Equilibriating Instructional Media for Cognitive Styles
James A. Redmond, Cathal Walsh and Adrian Parkinson,
Dept of Computer Science & Dept. of Statistics, Trinity College, Dublin, Ireland
redmond@cs.tcd.ie, cathal.walsh@tcd.ie & adrianarosa1@eircom.net

ABSTRACT
Two types of instructional environment (Text and Web) that had been used in a previous study [1] were adapted to accommodate Cognitive Style preferences for Witkin’s Field-dependent [2] and Riding’s Imager [3]. Ninety six Information Systems students were randomly allocated to each of these environments and their Cognitive Styles were assessed. The students studied an Introductory Course in Artificial Intelligence one hour per week for six weeks after which they were assessed by a one hour exam. It was found that Field-dependents and Field-independents performed similarly in both environments as indicated by their examination scores demonstrating the success of the adaptation of both environments for Field-dependents. The adaptation for Imagers as measured by Riding’s CSA [3] was not successful as Verbalisers performed better than Imagers in both Text and Web. This raises questions about the stability of Riding’s Verbaliser/Imager dimension. People performed significantly better in the Text environment than in the Web environment.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces - ergonomics, screen design, user-centered design.
J.4 [Computer Applications]: Social and Behavioral Sciences - psychology.

General Terms

Keywords
Cognitive Styles, CSA, GEFT, Learning performance.

1. INTRODUCTION
"Aristotle in 334 B.C. said "Each child possessed specific talents and skills". He also discussed the concept of Individual Differences in young children" [4]. "Individual differences make a difference - characteristic differences in cognition and creativity cast the form of individual learning and performance and hence have profound implications for teaching and training" [5]. “Awareness of individual differences will make educators more sensitive to their role in learning” [6]. Interest in the area of Individual Differences has been rekindled in recent years. This may be explained by (a) an increased awareness of the importance of individual differences and (b) the availability of powerful inexpensive computers which facilitate research in the area. Individual Differences include the study of Intelligence, Motivation, Locus of Control and Cognitive Styles. Educators now have a realistic opportunity of accommodating Cognitive Styles preferences when designing virtual learning environments. In this study we are interested in taking cognizance of Cognitive Style characteristics when designing learning environments and finding out if these environments can be successfully adapted.

2. COGNITIVE STYLES
The construct of Cognitive Style was originally proposed by Allport [7] referring to an individual’s habitual way of perceiving, remembering, thinking and problem solving. Messick [5] defined Cognitive Style in "terms of consistent patterns of organizing and processing information". Witkin has defined cognitive style as "characteristic modes of functioning that we reveal through our perceptual and intellectual activities in a highly consistent and pervasive way" [8].

These definitions are in pointed contrast to Riding and Rayner [9] who define Cognitive Style as being, in a much more limited manner, “an individual’s preferred and habitual approach to organizing and representing information ". Reading also states that Cognitive Styles should be independent of intelligence and personality. They should relate to observable behaviours such as learning performance and learning preferences [9]. Cognitive Styles are distinct from Cognitive Abilities. Cognitive Style emphasises how a person learns something, not what he/she learns. Cognitive Styles are non-pejorative whereas general Cognitive Abilities may not be so. Cognitive Styles are bipolar, characterised by a continuum. Cognitive Ability is unipolar denoted by a mark (e.g. I.Q.).
The Cognitive Styles studied in this work are: Field-dependence/Field-Independence (FD-FI), Verbaliser-Imager (V-I) and Wholist-Analytic (W-A), which are discussed in more detail next.

### 2.1 Field-Dependence/Field-Independence

This concept describes the ability of an individual to identify a specific element from within a complex field. Witkin, Goodenough and Cox’s [10] definition of Field-independence is “the extent to which a person perceives part of a field as discrete from the surrounding field as a whole rather than embedded in the field; the extent to which a person perceives analytically”. Some of the characteristics that best describe the Field-independent learner are: analytic, insensitive to social cues, internally directed, generates structure, less affected by structure and format, individualistic and ignores stress [6]. A Field-dependent person may be described by the following attributes: global, accepts structure, externally directed, influenced by salient features, influenced by structure and format, sensitive to others and affected by stress [6]. Studies suggest that individuals who are Field-independent perform better than those who are Field-dependent in computer assisted and hypermedia-assisted environments. Post [11] found that there was a positive relationship between Field-independence and achievement in a computer-assisted environment. Wey & Waugh [12] revealed that Field-independent students performed significantly better than Field-dependent students in a text only treatment. Weller, Repman and Lan [13] using a hypermedia-based program called the “Computer Ethics Stack Program” showed that Field-independent students’ scores were significantly higher than those for Field-dependents. They also report that Field-dependent students answered fewer questions and accessed more concept explanations than did Field-independent students. In a further study [14] they found that Field-independent students learned more effectively than Field-dependent students did. Wang and Jonassen's study [15] show that Field-independent students accessed more screens and spent less time per screen, than did Field-dependent students. They found that Field-independent students tended to cover most of the program by quickly skimming through the screens in the process. The research studies mentioned above indicate that Field-dependent learners don’t perform as well as Field-independents. One may assume that the way in which information was presented in the studies referred to above was readily and efficiently processed by the Field-independent learner. These studies illustrate well that where information is presented in a form that can be easily processed by the learner’s Cognitive Style significant learning can be achieved. As computer educators we are more likely to be involved in the design and use of web-based environments for course delivery given the potential of this new paradigm. Can we support and enhance the performance of the Field-dependent student?

Goodenough [16] showed that FD’s were influenced by salient cues, that they used a spectator-type approach to learning, and were very much influenced by negative reinforcement. Satterly and Telfer [17] found that FDs benefited when advance organizers were used in the instructional environment. Tannenbaum [18] showed that FDs scored well on tests when learning materials were highly structured. Thompson [19] found that text passages with headings improved the scores for FDs whereas FIs scored better than FDs when the passage headings were excluded. The implications of the research findings above suggest that the FD learner may be better supported by instructional conditions that are highly structured, provide appropriate cueing techniques and questioning strategies that provide positive feedback. Additionally stress can be reduced for the Field-dependent learner by well-designed navigational tools in the Web based interface.

### 2.3 Cognitive Styles Analysis (CSA)

The CSA [3] is a computerized psychometric test, which measures two independent dimensions of Cognitive Style the Verbaliser-Imager and the Wholist-Analytic. Riding and Douglas [20] reported that Verbalisers performed better than Imagers in a text-based environment. Riding’s research has shown that Verbalisers tend to perform better than Imagers in learning environments where the material is in a textual and/or auditory format. Imagers similarly tend to outperform Verbalisers where the presentation mode is graphical and visual. Imagers scored higher than Verbalisers in a similar type environment when the learning material was in text and picture format [9]. It is interesting to note that not only do individuals who engage in a learning environment compatible with their Cognitive Style perform better, but they also show an intuitive preference for learning material that best suits their Cognitive Style [21, 22]. Riding and Rayner [9] comment that “in terms of content type, individuals appear to learn best when information can be readily translated into their preferred verbal-imagery mode of representation. It is of interest to note that not only the mode of presentation, but also the content itself affects learning performance to an extent that it is of practical significance.” Riding’s other orthogonal dimension, the Wholist-Analytic dimension, is also assessed by the CSA [3]. Where an individual is located on the Wholist-Analytic continuum can often cause an interaction between learning material structure and learning performance. Riding and Douglas [20] found that Wholists did best when the title of a passage was given before the passage, as opposed to at the end. This interestingly enough had little affect on analytics. Other studies confirm this finding [22], [23].
3. AIM OF STUDY
In a previously published study where no account was taken of cognitive style characteristics when designing the different instructional media we found that Field-independents performed significantly better than Field-dependents [1]. In the present study we preferentially matched the Cognitive Style characteristics of Field-dependent learners and Imagers with the various characteristics of two learning environments Text and Web. We then investigated whether the disparity between Field-dependents/Field-independents examination performance could be eliminated. This disparity we felt was due to the lack of support for the attributes of the Field-dependent learner. It has been well-established that the Field-independent learner thrives in unstructured learning environments [6], [19].
We also investigated Riding's CSA in similar fashion. This was motivated by the somewhat unexpected result in the previous study which indicated that Riding's Verbaliser/Imager dimension was not a predictor of examination score where it was considered that the environments suited Verbalisers and Imagers. As a consequence, in this study, we incorporated more illustrative material so as to strengthen the environment for the Imager.

3.1 Study Implementation
"In education the time has come to vary the track conditions so that more runners can finish strong" [24]. In our study we have attempted to implement the idea that a person of a particular Cognitive Style should not be disadvantaged in an instructional environment. We redesigned two types of instructional environment previously used in another study [1]. First we wished to match the Cognitive Style characteristics of Field-dependents and Imagers with the presentation and structuring of the information in two environments Text and Web. We hoped that by addressing the characteristics of the Field-dependent learner and Imager in the design of these educational environments that we could enhance their learning performance.
In order to achieve this both environments were characterized by: a table of contents, a set of advance organizers, paragraph headings and sub-headings. Where possible the use of visual imagery was incorporated in both environments Text and Web. Both environments were also interspersed with questions of both a lower and higher cognitive level.
Ninety six, third year, Information Systems students participated in this study. They were taught an introductory course on Artificial Intelligence designed by one author (AP). The students attended over a six-week period, totaling seven hours in duration. The students were randomly allocated to one of the two studies. The studies were held concurrently and the students participating in these studies did so under identical but separate experimental conditions.

3.2 Studies
The subject-matter for the two studies was an Introductory Course in Artificial Intelligence. In Study 2 the study was run on the same machine types with identical CPU speed and memory. The students being third year Information Systems students were all considered computer-literate and were experienced in using the Internet. The studies are briefly described as follows:

3.2.1 Study 1 – Text
A set of course notes were presented to the students in traditional text format produced using Microsoft Word. The text consisted of ten modules. At the end of each 1-hour session the students’ sets of notes were collected and redistributed at the commencement of the next session. The students were encouraged to take notes during the one hour session if they so wished.
Each module had a set of advance organizers, paragraph headings and sub-headings. Every module had a set of questions interspersed with the text. These questions were both at lower and higher cognitive levels. The questions were designed to provide feedback and sustain learner extrinsic motivation (this being particularly relevant to the Field-dependent learner). Many of the modules were also illustrated with pictures and diagrams.

3.2.2 Study 2 – Text with Hyperlinking (Web)
An educational Internet site was developed using Java and CGI scripts. The site design was intended to match the characteristics of both Field-dependent learners and Imagers. At the commencement of each session the students logged on to this site using a password. A specially designed piece of software designed using CGI locked the users out of the site after exactly one hour. The students while studying the course material were encouraged to take notes if they so wished. They were not permitted to print any of the course material. An interactive site map was included in the site so as to assist user navigation. The map also indicated where the user was within the module. The modules were well-structured each having a set of aims, a list of contents, paragraph headings and questions. The modules were also illustrated with diagrams and pictures similar to that presented in Study 1 above. In this web-based environment different types of question formats were used – form filling, objective style questions and, in some cases, the students had the opportunity of emailing the answers to the Instructor. Where the students used text boxes they received feedback as to the correctness of their responses. The core subject matter was identical to that presented in Study 1 (Text) but with the addition of numerous links, where relevant, to pertinent sites on the Internet. This site was interactive containing additional hyperlinked information. A
high degree of hyperlinking was available within the course modules and, of course, to the Internet itself.

3.3 Learning Performance – Evaluation
The students’ knowledge of the material was examined at the end of 7 hours of instruction in a test that lasted one hour. The assessment test for the students contained twenty two questions. These questions were objective style questions and assessed the students’ knowledge and understanding of basic concepts in AI (e.g. Turing test, expert system development and application) at both lower and higher cognitive levels.

4. PSYCHOMETRIC TESTS
All participants were administered the GEFT – Group Embedded Figures Test [2], and Riding’s Cognitive Style Analysis [3]. For Witkin’s GEFT test, there are conflicting studies concerning the issue of its construct validity. Studies suggest that the GEFT is not particularly satisfactory as a measure of Field-independence/Field-dependence since it is related to spatial ability [25, 26]. Very acceptable reliability coefficients have been reported for Witkin’s GEFT. Riding and Rayner [9] make references to numerous studies, which support the construct validity of those fundamental dimensions as assessed by the CSA.

5. RESULTS
The data were analyzed using Data Desk V6.1. A stepwise multiple linear regression was fitted.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F-ratio</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1</td>
<td>13182.8</td>
<td>13182.8</td>
<td>1200.5</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Verbaliser / Imager</td>
<td>1</td>
<td>95.9949</td>
<td>95.9949</td>
<td>8.7416</td>
<td>0.0047</td>
</tr>
<tr>
<td>Study</td>
<td>52</td>
<td>577.032</td>
<td>10.9814</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>736.982</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Anova table for final linear model fitted using stepwise regression.

The analysis is given in Table 1 which shows the model arrived at after fitting a backwards stepwise multiple regression. Main effects and 2-way interactions were entered into the model. When effects had $p > 0.05$, they were removed from the model, 2-way interactions first. The analysis used was Type III sum of squares - the computer fits the model including everything except that factor, and then calculates the change in sum of squares with this entered last. It does this for each factor in turn, so that it gives a measure of how significant the factor is after allowing for everything else before it.

Table 1 shows that the Verbaliser/Imager dimension was a statistically significant predictor of examination score at the $p < 0.005$ level. Study Type was a statistically significant predictor of exam score at the $p < 0.01$ level.

6. DISCUSSION
Our results show that Witkin’s Field-dependence/ Field-independence is not a significant predictor of student examination score. This shows that our redesign of the environments so as to balance the situation for Field-dependents has been successful. In other words, those who were Field-dependent performed similarly to those who were Field-independent. In the previous study Field-independents had performed significantly better than Field-dependents where the learning environments were unstructured and with little support for the attributes of the Field-dependent learner [1]. We found that Riding's Wholist/Analytic dimension is not a significant predictor of examination score in either Text or Web in this study. We also found that Riding’s Verbaliser-Imager dimension was a significant predictor of examination score in both studies – Text and Web. Verbalizers performed better than Imagers in both studies. This is despite the fact that much use was made of imagery in the design of course material in both studies. The poor performance of the Imager may be explained by the fact that despite extra imaging material, the content, of necessity, remained largely textual. The Web-based interface has the potential for providing Imagers with highly interactive graphical, audio and visual learning materials. However speed, memory and bandwidth limitations have constrained the performance of the Web as an instructional environment especially for the Imager since using images slows down the performance of a website dramatically; the more images the slower the site.

In the previous study the Verbaliser/Imager was not a statistically significant predictor of examination score [1], but in this study it was. This raises a question about the ability of Riding’s CSA to accurately assess the Verbaliser/Imager dimension. We would have expected this VI dimension to be a predictor of examination score in the previous study because of the large amount of textual material which would have suited Verbalisers [1]. Our results also show that even while ignoring the affect of Cognitive Styles those in the text environment performed better than those in the Web. We postulate that this result could be explained in terms of the students’ greater familiarity with text rather than with any other instructional medium mainly because over their lifetime their instructional medium has been predominantly textual.

7. CONCLUSIONS
We have shown it is possible to redesign instructional environments (Text, Web) so as to balance or equilibrate the performance of Field-dependents and Field-independents.
We have found that the performance of Riding's Verbaliser/Imager dimension is unstable. Verbalisers performed better than Imagers in both studies - Text and Web. Irrespective of Cognitive Style, those studying in the Text-based environment did significantly better than those studying in the Web-based environment.

Acknowledgements: The third year students of the Information Systems degree course, Rosemary Welsh and Alan Mullally. We also would like to thank Dr. M. O'Moore for administering the GEFT.

8. REFERENCES