The Effects of Learners' Verbal and Visual Cognitive Styles on Instruction Selection

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Abstract. In designing learning instructions there is often the assumption that individual learners have different style preferences. Cognitive style may be defined as individual variation in ways of interacting with a learning environment and perceiving information. However, different styles of learning instructions may affect a learner's selection of an instruction, their appreciation of these instructions and learning outcomes. We have conducted a study to investigate how learners' verbal and visual cognitive style affected the selection of an instruction for learning Sudoku, their appreciation of the selected instruction, and the time they spent solving a Sudoku. Five different Sudoku instructions were used which varied in the media used. Two fundamental cognitive styles dimensions (Verbal-Visual) were assessed using the verbalizer and visualizer questionnaire (VVQ). This paper aims to consider the relationship between learning selection, learning appreciation and cognitive style and to suggest ways in which learning instructions may accommodate a learner's cognitive style in order to provide an effective learning environment.

Keywords: Cognitive style · Learning activity selection· Adaptation

1 Introduction

Much research investigates adaptive learning systems which use individual learner characteristics to adapt learning content in order to improve learner motivation and learning outcomes [6,16,27]. Also from an Educational Science point of view, according to [46] there is a growing body of learning theories, but these remain unrealistic if they do not include information about individual learners, and successful educational programs depend on understanding the individuals' learning needs. Similarly, [43] reported that educators should acknowledge learning differences and use technology to enhance the learning process. Whilst traditional e-learning has contributed to the flexibility in learning and reduced education cost, for the new generation of e-learning the concept of adaptation has received increasing attention [8,35]. Several studies have shown that the main problem with e-learning is the lack of personalisation [4,12,42]. The importance of adaptation has been identified in both traditional and computer-based instruction[20,50]. Utilizing an adaptive medium will support individual learning, leading to improved enjoyment of learning and goal achievement [7]. In addition, the impact

of individual differences, such as learning performance, learning style and ability has been widely investigated [17,48]. Several personalisation techniques have been proposed for developing adaptive learning systems, e.g. [45]. This paper investigates whether learners' cognitive style (focusing on the verbal-visual dimensions) impacts their instructional preferences and affects their learning material appreciation. We will use the theoretical framework of Dual Coding Theory to interpret learners' selections and suggest avenues for future research. The paper is structured as follows. Section 2 discusses related work. Section 3 presents the design of a study to investigate the impact of cognitive style on instruction material selection and appreciation of the instruction material. Section 4 discusses the study results. Section 5 concludes the paper. This study investigate the impact of learner's verbal and visual cognitive style on the selection of learning instruction by considering dual coding theory.

2 Related Work

Most personalization studies depend on an understanding of psychological phenomena, including cognitive topics such as learning structure, cognitive style, problem-solving and knowledge acquisition [1,22], as well as less cognitive topics, such as personality, learner interest, motivation and anxiety [38,14,49]. This study applies two dimensions of cognitive style (Verbal - Visual) and Dual Coding Theory (DCT), a theory of cognition which suggests that both verbal and non-verbal processing is essential for learning.

Dual Coding Theory. Cognition according to dual coding theory involves two mental subsystems, a verbal system which deals with language objects and an imagery system which deals with nonlinguistic objects. These two subsystems are thought to be separate but interconnected components of human cognition [31,32]. Several studies were conducted using the dual coding theory in teaching and learning processes. For example, Purnell et al. [37] investigated the effects of using texts and images on learners' comprehension. Combining Visualization-Verbalization has been used successfully to help learners who had experienced difficulty learning mathematics [28]. Other studies have shown that using a visual-verbal combination can improve reading-writing scores [34,44], and the teaching of numbers and mathematical operations [9].

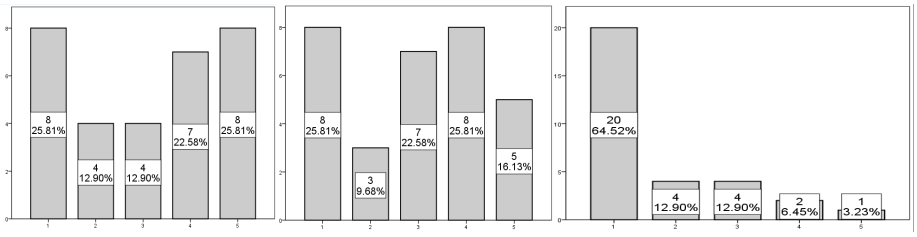
Cognitive Style. Cognitive style has generally been used to distinguish individual behaviour of thinking, interacting and perceiving information. Often, it is considered as a way to achieve intellectual goals [5]. Kogan [21] described cognitive style as *"individual variation in modes of perceiving, remembering and thinking, or as distinctive ways of apprehending, sorting, transforming and utilizing information"*. Grabowski and Jonassen [15] hold the view that *"We all differ in how we interact with our environment, extract and perceive information from it, and reflect and organize the knowledge that we have acquired"*. While a variety of definitions of cognitive style have been suggested, Messick [30] described cognitive style as an individual manner in the way of organizing and

processing information. A significant impact of personality and cognitive style has been shown in learning environments [13,23]. Cognitive style works as a bridge between cognition and personality [47]. In our previous work, the impact of personality and learning style on learning activity appreciation was investigated [2,3]. We found little impact of learning style. In this study we will investigate the verbal-visual cognitive style. The visual - verbal dimension has appeared in different contexts; sometimes it is described as a cognitive style [39], other times as a learning style [18], or learning preference [36]. However, this dimension has been involved in many studies as a cognitive style. The original theory was driven from dual-coding theory [32]. According to [25], perceiving and processing information can be through two mental representations: verbally and visually, and the combination of these two can lead to an increase in learning outcomes. Research on this dimension has mostly agreed that some people tend to think in words and others in pictures [26]. Students who preferred visual modes of presentation tended to select pictorial help screens, whereas students who preferred verbal models of presentation tended to select verbal help screens [24]. Despite this, the impact of being visual or verbal has been a controversial and a much disputed subject within the field of education and user behavior [19,24]. Several concerns about learning styles have been reported such as the uncorrelated findings to learning outcomes, and the lack of a relation between visualizer/verbalizer and visual/verbal materials [10,29,11]. It has even been suggested that providing materials for a non-preferred learning style would be more applicable than providing those for a preferred style [29]. Several measures have been developed for the verbal-visual style [40,41,18].

3 Study Design

First, an on-line survey was conducted to determine the perceived suitability of different learning activities for a verbal-visual learner, and to what extent these learning activity types contribute to obtaining a learner's appreciation in terms of enjoyability, increasing skills and confidence. Next, a study was conducted in which learners learned to solve Sudoku puzzles and tried to solve one, and we investigated the impact of their cognitive style (verbal-visual) on instruction selection, appreciation, and the time they took to solve the puzzle. The study is concerned with the Dual coding theory of learning and its application to the design of learning instructions. The aims of the present study were to:

1. Investigate if learners' cognitive styles (Verbal-Visual) have an influence on their selection of learning instructions.
2. Investigate to which extent learners appreciate their selection in terms of enjoyment, increasing skills and confidence.
3. Explore whether learners' instruction selection and cognitive style impacted the time they took to solve the Sudoko.
4. Provide insight for future research into the validity of matching learning instructions to learners' verbal-visual cognitive styles taking into account learning theory such as Dual coding theory.



(a) Listening (b) Reading (c) Visual

Fig. 1: Rating (a) listening, (b) reading, (c) visual instructions on scale from 1 (clearly suitable for visual) to 5 (clearly suitable for verbal)

3.1 Learning activities - Survey

31 participants responded to an on-line survey (10% aged 18-25, 48% 26-35, 26% 36-45, 16% over 46). Considering participants occupation: 42% were teachers, 10% trainee-teachers, 32% students, and 16% other. On a scale from 1 (clearly for visual learner) to 5 (clearly for verbal learner), participants indicated to what extent they felt the provided learning instructions suited a learner's cognitive styles, in particular verbal-visual. Here we focus on the learning activities which are most relevant to the second part of the study, namely: (1.) Which cognitive style is better suited to listening activities (e.g. audio recorded lectures), (2.) Which cognitive style is better suited to reading activities (e.g. hand-outs, books), (3.) Which cognitive style is better suited to visual activities (e.g. pictures, diagrams). Next, participants rated activities on how enjoyable they think they are, and to what extent they will increase the learner's skills and confidence.

3.2 Sudoku learning instructions - User study

Participants were recruited through an on-line platform. Five versions of learning instructions were created with the same information about playing Sudoku: (1.) AO consisted of an audio file only, (2.) AT$_\text{I}$ consisted of an audio file and a long text containing the same information as the audio (no figures), (3.) FT$_\text{S}$ consisted of figures and a short text, (4.) FA consisted of figures and an audio file, and (5.) FT$_\text{I}$ consisted of figures and the long text.

Hypotheses. This study concerned with the Dual coding theory of learning and its application to the design of learning instructions. We hypothesise that learners will prefer and appreciate learning instructions that are aligned with the use of their two subsystems (verbal-nonverbal), in particular:

1. Verbal learners will select AO, AT$_\text{I}$ and FA. AO because it is a verbal activity which matches their cognitive style, and AT$_\text{I}$ and FA because they combine Audio (a verbal activity) with visual information (text or figures) allowing for dual processing.

2. Visual learners will select FT_S, AT_I and FA. FT_S because it is a visual activity (with predominately figures) which matches their cognitive style, and AT_I and FA because they combine Audio (a verbal activity) with visual information (text or figures) allowing for dual processing.

We believe that learners will avoid selecting learning instructions that may cause split attention effects. In particular, we believe that learners will not select FT_I because reading the long text would use much visual processing (in addition to verbal processing) which would interfere with looking at the figures.

Measures. Cognitive styles were identified by the Verbalizer-Visualizer Questionnaire (VVQ) which was devised by [39]. This consists of a self-report of 15 true-false items, selected from a longer 86-items ways of thinking questionnaire, proposed by [33]. The items of the VVQ are coded in such a way that higher scores indicate a visual style and lower scores a verbal style.

Participants. 31 participants took part (25 female, 6 male; 9 aged 18-25, 21 aged 26-40, 1 aged 41-65). All had no prior experience with Sudoku.

Procedure. First, participants provided their demographic information such as age and gender. Next, participants completed 15 True - false questions to determine their learning mode (Visual or Verbal) [33]. Then they selected their favourite learning instruction, and used this to learn about Sudoku. Next, participants rated their selection on how enjoyable they think it was, and to what extent it increased their Sudoku skills and confidence. Next, they played an on-line Sudoku game. When they finished, they rated their learning instruction selection once more on how enjoyable they felt it was, and to what extent it increased their Sudoku skills and confidence.

4 Results

4.1 Learning activities - Survey

Suitability for verbal-visual learners. Figure 1 shows participants' views on the suitability of learning instructions for learners with verbal - visual cognitive styles. More participants rated listening activities as suitable for verbal learners than as suitable for visual learners. Regarding reading activities, whilst 42% rated them as more suitable for verbal learners, 23% felt that reading activities are equally suitable for verbal and visual learners. Reflecting on this, we believe that reading may be regarded as using both verbal and visual processing. Regarding visual activities which involve visual elements such as pictures and diagrams, 78% rated these as more suitable for visual learners.

Learning activity appreciation. On a scale from 1 (Strongly Disagree) to 5 (Strongly Agree), participants rated learning activities on how enjoyable they are, and to what extent they increase learner's skills and confidence. The results are summarized in Table 1 only including teacher and student participants (as those had high participation rates). Overall, both teachers and students seemed

Table 1: Survey: Mean(stdev) for listening, reading and visual activities

	Activity type	Enjoyable	Skills	Confidence
Teacher	Listening	2.83(1.03)	2.83(1.33)	2.92(1.24)
	Reading	2.92(1.37)	3.25(1.42)	3.17(1.40)
	Visual	3.58(1.16)	3.50(1.44)	3.42(1.37)
Student	Listening	2.60(0.96)	3.20(0.91)	2.90(0.73)
	Reading	2.80(1.22)	3.60(1.57)	3.20(1.47)
	Visual	3.60(1.07)	3.40(0.98)	3.20(0.91)

to have only a slight preference for the visual activities, and all activities were rated around or above the mid-point of the scale. Based on this, we decided to use these activity types in our next study.

4.2 Sudoku learning instructions - User Study

Learners' verbal - visual cognitive styles. Table 2 shows the number of participants and their selection. Using the official scoring of the questionnaire, 10 participants were classified as having a verbal cognitive style (scored less than or equal to 7), only 3 as having a visual cognitive style (scored greater than or equal to 12), and 18 (most participants) as moderate (scored between 8 to 11). Participants selected their preferred instruction for learning about Sudoku. Verbal learners tended to select AO instruction substantially more often (in 70% of cases) than other instructions; additionally one learner selected FA. These selections are in line with our hypothesis. Only two participants selected a learning material we had not predicted, namely FT_l. Interestingly, no verbal learners selected AT_l. On reflection, we believe that this is because they avoided information overload, as both the audio and the long text require much processing. Most visual learners selected FT_s and FA which in line with our hypothesis, but the number of visual learners is too small to draw any conclusions from this. Learners who were moderate in their cognitive style most often selected FT_s, which may be because this would require least processing or because it most matches the normal way instructions tend to be provided.

Table 2: Participant number per style and instruction selected

	Learning instructions				
Cognitive style	AO	AT_l	FT_s	FA	FT_l
Verbal	7	-	-	1	2
Visual	1	-	1	1	-
Moderate	5	4	8	1	-

Relation between cognitive style and appreciation for the selected instruction. Learners rated their *selection* of instruction before and after the Sudoku game (See Table 4). Verbal learners rated the verbal AO instruction higher than moderate learners in terms of enjoyment and increasing skills, but not in terms of increasing confidence. In general, learners' ratings were higher

for the AO instruction after the game than before the game. Moderate learners tended to rate FTs slightly higher after the game in terms of of enjoyment, increasing skills and confidence. In contrast, ratings for ATl remained about same after the game. We also investigated the Pearson correlation between the learners' degree of verbalness and their ratings for their selected instructions (but only for those instructions that were selected by a good number of participants). We found no significant correlations between the learners' degree of verbalness and their appreciation for AO and FTs instructions (see Table 3). This seems to indicate that once a person has been classified as verbal or moderate the degree of verbalness does not really make a difference.

Table 3: Correlations between degree of verbalness and appreciation (before playing Sudoku) of the most selected instructions

Instructions	Enjoyable	Skills	Confidence
AO	-.012	-.115	.167
FTs	-.205	.054	.183

Table 4: Mean(stdev) for verbal, moderate learners and appreciation for the selected instructions

Before				
Cognitive style	Learning instruction	Enjoyable	Skills	Confidence
Verbal	AO	2.57(1.39)	3.71(1.38)	2.57(1.27)
Moderate	AO	2.20(.83)	3.20(1.30)	2.57(1.27)
	ATl	3.00(1.41)	3.50(1.00)	3.25(.95)
	FTs	3.25(1.38)	3.50(1.30)	3.12(1.12)
After				
Cognitive style	Learning instruction	Enjoyable	Skills	Confidence
Verbal	AO	4.00(1.26)	4.16(.98)	3.16(1.16)
Moderate	AO	2.75(1.25)	4.25(.95)	4.00(1.41)
	ATl	3.00(1.73)	3.33(1.15)	3.33(1.15)
	FTs	3.57(1.39)	3.71(1.38)	3.14(1.06)

The completion time of Sudoku depending on the selected instruction. Table 5 shows the Sodoku completion time depending on the instruction used. The duration means varied substantially between the selected instructions (however, due to the small number of participants who selected certain instructions, statistics cannot be done). AO and FTs seemed to lead to lowest completions times. The ATl instruction seemed to lead to substantially higher completion times. This may provide some evidence that the AT l instruction lead to information overload and a resulting lack of understanding on how to play Sudoku.

We also considered learner's cognitive styles to investigate if there was any influence on the duration. We found that verbal learners who selected AO had slightly faster performance than moderate learners with the same learning instruction, which provides some evidence that matching the instruction to the cognitive style improved performance. Moderate learners performed best with the FTs instruction, and poorly with the ATl instruction. It is possible that the highly visual nature of the Sudoku task benefited from the figures in the FTs instruction. Overall, there clearly is a trend that the learner's cognitive style

Table 5: Minimum, maximum and mean (stdev) in minutes for the duration of solving Sudoku, considering the selected instructions

Learning instructions	Minimum	Maximum	Mean (stdev)
AO (n=13)	3.40	21.42	8.96 (4.70)
ATl (n=4)	12.10	57.21	33.96 (18.50)
FTs (n=9)	2.48	10.90	6.76 (3.07)
FA (n=3)	5.27	22.55	14.01(8.68)
FTl (n=2)	9.56	12.58	11.07 (2.13)

Table 6: Mean(sdev) in minutes for the duration of solving Sudoku, considering cognitive styles.

Cogntive styles	Learning instructions	Minimum	Maximum	Mean (sdev)
Verbal	AO	5.51	9.20	7.30 (1.30)
Moderate	AO	3.40	13.33	8.10 (4.40)
	ATl	12.10	57.21	33.96 (18.50)
	FTs	2.48	10.90	6.46 (3.14)

(verbal - visual) and the media combination of learning instructions effects the completion time of Sudoku (see Table 6).

5 Conclusions

In designing learning instructions there is often the assumption that some instructions are more effective than others. This study investigated the impact of learner's cognitive styles (verbal - visual) on the selection of learning instructions, learning appreciation and time completion. We believe that considering DCT when adapting learning contents will enhance the learning process and improve the selection of materials for individuals. Overall, we found that cognitive styles have an impact on learner's selections. Learners with a particular style are more likely to select learning instructions that matched their style, or require less processing. A limitation of the study is the low number of participants, in particular of visual learners. Also, appreciation was only measured for the instruction *selected*; another study needs to investigate whether cognitive style influences the appreciation of instructions that were not selected. This study also focused on novice learners, and the impact of learners' experience needs studying as well.

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