Effects of Cognitive Styles on Performance in CAAD Tasks

Sule Tasli Pektas
Bilkent University, Turkey
http://www.art.bilkent.edu.tr/iaed/hometasli.html
tasli@bilkent.edu.tr

Outcomes of individual differences of learners are rarely discussed in CAAD education. This paper investigates interactions between architectural students' cognitive styles, as measured by Riding's Cognitive Styles Analysis, and their performance in computer aided drafting and design processes. An empirical research revealed that Imager students outperformed Verbalisers in both drafting and creativity scores. Technical quality scores were found to be independent from cognitive styles. Contrary to the assumptions of design theory, Wholist students did not perform better than Analytics in design. The study suggests that examining the cognitive styles of students in CAAD education deserves attention and may facilitate for learning.

Keywords: *CAAD education; individual differences of learners; cognitive styles; creativity.*

Computer Aided Architectural Design (CAAD) is increasingly dominating both architectural profession and its education. CAAD education research is also rapidly proliferating through multidisciplinary approaches to new technology. However, it was observed that most of the existing studies in the field have focused on relatively technical issues such as experimental uses of the new media, development of digital tools or courses. The wide socio-cultural and behavioural contexts of CAAD education are often ignored (Pektas and Erkip, 2006). It is widely accepted that there may be some characteristics of individuals that affect performance in CAAD tasks, but such interactions have not been studied in a systematic way, yet. In order to alleviate the problem, this research aims to investigate the effects of particular cognitive styles on design students' performance in computer aided drafting and design processes.

The concept of cognitive style has been widely used by educational theorists for the past 60 years. Different cognitive style definitions have been made during this period, but many agreed that cognitive styles refer to individuals' typical or habitual modes of encoding, storing, and processing information and that they are innate, relatively permanent and mainly independent of intelligence. Riding and Cheema, in their highly cited article, (1991) attempted to unite existing approaches and claimed that different cognitive style definitions can be clustered around two bipolar axis: Wholist-Analytic and Verbaliser-Imager. The Wholist-Analytic (WA) dimension describes individuals' tendency to process information either as a whole or through dividing into parts. It is assumed that Analytic individuals prefer to abstract things from their environments and to process information in a sequential manner, while Wholists are more likely to see "the whole picture" and to use intuition. The Verbaliser-Imager (VI) dimension refers to individuals' inclination toward coding information either verbally or pictorially. These two dimensions are assumed to be independent from each other.

It was acknowledged that cognitive styles might affect learning preferences as well as problem solving styles and task performance. Previous studies investigated the relationship between cognitive styles and academic performance in several fields such as teacher training (Altun and Cakan, 2006), management education (Armstrong, 2000), and psychology education (Diseth and Martinsen, 2003). However, the results of these studies were quite contradictory. Armstrong (2000) discussed that Analytics performed better than Wholists even in the tasks believed to be more suited to the Wholist cognitive style. Diseth and Martinsen (2003) showed that cognitive styles only had indirect effect on achievement, while Altun and Cakan (2006) found no significant relationship between cognitive styles and academic performance.

Several works of design theory suggest that an individual's cognitive style might be related to his/her performance in CAAD tasks. In design methods tradition, design has been conceived as an "ill-defined" problem solving activity involving a number of sub-activities such as analysis, synthesis and evaluation (Cross, 1993). All of these activities require intensive information processing whether as wholes or through abstraction, in images or in words. Design theorists suggested that design, being a holistic process, requires consideration of various and sometimes conflicting goals in a simultaneous rather than a sequential manner (Schon, 1985; Lawson, 1997). This implies that Wholists may be more successful in design tasks compared to the other end of WA spectrum: Analytics. On the other hand, much of the tension in architectural design stems from compromises between creativity and technical requirements, thus, students belonging to different cognitive style groups may also differ in these aspects. The connection between the VI cognitive style dimension and designing seems to be more straightforward, since imagining is regarded as crucial for the generation of new design ideas (Finke 1990, Lawson, 1997). Considering the interactions between cognitive styles and design performance, the use of CAAD tools in the process might also be important. Modelling with CAAD requires both procedural and declarative modes of thinking i.e. mentally breaking an object into simple objects and executing a series of commands (Hamade et al., in press). Thus, drafting and design using computers may favour Analytics who tend to abstract objects from the environment and prefer to work sequentially.

In order to test the hypotheses mentioned above, an experiment was designed and conducted. This paper reports the findings of the study. Implications of the results and the limitations of the study are also discussed and suggestions are made for further research.

1. The experiment

1.1 Participants

The participants were sophomore students of the Department of Interior Architecture and Environmental Design, in Bilkent University. The research was conducted in a one-semester introductory level CAD course. In this course, students acquire basic CAD skills and toward the end of the semester, they are expected to utilize these skills in a simple design project in which computer is the sole design medium. Data was collected in three class sessions in December 2006. The sample consisted of 46 students whose ages ranged from 18 to 24. The mean age was 20.28 and the standard deviation was 1.59. There were 34 females (74%) and 12 males (26%). Participants were informed about their cognitive styles at the end of the study.

1.2 Procedures

The experiment spanned the last three weeks of the semester. In the first week, the students received the design brief which specified design requirements of a small-scale architectural design project in detail. They were asked to design an entrance building at the main gate of a university campus. Main function of the space was controlling entrance to and exit from the university. It was assumed that two members of security staff would occupy the space and they would check the identity cards of the vehicles approaching the gate. The brief included basic private requirements of the staff (such as a WC, a kitchenette and some means of sitting) besides the main public activity. It was also requested that the building should have a symbolic meaning representing the identity of the university. In the first meeting, the subjects produced conceptual designs using the SKETCH command and the other relevant commands of AutoCAD during three lab hours. At the end of the session, they submitted their works in AutoCAD file format. During the following week, the students were allowed to develop their designs and in the second meeting, they discussed their designs with the course instructor. The design works were also collected in that day.

Three expert judges, composed of design faculty, were asked to evaluate the design solutions in three stages following Amabile's (1996) Consensual Assessment Technique (CAT). The judges were instructed to rate the creativity and technical quality of students' works relative to one another and to work independently. The assessments were based on a scale of 1-5 where 1 indicating low performance and 5 indicating high performance.

In the semester, participants took also CSA test and their cognitive styles were identified. Although there are several instruments to measure different aspects of cognitive styles, Cognitive Styles Analysis (CSA) developed by Riding (Riding, 1991) was preferred in this research, since it synthesizes various approaches to cognitive styles construct and its reliability and validity were established well via empirical research. CSA is a computer presented and self-administered instrument which identifies cognitive styles of individuals on the Wholist-Analytic and Verbaliser-Imager dimensions. Its application is easier and less prone to biases compared to that of paper-based tools. Every member of the sample completed the CSA in the manner prescribed in the CSA administration documentation.

2. Analysis and results

2.1 Cognitive style characteristics of the sample group

The WA ratios of the total sample ranged from 0.56 to 2.97 with a mean of 1.38 (SD = 0.57) and a median of 1.26. The VI ratios ranged from 0.83 to 1.63 with a mean of 1.07 (SD = 0.18) and a median of 1.04. There were 30 (60%) Analytics, 10 (20%) Wholists, and 6 (12%) Intermediates. The distribution of the sample on the VI dimension was more balanced. There were 19 (38%) Verbalisers, 14 (28%) Bimodals, and 13 (26%) Imagers.

2.2 Reliability and validity of measures

The correlation between the two cognitive style dimensions was -0.025 indicating the orthogonality of the two dimensions (Riding and Cheema, 1991). Inter-rater reliabilities of the judges were calculated for the creativity and the technical quality scores in the three stages. The reliability levels were above the acceptable level of 0.70 recognized by Amabile (1996) (table 1).

Table 1
Inter-rater reliabilities of performance evaluation

Evaluation Category	Stage	Inter-rater Reliability
Creativity	Stage 1	0.66
	Stage 2	0.73
	Stage 3	0.78
Technical quality	Stage 1	0.76
	Stage 2	0.79
	Stage 3	0.81

2.3 Relationships between cognitive styles and performance in computer aided design processes

The data was initially analysed using the raw CSA ratios as recommended by Peterson at al. (2002). A significant positive correlation was found between the VI ratios and the average creativity scores ($r = 0.32$, $p<0.05$). The correlation between the WA ratios and the average creativity scores was not statistically significant ($r = 0.14$). The data suggested that average technical quality scores were independent from WA ($r = 0.06$) and VI ($r = 0.1$) ratios.

Then, the sample was grouped by the cognitive style categories defined in the CSA administration documentation (Riding, 1991), Analytic-Intermediate-Wholist in one dimension and Imager-Bimodal-Verbaliser on the other. The analysis of variance (ANOVA) tests were conducted in order to find out if the cognitive styles had any effect on the average creativity and technical quality performance scores at the end of the process. The ANOVA indicated that there were statistically significant mean creativity score differences only on the VI dimension of CSA ($F = 3.95$, $p = 0.027$) (table 2). No such difference was observed on the WA dimension (table 3) or in the mean technical quality scores across the cognitive style groups (table 4 and 5). The Bonferroni test indicated that mean creativity scores of Imagers were significantly higher than that of Verbalisers ($p<0.05$), but no other significant difference was found.

VI	Stage 1 Creativity Mean (SD)	Stage 2 Creativity Mean (SD)	Stage 3 Creativity Mean (SD)	Overall Creativity Mean (SD)
Imager	2.61 (0.49)	2.61 (0.75)	2.97 (0.78)	2.73 (0.53)
Bimodal	2.48 (0.61)	2.57 (0.61)	2.90 (0.83)	2.63 (0.56)
Verbaliser	2.27 (0.43)	2.17 (0.30)	2.49 (0.60)	2.28 (0.39)
Total	2.45 (0.52)	2.44 (0.60)	2.75 (0.75)	2.51 (0.51)

Table 2
Mean creativity scores on the VI dimension

WA	Stage 1 Creativity Mean (SD)	Stage 2 Creativity Mean (SD)	Stage 3 Creativity Mean (SD)	Overall Creativity Mean (SD)
Analytic	2.39 (0.46)	2.33 (0.52)	2.82 (0.75)	2.47 (0.48)
Intermediate	2.72 (0.77)	3.00 (0.94)	3.00 (0.84)	2.89 (0.80)
Wholist	2.40 (0.49)	2.38 (0.36)	2.47 (0.69)	2.42 (0.37)
Total	2.45 (0.52)	2.44 (0.60)	2.75 (0.75)	2.51 (0.51)

Table 3
Mean creativity scores on the WA dimension

VI	Stage 1 Technical Quality Mean (SD)	Stage 2 Technical Quality Mean (SD)	Stage 3 Technical Quality Mean (SD)	Overall Technical Quality Mean (SD)
Imager	2.51 (0.44)	2.46 (0.48)	2.85 (0.74)	2.61 (0.43)
Bimodal	2.43 (0.62)	2.81 (0.95)	2.95 (0.98)	2.73 (0.70)
Verbaliser	2.39 (0.56)	2.72 (1.04)	2.71 (0.91)	2.55 (0.74)
Total	2.44 (0.53)	2.66 (0.87)	2.80 (0.88)	2.61 (0.64)

Table 4
Mean technical quality scores on the VI dimension

Table 5
Mean technical quality scores on the WA dimension

WA	Stage 1 Technical Quality Mean (SD)	Stage 2 Technical Quality Mean (SD)	Stage 3 Technical Quality Mean (SD)	Overall Technical Quality Mean (SD)
Analytic	2.40 (0.50)	2.73 (0.94)	2.83 (0.89)	2.62 (0.67)
Intermediate	2.89 (0.45)	2.67 (0.70)	2.89 (1.11)	2.81 (0.69)
Wholist	2.27 (0.58)	2.50 (0.82)	2.77 (0.75)	2.51 (0.57)
Total	2.44 (0.53)	2.66 (0.87)	2.80 (0.88)	2.61 (0.64)

2.4 Cognitive styles and performance in different stages of the design process

The effects of cognitive styles on creative performance were also analyzed in relation to the three stages of the design process. The analysis of variance tests for repeated measures did not indicate any evidence that the interaction between cognitive styles and performance scores changed over the stages ($F = 1.66$, $p = 0.18$). Although there were slight differences in the progression of different cognitive style groups, the relation between cognitive styles and creative performance scores remained similar through the stages.

Due to the nature of the educational process, it was expected that performance scores would increase from stage 1 to stage 3. Paired samples t-tests showed that mean creativity scores in stage 3 were significantly higher than that of stage 1 ($t = -2.09$, $p = 0.043$) and stage 2 ($t = -4.16$, $p<0.001$). However, mean difference between creativity scores of stage 1 and stage 2 was not significant. The same tests were applied in the technical quality scores and it was found that although there was a statistically significant increase between the mean technical quality scores of stage 1 and stage 3 ($t = -2.33$, $p = 0.024$), the mean differences at the consecutive stages (stage 1 – stage 2 and stage 2 – stage 3) were not significant.

2.5 Cognitive styles and drafting performance

In order to investigate the relationships between cognitive styles and drafting performance, Pearson correlation coefficients were calculated between the cognitive dimensions' raw scores and the scores of a drafting exam which was given as a requirement of the course before the experiment. A significant correlation was found between VI raw scores and drafting performance scores ($r = 0.54$, $p<0.001$), while drafting performance scores seemed to be independent from WA raw scores ($r = 0.06$, $p = 0.7$). One-way Analysis of variance tests also indicated a significant difference among the drafting performance scores of the students belonging to different cognitive styles on the VI dimension ($F = 5.34$, $p = 0.009$). The Bonferroni test showed that mean drafting performance scores of Imagers were significantly higher than that of Verbalisers ($p = 0.007$). No other difference was significant (table 6).

Table 6
Mean drafting performance scores on the WA and VI dimensions

WA	Drafting Score Mean (SD)	VI	Drafting Score Mean (SD)
Analytic	79.33 (10.90)	**Imager**	88.53 (11.36)
Intermediate	90.83 (13.96)	**Bimodal**	78.89 (7.94)
Wholist	76.20 (13.50)	**Verbaliser**	75.34 (13.28)
Total			79.97 (12.17)

3. Discussion and conclusions

This study provided valuable insights into the cognitive styles of architectural students and the effects of cognitive styles in several stages of design development through CAAD. It was found that on the WA dimension, the sample was predominantly Analytic. Previous research also reported that architecture students were more Analytic-oriented compared to business studies students (Bergum, 1977). On the VI dimension, the sample was more evenly distributed. This result was probably due to the university admissions process. In Turkey, the students are admitted to university education through a general multiple choice test exam which is possibly filtering out the Wholists.

The findings indicated some relations between a student's cognitive style and his/her performance in computer aided design and drafting tasks. Such associations were significant on the VI dimension with Imagers performing much better than Verbalisers. Imagers' superiority over Verbalisers were more apparent in the drafting task ($r = 0.54$, $p<0.001$) compared to the design tasks ($r = 0.32$ $p<0.05$). The data suggested that Imagers' high creativity scores in the design tasks were partly due to their proficiencies in using the CAAD tool. When the drafting performance scores were controlled, the correlation between the VI raw scores and the average creativity scores were not significant ($r = 0.14$, $p = 0.35$).

Contrary to the assumptions of design theory, Wholists did not outperformed Intermediates and Analytics in design. Although none of the differences on the WA dimension was statistically significant, Intermediates were the most successful group. In cognitive styles literature, Intermediates were viewed as flexible individuals who are not at the extremes of the WA dimension (Riding and Cheema, 1991). It may be inferred that the versatility of Intermediates enabled them to adapt themselves to a wide range of requirements of the design process easily. The limited size and the uneven distribution of the sample in this study did not led to conclusive statements. However, further studies with larger sample sizes may facilitate for better understanding of this phenomenon.

Surprisingly, the technical quality scores were found to be independent from both cognitive style dimensions. This suggests that no matter which cognitive styles they had, students develop appropriate strategies to cope with the technical requirements of design tasks and can attain similar results. However, when drafting skills and creativity are concerns, Imager students are clearly in a more advantageous position.

Educational implications of these findings could be more significant, if similar results were replicated in larger samples. However, this study suggests that monitoring cognitive styles of design students deserves attention and may facilitate for improving teaching strategies and course designs.

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