stages of action models
Usability
Accessibility
Principles of Good Layout

High Fidelity Prototyping
Eight Golden Rules of Interface
Design
Three principles of design
Aids to Multimedia Learning

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