RELATIONS BETWEEN COGNITIVE RESOURCES AND TWO TYPES OF GERMANE LOAD FOR LEARNING

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ABSTRACT

Cognitive load theory (CLT) distinguishes three types of cognitive loads: intrinsic, extraneous, and germane, of which the latter is generally imposed in learning activities. To examine the nature of germane cognitive load, the participants engaged in 8-by-8 Reversi games against computerized opponents. The experimental results indicated that germane load decreases as extraneous load increases because the cognitive resources for assigning the germane load are exhausted by the extraneous load, and that there are two types of germane load: one that increases with an increase in intrinsic load and the other increases as intrinsic load decreases.

KEYWORDS

Cognitive load theory, extraneous load, intrinsic load, germane load

1. INTRODUCTION

Cognitive load theory (CLT) plays a central role in designing learning environments (Sweller, 1988; Sweller, Van Merrienboer, & Paas, 1998). The theory distinguishes three types of cognitive loads: intrinsic, extraneous, and germane. Previous CLT studies have focused on the distinction between intrinsic and extraneous load. In this regard, intrinsic load is the basic cognitive load required to perform a particular task. Conversely, extraneous load is defined as the wasted cognitive load that is unrelated to primary cognitive activities. Overall, extraneous load can have a negative impact on learning activities. On the other hand, positive cognitive load that increases learning effects was found in the mid-1990s. Some studies reported that, when a large cognitive load was imposed on the participants in an experimental group, there were significant learning gains. Such a cognitive load is defined as germane load, which is the load used for learning (Paas & Van Merrienboer, 1994; Paas & van Gog, 2006; Ayres & van Gog, 2009).

Although the negative impact of extraneous load on learning has been widely accepted, the effects of germane load have been subject to debate. Essentially, there are two views regarding the relationship between intrinsic and germane cognitive loads:

Part-of-intrinsic view: Germane cognitive load is a part of intrinsic cognitive load; that is, germane load emerges in cooperation with intrinsic load.

Independent-from-intrinsic view: The nature of germane and intrinsic cognitive loads differs; that is, germane cognitive load independently emerges from intrinsic cognitive load.

The present study measures germane load as learning effects. More specifically, it manipulates the amounts of extraneous and intrinsic loads as independent variables, and measures germane load as a dependent variable. The following hypotheses are posited:

Hypothesis 1: This hypothesis is clearly drawn from numerous CLT studies that have indicated the negative impacts of extraneous load on learning activities. When extraneous load increases, germane load decreases, since the cognitive resources for assigning the germane load are exhausted by the extraneous load.

Hypotheses 2a and 2b refer to a relationship of intrinsic and germane cognitive loads.

Hypothesis 2a: This hypothesis is drawn from the part-of-intrinsic view. Germane load increases with an increase in intrinsic load, since the amounts of both cognitive loads are correlated.

Hypothesis 2b: This hypothesis is drawn from the independent-from-intrinsic view. Germane load increases with a decrease in intrinsic load, since this decrease causes an increase in the cognitive resources for assigning germane load in working memory capacity.

2. EXPERIMENT

2.1 Procedure

The task used in this study was an 8-by-8, computer-based Reversi game. The participants play the game against a computerized opponent (i.e., opponent agent). Meanwhile, the computerized partner-agent assists the participant in selecting the winning moves. Both agents (i.e., the opponent and partner) are controlled by the Reversi engine (Edax 4.0), which suggests the best moves by assessing the situation in the game.

2.2 Procedure

In order to determine the baseline for measuring learning gains, the participants performed a pre-test consisting of 12 problems. Then, the participants moved on to the learning (training) phase in which they played 16 games. Each game started in the middle stage in which approximately half of the discs were already placed on the board. The learning phase consisted of four blocks in which the participants played four games in each block. A set of winning strategies in Reverse games was known. The trainings in each block were intended to allow the participants to learn one of the strategies. The first three games in each block began with an identical disc arrangement, while the fourth (final) game began with a different arrangement from the arrangement in the preceding three games. After the learning phase, the participants performed a post-test consisting of the same 12 problems as those in the pre-test.

2.3 Independent Variable

Two factors, i.e., the disc representation factor and the hint information factor, were applied for manipulation. The former factor was expected to manipulate the extraneous load, whereas the latter factor was expected to manipulate the intrinsic load.

Disc representation factor: Figure 1 presents a sample disc arrangement of the Black and White and L and rL (reversal L) conditions.

(a) Black and White condition (b) L and reversal L condition
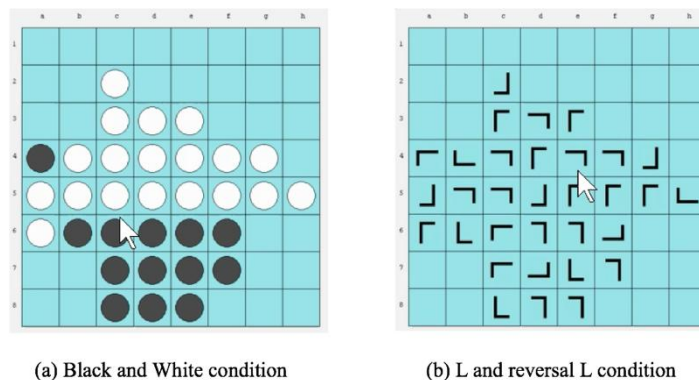
Figure 1. A screenshot of the game board in the Black and White and L and rL (reversal L) conditions

When the Black and White condition was considered, the Black and White discs were arranged, whereas when the L and rL condition was considered, the Ls or rotated Ls (black discs) and the mirror reversal Ls or rotated reversal Ls (white discs) were arranged. In the L and rL condition, in order to perceive the status of the disc arrangement and decide the best move, the participants had to mentally rotate the L or reversal L

images in each trial, thus causing significant extraneous load. As a result, the L and rL condition increased the extraneous load more than the Black and White condition.

Hint information factor: In each trial of the game, the main task was to choose the best move for winning the game. In order to do so, the participants had to understand the status of the disc arrangement, search the problem space, and estimate the best move, thus increasing intrinsic load. Under the hint presentation condition, the computerized partner-agent suggested the best moves to the participants, whereas under the no hint condition, no such information was presented. This suggests that the intrinsic load of the participants was lower in the hint presentation condition than in the no hint condition.

2.4 Experimental Conditions

Based on the aforementioned understandings, three experimental conditions were established:

No hint and Black and White condition: A small extraneous load is imposed, and a large intrinsic load would emerge.

Hint presentation and Black and White condition: A small extraneous load is imposed, and an intrinsic load would be minimized.

Hint presentation and L and rL condition: A significant extraneous load is imposed; therefore, only little cognitive resource to which the intrinsic and germane loads are assigned.

2.5 Dependent Variable

Pre- and post-tests were performed in order to evaluate the learning gains. Each test consisted of 12 problems, and the problems used in the post-test were identical to those in the pre-test. In each problem, the participants were presented with a disc arrangement, after which they were required to determine the best possible move. The 12 problems were grouped into the following three categories, each of which consisted of four problems:

Identical problems: The disc arrangements, identical to those used in the training phase, were presented.

Near transfer problems: The presented disc arrangements were modified from the original arrangements used in the learning phase. More specifically, they were rotated 90, 180 or 270 degrees from the original arrangements or mirror-reversed from the rotated arrangements.

Far transfer problems: The presented disc arrangements were new. However, the participants were able to determine the best possible move if they had learned the strategies that were intended to be found during the learning phase.

Since the number of problems in each category was four, the full score was also four. This study used the increase in the scores from the pre- to the post-test as a dependent variable (i.e., learning gains). The germane load assigned in the learning phase was evaluated based on the increase of the test scores.

2.6 Participants

A total of 61 undergraduates from Nagoya University participated in this study. All of the participants were not experts in playing Reversi, even though they had some experience with the game. The participants were divided into three groups: 21 for the no hint and Black and White condition; 19 for the hint presentation and Black and White condition; and 21 for the hint presentation and L and rL condition.

3. RESULTS

3.1 Prediction

Since the germane load is evaluated based on the increase of the test scores, the following predictions are made: Hypothesis 1 predicts: (1) no increase in the test scores under the hint presentation and L and rL condition, and (2) substantial increases in the hint presentation and Black and White condition as well as in the no hint and Black and White condition, compared to the hint presentation and L and rL condition. More

specifically, Hypothesis 2a predicts an increase in the test scores under the no hint and Black and White condition, whereas Hypothesis 2b predicts an increase in the hint presentation and Black and White condition.

3.2 Increase of Test Scores from Pre to Post Test

Table 1 shows the increase in the test scores from the pre- to the post-test in the identical problem category. In order to confirm whether significant increases in the test scores occurred, one-sample t-tests were conducted, which indicated that there were substantial increases in the no hint and Black and White condition as well as in the hint presentation and Black and White condition ($t(20) = 3.09$, p < 0.01; $t(18) = 4.72$, $p < 0.001$). Conversely, there was no increase in the hint presentation and L and rL condition ($t(20) < 1$, n.s.).

Table 1. Increases in the test scores from the pre- to the post-test in three experimental conditions. * shows a substantial increase, while the numerals in parentheses show the standard errors

	No Hint Black/White	Hint Black/White	Hint L/rL
Identical	0.90* (0.28)	1.16* (0.24)	-0.05 (0.16)
Near Transfer	0.76* (0.24)	1.21* (0.24)	0.29 (0.22)
Far Transfer	0.33 (0.35)	0.58 (0.27)	0.24 (0.29)

Similarly, the table presents the results of the near transfer problem category. The same one-sample t-tests were conducted to confirm whether there were significant increases in the test scores. Similar results were obtained, thus indicating substantial increases in the no hint and Black and White condition as well as in the hint presentation and Black and White condition ($t(20) = 3.07$, p < 0.01; $t(18) = 4.86$, $p < 0.001$), whereas no increase was found in the hint presentation and L and rL condition ($t(20) = 1.24$, n.s.). In the far transfer problem category, no increases were found in all three conditions ($t(20) < 1$, n.s.; $t(18) = 2.07$, n.s.; $t(20) < 1$, n.s.).

4. CONCLUSION

First, the results of this study confirmed Hypothesis 1. In the L and rL condition, a significant extraneous cognitive load was expected to emerge through the irrelevant cognitive activities such as performing mental rotations of L and reversal L.

Second, both Hypothesis 2a and 2b were also confirmed, implying that there are two types of germane load relating to the part-of and independent-from intrinsic views. However, the generality of the two hypotheses is still limited. Although substantial increases were found in the test scores from the pre- to the post-test in Black and White conditions, the increases were only found in the identical and near transfer problem categories. Meanwhile, no increases were found in the far transfer problems.

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