CONCEPTUALIZING GUIs — A CASE STUDY OF AN ONLINE APTITUDE TESTING SYSTEM FOR ADMITTING STUDENTS IN DESIGN PROGRAMS

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This paper reports a study involving students' responses to existing online aptitude tests, their influences on the cognitive workload of students while taking the exams and based on this — proposes an online aptitude testing system for admitting students into design programs. Using a subject base of 33 students and 3 online tests, a study based on questionnaires and interviews was done to understand factors influencing the efficiency of students undergoing such tests. Based on this a few questions intended to test design aptitude were formulated and are depicted through conceptualized GUIs and are presented as a case study.

Keywords: Aptitude, tests, design, Cognitive workload, efficiency.

1. INTRODUCTION

A **psychological test** or educational test is a set of items designed to measure characteristics of human beings that pertain to behavior. There are many types of behavior. *Overt* behavior is an individual's observable activity. Behavior can also be *covert* — that is, it takes place within an individual and cannot be directly observed. Psychological and educational tests thus measure past or present behavior to a given situation or context. Some also attempt to predict the future behavior, such as success in college or in an advanced degree program [1].

Test scores can be related to traits, which are enduring characteristics or tendencies to respond in a certain manner. Historically, experts have distinguished among achievement, aptitude, and intelligence as different types of ability. **Achievement** refers to previous learning. A test that measures or evaluates how many words a person can spell correctly is called a *spelling achievement test*. **Aptitude**, by contrast, refers to the potential for learning or acquiring a specific skill. Traditionally distinguished from achievement and aptitude, **intelligence** refers to a person's general potential to solve problems, adapt to changing circumstances, think abstractly, and profit from experience [2].

When a design student shifts from the traditional way of taking a paper based test to an online version, he/she is likely to encounter difficulties during the test session making it a stress full experience which can interfere with creativity that is being tested. In the case of multidisciplinary Design programs, students from various backgrounds are tested and selected through what can be called as skill cum aptitude tests involving sketching, visualizing and conceptualizing.

1.1. Computer based tests Vs Paper based tests

The standardization of test administration conditions is one of the many benefits offered by computer-based testing (CBT). No matter what the tests' population size, CBT helps test developers to set the

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same test conditions for all participants. It also improves all aspects of test security by storing questions and responses in encrypted databases and enables testers to create randomized questions and answers from vast question pools. Moreover, offering different test formats and the immediate presentation of different types of feedback, either to students or testers, are other great advantages of CBT (Olsen *et al.*, 1989). On the examinees' side, they are able to receive greater measurement efficiency and the possibility to take the test at any time. On the other hand, there are some disadvantages that users have to be aware of before opting for computer-based testing, which led many scholars to suggest conducting systematic studies to check equivalency and comparability of paper-based tests and computer based tests (Parshall *et al.*, 2002). For example, students need some degree of computer literacy in order to avoid the mode effect on computer-based testing (Alderson, 2000).

Here are some advantages computers offers:

(a) Excellence of standardization.
(b) Individually tailored sequential administration.
(c) Precision of timing responses.
(d) Release of human testers from other duties.
(e) Patience (test taker not rushed).
(f) Control of bias.

Different studies have explored examinees' computer attitudes and preferences for computer-based testing and found a variety of views. Some participants negatively evaluated their experience with the computers in general and CBT in particular (Ward *et al.*, 1989). However, that was explained by the investigators as the respondents were new to this type of test administration mode and such a negative attitude might disappear with more exposure to CBT. On the other hand, many other studies found that the examinees positively preferred CBT for several reasons such as time efficiency, focussing attention, enjoyment and confidentiality (Bresolin, 1984, cited in Boo, (1997)). Other participants were very positive about computer-based testing because it seemed less difficult, more useful and engaged their attention more than paper-based testing (Harrel *et al.*, 1987).

Traditionally in Design, questions consisted of testing conceptualising, visualising and idea communication ability (sketching) sills. Of late other aspects such as language comprehension, fundamental understandings of technology etc are also being included. Most of the tests are either fully paper based or partly paper and partly computer based. Computerisation , it is feared is not likely to test for example sketching skills which can only be done using papers till such time as digital tablets become widespread.

1.1.1. Research Questions

To seek possible explanation and answers to some questions, an experiment was conducted involving students from various backgrounds. The questions that prompted our research are stated below:

(i) What are the obstacles a student encounters when he/she gives an online test for the first time?
(ii) Which are the areas where an online testing system failed to satisfy students in terms of their freedom in answering or understanding the questions in comparison to a paper based format?
(iii) How online aptitude tests can be made more persuasive with respect to paper based ones?
(iv) What are the factors that should be taken into consideration to judge aptitude for recruiting students in design programs?
(v) How to convert/transform/find alternatives to existing paper based Design aptitude tests for online versions?

2. METHOD

A questionnaire survey was conducted involving 33 students, the details of which are given in the Table 3.1. and 4.1.. Their understanding of various test sessions experienced earlier was sought to be

Table 1. Details of the respondents participated in Questionnaire survey.

Respondents	PhD students	M.tech/M.Des Students	B.Tech/B.Des Students
Male: 22	5	9	8
Female: 11	3	4	4
Total: 33	8	13	12

Table 2. Details of the respondents participated in protocol analysis.

Respondents	Subjects who could complete the test	Subjects who could not complete the test
Male: 22	17	5
Female: 11	8	3
Total: 33	25	8

understood from the usability point of view. Subsequently a protocol analysis was done with the same respondents and we asked them to complete an online testing session so that we could relate their answering pattern in the questionnaire with their cognitive processes when online. Finally we identified the areas in an online test which possibly hinders/influenced a student's test session. Based on the understanding of the survey and protocol analysis a series of mockup questions were conceptualized specifically for online testing using Graphic User Interfaces (GUIs) for further testing.

2.1. Questionnaire survey

Data collected using a questionnaire was in two stages. In the first stage 33 subjects were interviewed and in the second stage 25 users were asked to complete a test using available testing products from the market.

In order to find out how best to convert/transform/find alternatives to the existing paper based Design aptitude tests the following questionnaire was formulated and asked to the student subjects:

1. Which online exam did you appear or are preparing to appear?
2. Which mode suits you the best when given the question paper?
   (a) Seeing all the questions at a time.
   (b) Seeing one question/section at a time.
3. In a computer screen based exam system, the following five types of questions are available
   Category 1: Questions that require conventional sentences to be typed in.
   Category 2: Objective questions. Category 3: Diagram based questions.
   Category 4: Puzzle based questions. Category 5: Game based questions.
   If you have 4 sets of subjects namely Mathematics, Science, Social Science & Engineering Drawing, which types of questions will you choose for each of them.
4. Could you complete the test s you have taken on time?
5. List the steps you generally follow while answering questions in a paper based test.
6. Could you follow the same steps in the CBT?
7. Do you think you need to undergo a mock CBT test to increase your efficiency before taking a real one?

2.2. Protocol Analysis

This technique is generally used to capture the mental model of users while they are asked to complete a given task and they are also asked to verbally speak aloud their thoughts. Here our main intention was to understand the obstacles a student encounters when he/she gives an online test and to find the

areas where an online testing system failed to satisfy students in terms of their freedom in answering or understanding the questions in comparison to a paper based format. 25 subjects were given the task of answering questions of an aptitude section in 20 minutes using an the online portal [18]. Out of twenty five, ten students were newcomers who had no previous experience of taking an online test on a computer and fifteen students had some previous exposure.

3. PRELIMINARY ANALYSIS AND INFERENCES

The analysis of the data gathered from the questionnaire survey and the protocol analysis has resulted in some inferences that possibly answer questions that have been raised earlier in Section 1.1.1. However no attempt has been made to validate the results using statistical tests as the sample size was limited to only 33 students in the case of questionnaire survey and 25 students who could complete the test in case of protocol analysis. This experiment was meant as an exploratory study before planning a large scale one.

3.1. Inferences from the Questionnaire survey responses

Only selected results for a few selected questions have been statistically compiled from the data collected and are presented below keeping the length of this paper in view. The percentage distribution of the responses to each of the question is shown in the Figures 1 & 2 respectively.

Among the 33 students with whom the questionnaire survey was conducted 8 students had given the BITSAT (Birla Institute of technology & sciences admission test) online test and 7 students had already given GRE (Graduate record examination) tests. The breakup of the students who has applied or given online tests has been shown in the Figure 2.

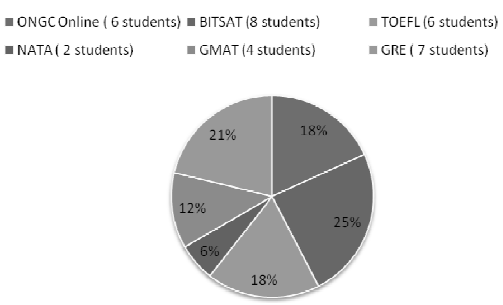


Figure 1. Diagram showing the answer of the respondents during the questionnaire survey when they were asked "Which online exam did you appear or preparing to appear".

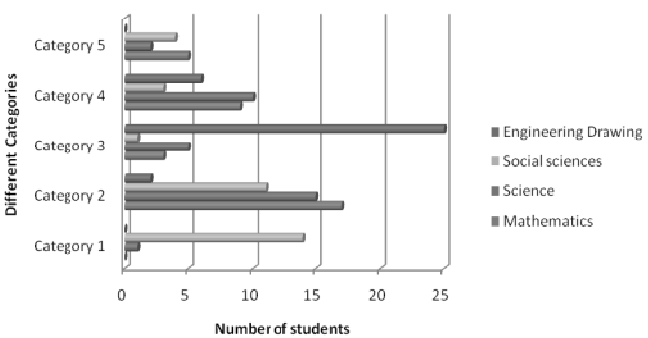


Figure 2. Diagram showing the answer of the respondents when they were asked to choose from the categories.

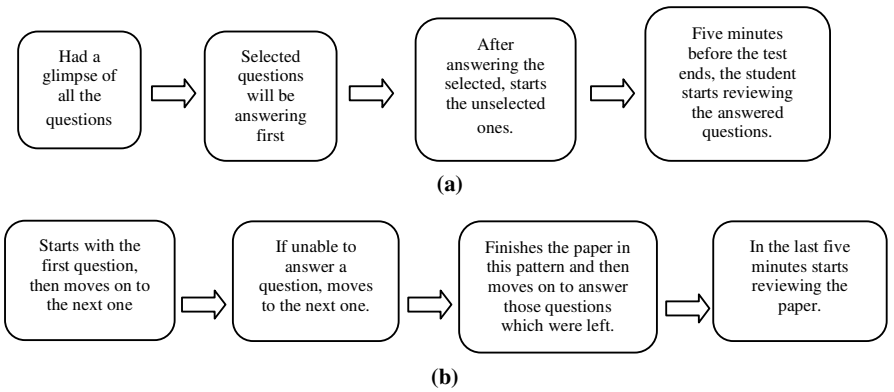


Figure 3. (a) Answering pattern of 24 students, when they were asked to list the steps they generally follow while answering questions in a paper based test. (b) answering pattern of 9 students, when they were asked to list the steps they generally follow while answering questions in a paper based test.

A unique attitude was observed when the students were asked about the mode that suits them the best in the examination. Out of 33 students 26 of them opted for seeing all the questions to start with and then decide the order of answering questions, whereas only seven of the twenty six subjects preferred to see one question at a time.

In another question (question no. 3, of Subsection 2.1), most of the respondents choose category 2 (Fig. 2): objective questions as their most favorite option for answering mathematics, science and social science subjects.

In another question 22 respondents said that they could complete the test on time and 11 respondents said they could not.

During the survey the students were asked to describe their way or style of answering questions (Fig. 3). Two types of processes could be discerned. That reinforced the 'all questions at first glance' — view.

3.2. Protocol analysis — Inferences

This analysis was done to understand and get a first hand impression of what a student does and what is the behavior during a test session. 33 students were asked to complete the aptitude section of the National Aptitude Test in architecture in the website [18]. The test section had 15 questions and 30 mints were given to complete the section. While the subjects were taking the tests they were asked to think aloud and their task flow was recorded. Out of the 33 students 25 of them could complete the task. The two flows shown in Fig. 4 represent the two processes that have been observed during the analysis of the talk aloud protocol. The subjects wanted the same freedom of answering questions in a CBT as they have in a PBT. They want to decide their order of answering questions; they want to review/change their answers.

3.3. Heuristic Evaluation — Inferences

Three online portals were chosen [19] and were evaluated on the basis of ten heuristics; the inferences are stated in the Table 3.

This analysis gives a possible explanation as to why the subjects couldn't complete given tasks during the think aloud protocol session. Each element in the GUI plays a vital role and acts as affordances for the students. Perhaps the students are interacting with the GUI elements for the first time but during these interactions if the student is assisted to find the correct semantic insight it may help them save time otherwise lost in trying to comprehend the GUI confronting them for the first time. Orientation to next action if incorporated in the GUIs would help better efficiency for the student.

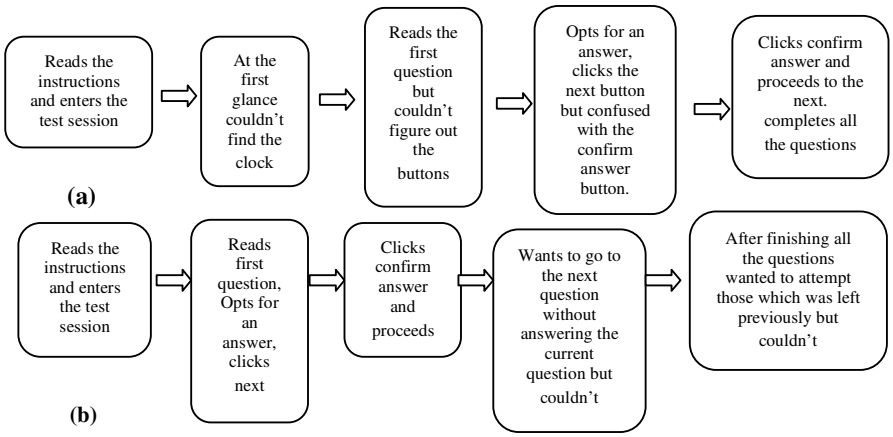


Figure 4. (a) The task flow pattern of 10 students came up during protocol analysis. (b) The task flow pattern of 12 students came up during the protocol analysis.

Table 3. Details of heuristic evaluation of tcyonline, whathalf and NATA web portals.

	Whathalf.com	tcyonline.com	NATA
Heuristics			
1. Clearly visible and understandable iconic representation.	Provided	Not provided	Not very clear
2. Highlighting the options to indicate the selection.	Provided	Not highlighted	Not highlighted
3. Provide tool tips for explaining the options, their implication.	Provided	Provided but not very clear	Not provided
4. Consistent size of buttons by following a grid.	Consistent	Consistent	Consistent
5. Logical sequence of options	Logically arranged	Randomly arranged	Logically arranged
6. Form visibly proximate groups of related options	provided	scattered	scattered
7. Describing the screen/groups by precise title.	Poorly described	Described	Not Described
8. Clear and understandable wordings of buttons and other information in the UI.	clear	Not Clear	Clear
9. Use appropriate symbols or icons for related options.	Provided	Not provided	Not provided
10. Legibility of text	Legible	Legible	Legible

4. FORMULATING TEST CONTENT FOR A DESIGN APTITUDE TEST

In the field of design, spatial ability is regarded as a crucial factor and is an indicator of aptitude for design which requires visualizing in three dimensions. Many studies have shown that spatial ability is a good predictor for success in the design area (Smith 1964; Ghiselli 1973, cited in Lohman 1988).

It is known that design spatial ability involves the ability to apply spatial transformations with different kind of 2D and 3D drawings, but very little is known about how those skills can be developed. One of the biggest but implicit assumptions in architectural and design education is that the educationists are able to increase students' spatial ability through academic training (Ho, Eastman and Catrambone 2005).

Ho, Eastman and Catrambone (2005) noted, architecture students usually learn design starting from mapping real objects onto 2D drawings and also learn to represent their design concepts in 3D in charcoal and watercolor drawings, but there is no study investigating the impact of these kinds of courses on students' spatial reasoning skills.

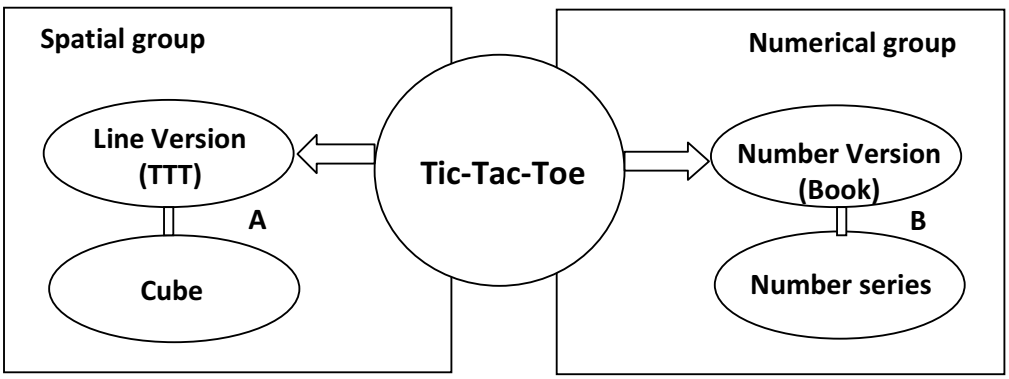


Figure 5. The experiment framework Ho *et al.* (2005) study. Cited from the paper "A study to clarify the relationship between 2D and 3D strategies of architects who rely heavily on both 2D and 3D representations, Ho *et al.* (2005)."

What intellectual development happens as a result of such exercises has not been demonstrated by design educators or design researchers. Since architects heavily rely on both 2D and 3D representations, Ho *et al.* (2005) conducted a study to clarify the relationship between 2D and 3D strategies. Even though the line version of Tic-Tac-Toe and the number version of Tic-Tac-Toe game (named Tic-Tac-Toe and Book respectively in Figure 5) are isomorphs, people treat them differently. The difference not only came from the different representations but also from the differences in strategy that people used to approach the tasks (Zhang 1997). More importantly, it seemed that there are certain people with high mathematical ability can see the symmetry of numerical representation which is very different from the spatial one. Or is it really so? The lateralization theory could provide a possible lead.

The human brain is divided into two hemispheres, the left and the right, joined in the centre by a large nerve track called the corpus callosum. The two hemispheres process information in quite contrasting modes. The left thinks analytically, discreetly and reductively. It is aware of temporal sequences and linearity and is involved in language and mathematics. The right hemisphere thinks holistically, synthetically, diffusely, processes inputs simultaneously and Visio spatially and recognizes patterns and faces. Research supports left hemisphere domination over right hemisphere [4]. It is believed that performance can be improved by giving the right hemisphere an artificial advantage. The right hemisphere which is the seat of lateral thinking (left is vertical thinking) can be trained to perform better [2]. Based on the above it can be inferred that students having well developed left hemispheres (high IQ) along with highly developed right hemisphere are more likely to be suited for multidisciplinary Design programs rather than those with highly developed right hemisphere alone. In order to select such candidates (with what can be termed as synergistic mind) the attributes of the right hemisphere have to be tested in addition to the left. It is assumed here that left hemisphere is any way well developed due to the emphasis on analytical reasoning in Indian schools. Of the several attributes associated with the right hemisphere it is posited in this paper that the following needs to be tested:

(a) Cognition and perception.
(b) Visio — spatiality (imagination).
(c) Communication skills.
(d) Aesthetic sensitivity.

In addition the following areas of significance in design learning need to be included

(e) Inquisitiveness.
(f) Observation (Eye for detail).
(g) State-of — the -art awareness.
(h) Logical thinking.

It should be noted that these above tests are being proposed in addition to the following tests which form part of any staple aptitude question bank:

(i) Quantitative aptitude.
(j) Analytical Reasoning.
(k) Mechanical Aptitude.
(l) Numerical reasoning.
(m) Analogy tests.
(n) Non verbal reasoning.

Since the design program demands the use of the left brain attributes as much as it stresses the need of testing the right brain attributes [4]. A new online mockup question bank was conceptualized consisting of all the above types of tests. In the Figures 6–8 some of the designed questions for cognition and perception test, visuo-spatiality test, visualizing ability in three dimensions & aesthetic sensitivity test are shown. In the case of aesthetic sensitivity the test formulated tries to find out if the candidate has sufficient sensitivity in distinguishing.

(a) Order from disorder.
(b) Harmony from disharmony.
(c) Vulgarity from elegance.
(d) Uniqueness from banal.
(e) Simplicity from complexity.

With these inputs and the GUI considerations we created the mock test session (Figure 9). An expert educationalist with a professional background of both Design and Psychology was sourced for

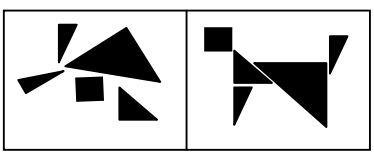


Figure 6. Tanagrams. The student is asked to arrange the Tanagrams in the design aptitude test, the way the candidate goes about doing it reveals his/her cognition, perception & reorganization of information.

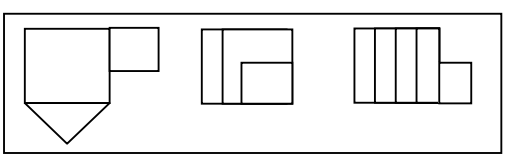
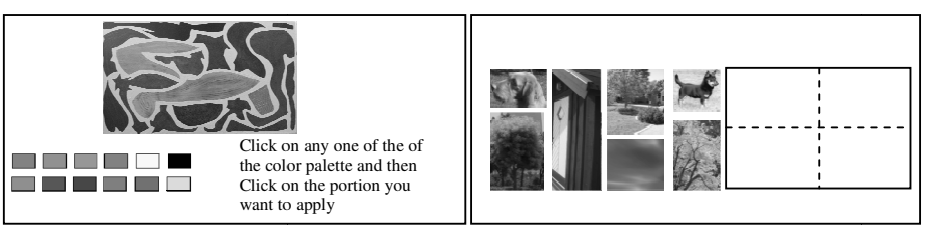


Figure 7. A question from the design aptitude test where the student is asked to guess the 3-D view of the object from by seeing the different views of the same object. This tests the student's capability of thinking visually in three dimensions.



(a) **(b)**

Figure 8. (a) A question where the student is asked to recolor an abstract painting; using the colors from the boxes provided below the picture. This tests the student's aesthetic sensitivity. (b) A question from the design aptitude test where the student is asked to compose a thematic picture using the different pictures given. This tests the student's aesthetic sensitivity.

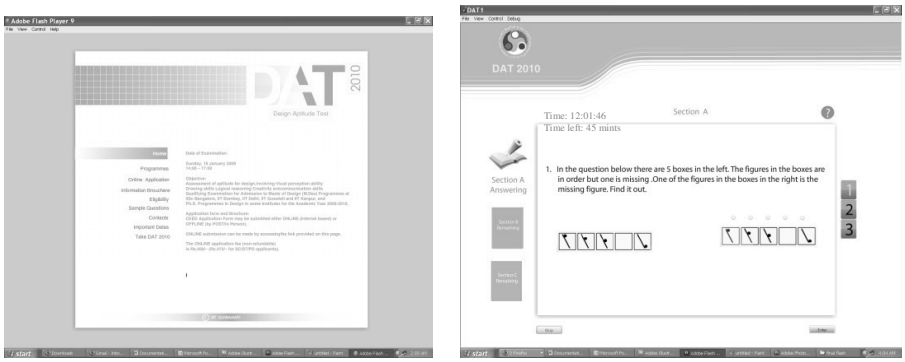


Figure 9. Home page and a test session page of the final GUI.

validating as well as creating a set of pilot questions suitable for online testing some of which are depicted in Figs. 6–8.

5. CONCLUSIONS

In comparison with a paper based test a computer based test has certain issues that need attention. Merely duplicating existing paper based design tests or adopting them to computer screens would not suffice. Limitations and negative experiences can be addressed through careful design of GUI as it plays a vital role in the cognitive workload of the students while undergoing the test session.

It follows that care should be taken in the design of the GUI considering culture and local context of the test taker. This paper reports only a preliminary exploratory study. Further in depth research involving the new aptitude questions is necessary to confirm increase in efficiency as well as lowering of stress in the student. As design is multidisciplinary, any test needs to be designed for both left hemisphere as well as right hemisphere processing. It has been postulated that in a design aptitude test not only aesthetic sensitivity but also numerical ability need to be tested.

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