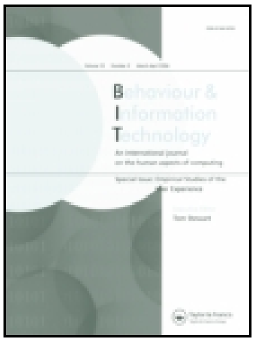

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The effect of levels of processing with navigation design types on recall and retention in e-learning environments

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The purpose of this study was to investigate the effects of levels of processing (LOP) and various navigation design types (NDTs) on high school students' recall and retention performances in e-learning environments. The participants' ($N = 90$) performances of free recall, title recognition, location memory and their retentions were measured in two different navigational layout design types by giving participants the instructional tasks which were designed in shallow, medium and deep LOP. Results are in accordance with the main argument of LOP; deeply processed elements are remembered better and the strength of the encoded memory trace depends on the mental processes carried out with different types of tasks. Results show that the main effects of LOP and NDT on memory performance are significant.

Keywords: e-learning; levels of processing; navigation design; recall; retention; memory

1. Introduction

The levels of processing (LOP) predict that the depth of the processing level determines the strength of the encoding and the durability of the retrieval processes by contributing to stronger trace persistence (Craik 2002; Craik and Lockhart 1972; Lockhart and Craik 1990; Craik and Lockhart 2008). The main argument in LOP is that deep (e.g. semantic) processing associated with stronger traces lead to better memory performance than shallow (e.g. phonemic) processing, and deeply processed items increase memory performance during recall and retention. Craik and Tulving (1975) used phonemic, orthographic and semantic orienting questions in their research, and the results indicated that the memory performance was directly dependent on the type of the question leading to best, intermediate and worst memory performances.

The popularity of the processing framework had a major impact on cognitive psychology. Furthermore, there is substantial evidence suggesting that several methods in the framework of LOP can be applied relevantly to increase memory performance depending on manipulated task characteristics (Bisby et al. 2010; Challis, Velichkovsky, and Craik 1996; Foos and Goolkasian 2008; Java, Gregg, and Gardiner 1997; Kronlund and Whittlesea 2005; Mulligan and Picklesimer 2012; Paap and Cooke 1997; Parkin 1979; Rodrigues et al. 2010; Roediger, Gallo, and Geraci 2002; Rose et al. 2010; Zannino et al. 2010). Yet, it is not explored whether the ongoing debate could be extended to the digital learning environments such as to e-learning.

Looking from learners' cognitive differences perspective and regarding memory performance as an individual difference, the visual characteristics and the design properties of the learning material might be crucial as well as the designed tasks. Moreover, how LOP manipulates the strength of the encoding by given tasks or visual characteristics of the designed instructional content remains an unanswered question.

Related research examining the correlation between web interaction and memory emphasises the importance of memory research examining the role of hypertext, web element locations, orienting tasks and various navigation design principles. Lee and Tedder (2003) investigated the effects of three different computer texts on readers' recall based on individuals' different working memory capacities, and found that the type of text presenting structure influences memory. Recall scores were better in linear text than hypertexts. Furthermore, the participants' working memory capacity was a differing factor for their memory performances. Oulasvirta (2004) applied LOP in the context of web interaction by implementing several information finding tasks with printed web pages and comparing two common orienting tasks, navigation orientation and content orientation. The results were in accordance with the LOP, showing significant differences between the mem-

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ory performances of two tasks in locations and features of task relevant and irrelevant elements. In follow-up research (Oulasvirta, Kärkkäinen, and Laarni 2005), researchers aimed to study information search behaviour and compared different layouts by task completion times or user opinions. Starting from the point that memory has several subsystems (Schacter and Tulving 1994; Squire 1992, 2004), they set out to examine how the human memory can either support or fail to support users in web navigation by emphasising that a web page can rely either on expectations of locations or on prior experiences of visiting the page. They recorded eye movements and tested the users' location memory of web objects immediately. Results pointed to a left-side link panel preference, indicating a robust expectation of links residing on the left side of the page. Another significant finding of the study revealed that the approximate locations of link panels were better remembered than an individual link's location.

The effects of web elements depend on users' cognitive differences and the difficulty level of the task itself (Juvina and van Oostendorp 2006; Puerta Melguizo, Vidya, and van Oostendorp 2011; Indurkhya, van Oostendorp, and van Schaik 2012). Navigation involves cognitive processes by its nature (Altun 2000; DeStefano and LeFevre 2007) incorporating search strategies on the Web, including web elements. The locations of the target elements in a text are about positional information encoded during reading from a screen or paper. Navigating through web elements is an example of a reading task (Guthrie and Kirsch 1987), and the location memory performance during reading is argued to be non-persistent (Therriault and Raney 2002). While navigating, users' mental processes relate to their expectations of web page orientation as well as providing them with a faster visual recognition of web elements (Leuthold et al. 2011). For example, Oulasvirta, Kärkkäinen, and Laarni (2005) experimented by studying three different page layouts whether the web elements were located according to users' expectations, and whether the results pointed to higher levels of memory performance for web elements. It has been found that web element recognition can be facilitated when these elements are located properly (Davenport and Potter 2004). Web interaction and the recognition of its elements had the prior role of constructing patterns (Cangöz and Altun 2012) and individual learning strategies. Memory research addressing web interaction also explored the roles of design and visual characteristics of the environments. Thus, it is important to manipulate the reading process by implementing shallow, medium and deep LOP tasks so as to see how readers' memory performance changes by using LOP as an independent variable (IV) (Cangöz and Altun 2012). Therefore, this study aims to explore the roles played by navigation design types (NDTs) (left panel navigation design (LPND) and right panel navigation design (RPND)) and layouts in an e-learning environment on learners' memory performances (recall and retention) with shallow, medium and deep LOP tasks.

2. Method

2.1. Participants

A total of 90 adolescents (47 female, 43 male) aged 16 from a public high school were recruited from the psychology course and took part in the study. This high school, which ranks third in the city, accepts its students with a nationwide central examination score. At the time of data collection, the students were given a national placement test and were requested to make choices to further attend their high school degree. Students usually tend to choose the schools close to their neighbourhood, but mostly within their city borders. The high school where this study was conducted was in the top 2% according to examination score rankings in the city. In addition, students in this study could be considered as homogenous in terms of their academic performance. No intelligence tests were performed.

Participants were randomly assigned to six groups ($n =$ 15 for each group) to read an award-winning sci-fi short story from a 15-inch LCD computer screen online. Randomisation was ensured by using the random number table. Groups were coded and identified as follows by their task processing levels and NDTs: SL (shallow left), ML (medium left), DL (deep Left), SR (shallow right), MR (medium right) and DR (deep right). Each group accomplished an instructional task which was prepared within the framework of LOP: shallow, medium and deep by studying with one of the NDTs: LPND and RPND. The participants considered themselves as frequent Internet users without prior e-learning background.

2.2. Design

A 3 (LOP; shallow vs. medium vs. deep) $\times 2$ (NDT; LPND vs. RPND) general linear model (GLM) factorial MANOVA design was utilised. The dependent variables (DVs) were recall and retention test scores for free recall, title and location memories. The IVs were the NDT and LOP (shallow, medium and deep LOP). Taking into consideration the paradigm of incidental learning, participants were not informed about the memory tests, target words and titles, and at the end of the experimental sessions, surprise immediate memory tests were given to the groups. Prior to the experimental sessions, the participants were instructed to complete the tasks by reading the online story without missing out any of the chapters and to write down the answers on the paper handout formatted task forms. In order to gather the data for retention scores of memory performance, the memory test was repeated after two weeks. Participants were not informed about the contextual details of the two-week delay testing sessions.

2.3. Materials

2.3.1. E-learning environments and navigation design

An unpublished sci-fi story entitled ‘Doppelganger’ selected by the committee of a scientific research association (Kocagoz 2011) was adopted for the research design. Based on expert views, a new unpublished (and so unlikely to be known to the participants) and context-free sci-fi story was chosen as suitable for the participants’ age and interests.

The story was designed and programmed for screen reading by the researchers using PHP codes, Adobe CS3 and Flash software. The story was presented online in a linear navigation design structure including 10 titled chapters and 20 pages. One or two words per page and 25 words in total were determined as target words from the text and written in red font in the text page design. These e-learning environments were presented on 15-inch monitors with standardised screen resolution by computers running Internet Explorer 8 in full screen mode. Each page of the online story text was to fit on one screen, ensuring that no scrolling was required to read the text. The font size, style and colours remained constant for the e-learning environments. Although the content was the same, researchers designed two visually different e-learning environments by their navigational layout design types (see Figure 1). The difference was presented by the left and right panels (LPND and RPND) which were the interactive buttons of 10 chapter titles of the story, providing navigation between chapters. In LPND the title buttons were located on the left side of the screen, and in RPND, on the right. Each chapter included two pages and the navigation between pages was provided by next and previous page buttons located at the bottom of the screen. An additional button named ‘completed’ was located at the end of the panel in order to control and provide a reminder of the missing page and chapters of the story.

E-learning environments consisted of three main phases; (1) a brief information page with a start button, where participants were informed about reading the following story and immediately after reading, clicking the ‘completed’ button. An information page was added in order to minimise any possible misunderstanding and questions about the session. A start button was added to the information page in order to provide a synchronous starting of the participants’ experimental session; (2) a study environment, where the story was presented including target words, chapters, pages and titles; and (3) a session end page, listing notifications about missing chapters and pages and/or a congratulation message indicating that reading the story had been completed.

Expert reviews were taken into consideration in order to ensure that target words were selected impartially from the text using the following criteria; (1) making a selection of simple nouns and concrete words; (2) omitting homonyms, synonyms, pairs, private words, connotations, words consisting stressed sounds such as ‘ch’ and ‘sh’ and technical or scientific terms from the target word list and (3) selecting words with an equivalent average number of letters and syllables. The locations of the target words in the text were also taken into consideration (see Figure 2).

While selecting the target words by their locations on the screen, the text region was imagined as split by an imaginary coordinate plane’s four quadrants. The paragraphs were distributed carefully and the words from different quadrant regions of the text were written in red font as target words.

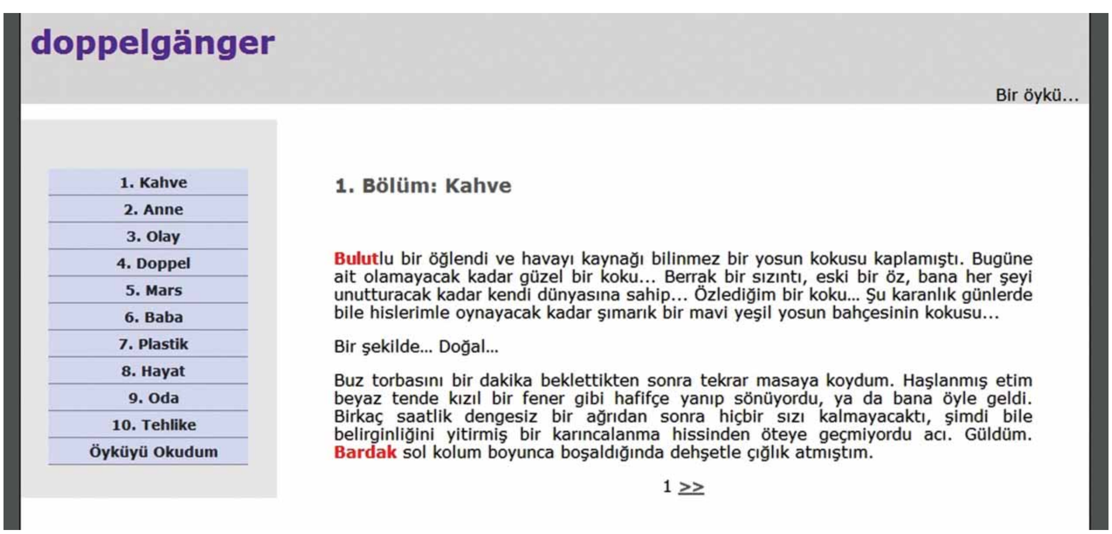

Figure 1. Screenshot of the LPND where an interactive buttons list (chapter titles) is located on the left side of the screen. In e-learning environments, layouts are differentiated by their panel locations.

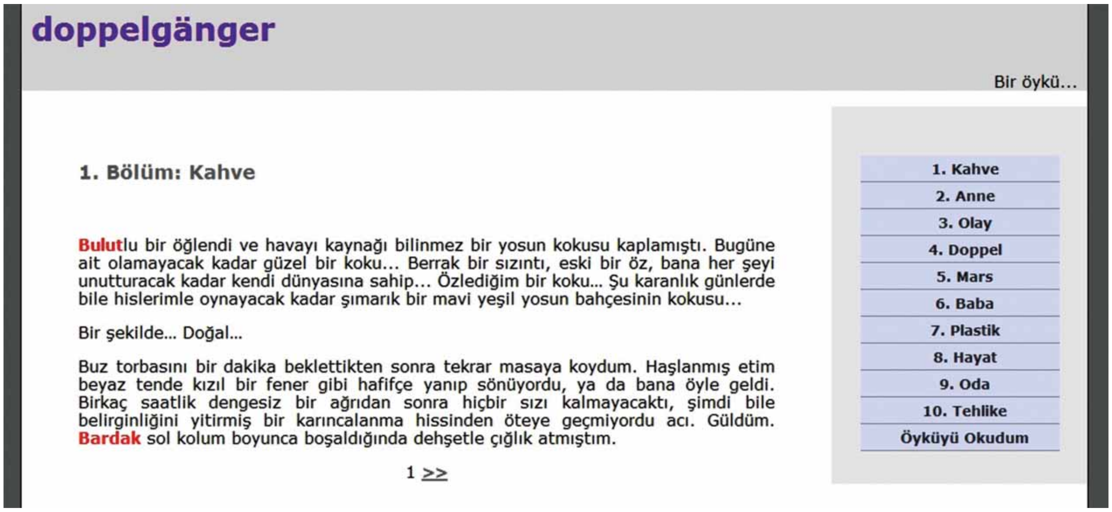

Figure 2. Screenshot of the RPND where an interactive buttons list (chapter titles) is located on the right side of the screen. In e-learning environments, layouts are differentiated by their panel locations.

2.4. *Tasks*

The main argument in LOP is that the depth of the processing level determines the durability of memory traces. In other words, deeper (semantic features) LOP are associated with the strength of the encoding and increase memory performance. In this study, within the framework of LOP three different types of tasks (shallow, medium and deep) were developed according to their processing levels. During the online reading phase, participants' levels of reading and the depth of the processes were manipulated by the given tasks. The groups SL and SR studied a shallow task ('please count and find the sum of the total number of vowels in the words that were written in red font in the text') and wrote down the answers in the paper handout formatted task forms. The second groups ML and MR studied a medium level task ('please find and make a list of new words rhyming with the words that were written in red font in the text') and wrote their own rhyming word list in their paper handouts. For the third groups DL and DR, a deep level processing task was given ('please compose new meaningful sentences with the words that were written in red font in the text'), and the participants wrote their own new 25 sentences in the given task forms.

2.5. *Memory performance test*

The immediate recall and two-week delay tests were used to determine students' performance on free recall, title recognition and location memory with a paper handout-formatted memory performance determination and measurement instrument (Memory performance test (MPT)) which was developed by the researchers. MPT consisted of three subtests:

- Free recall, where participants wrote as many target words as they could recall from the text. Each correct answer was evaluated with 1 score point.
- Title recognition was a multiple-choice test, where participants marked the correct title with a correct sequencing from the given choices. The title memory test included 10 questions (total number of the titles of 10 chapters). Each correct answer was evaluated with 1 score point.
- Location memory, where participants tried to mark (indicating the location by putting an $\times$ sign to the correct quadrant which is representing the text screen on paper with a symbolic coordinate plane for each target word) the screen locations of the target words correctly. For each correct sign, 1 score point was added.

2.6. *Procedure*

Prior to the main experiment, a pilot study was conducted with 30 participants in six groups ($n = 5$) in order to minimise any problems or unforeseen issues during sessions. The pilot study was identical to the main experimental sessions but using a smaller sample size. The aim was for the sample group to be as representative as possible of the study group. Moreover, an effort was made to ensure that the sample group would not be in contact with the research study group members. A to-do list for the experimental sessions was developed and checked. The following sequence was used in experimental sessions: (1) informing phase; (2) online reading and task phase; (3) recall and retention tests (free recall, title memory, location memory and two-week delay retention tests). All the experimental sessions (1 session for each group, 12 sessions in total: 6 sessions of reading and immediate recall tests and 6 sessions of two-week delay tests) were carried out in a computer laboratory (20 computers: 15 for experimental sessions, 5 spare for any technical problem during sessions) with a total of 90 participants in 6 groups ($n = 15$). Each participant was tested

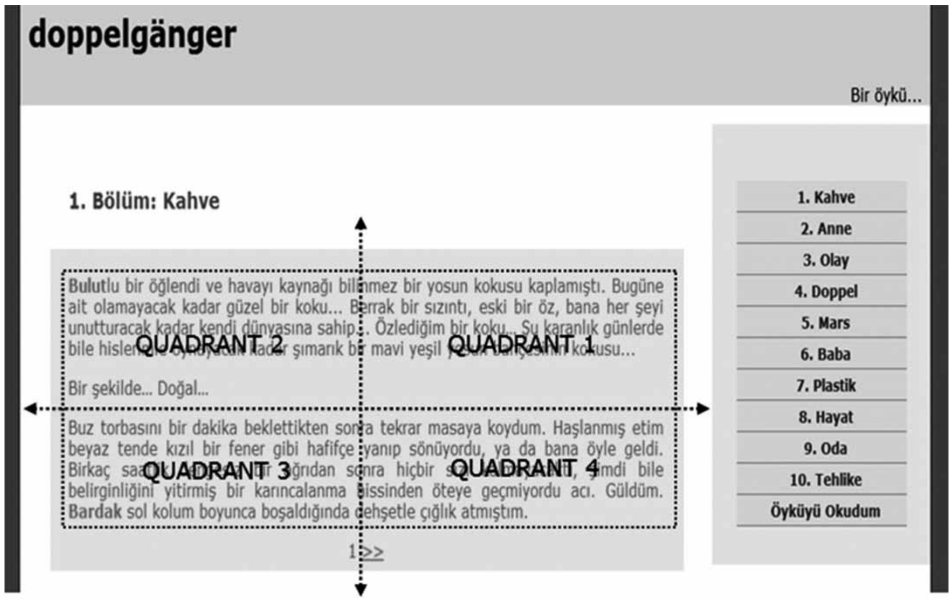

Figure 3. Selecting target words from the text by their locations and distributing text paragraphs onto an imaginary coordinate plane. Words with a closer location to the origin were not selected as target words.

individually. The participants were not instructed about the forthcoming memory tests or why some of the words were written in red during their reading relevant to incidental learning (see Figure 3).

The first experimental session was carried out with group SL. First, the paper handout task forms were given to the participants. The reading phase started synchronously. Participants studied the shallow task by processing with target words' phonemic features. At the end of the reading phase, each participant noted his/her own answers on the task forms. The researcher turned the computers off centrally, collected task forms and asked the participants to be ready for a test. Immediately after the reading phase, the participants were given hard copy MPT handouts. The free recall test was given followed by the title recognition test and lastly, the location memory test. After two weeks, MPT was repeated in the same computer laboratory as a test-only session in order to measure the participants' memory retention. During the sessions, time was unlimited; therefore, in order to see the average time spent on tasks and tests, researchers noted the task implementation time for each participant. The third and fourth experimental sessions of the first half were administered with group ML by implementing the medium task in which participants noted their own rhyming words. The immediate recall and two-week delay tests were given.

The next two experimental sessions were administered with group DL and the participants wrote their own sentences by using the target words with a semantic level of the task. After the recall and retention tests, the first half of the total of 12 experimental sessions designed for the LPND had been applied. The same experimental processes were implemented in the next six sessions with groups SR, MR and DR where the participants studied with RPND.

3. Results

A factorial design of 3 (LOP; shallow vs. medium vs. deep) $\times 2$ (NDT; LPND vs. RPND) GLM MANOVA was applied to the number of target words and titles correctly retrieved in the recall and the delay retention tests, including free recall, title recognition and location memory subtests. Two-way ANOVAs for each DV were also conducted. All data were checked for normal distribution and Mauchly's test for sphericity was calculated. All of the reported significant results met a criterion of $p < .05$. Moreover, all the main effects and interactions of the factors were significant.

The analysis revealed a significant main effect of LOP (Wilks' Lambda $= .422, F(2.83) = 56.734, p < .001$) with a large effect size ($\eta^2 = .58$), as well as a significant main effect of NDT (Wilks' Lambda $= .233, F(1.84) = 277.266$, $p < .001$, $\eta^2 = .77$). The results indicated that NDT has a bigger effect than LOP on defining participants' memory performance. In other words, in this study, the design type of the environment was more indicative of memory performance than the processing level of the task. Concerning LOP interactions, MANOVA revealed that the LOP $\times$ group interaction was significant (Wilks' Lambda $=.672, F(10.166) = 3.655, p < .001, \eta^2 = .18$). There was also a significant interaction between the LOP and NDT (Wilks' Lambda $= .903$, $F(2.83) = 4.461$, $p < .05$, $\eta^2 = .01$) and between the NDT and group (Wilks' Lambda $= .837$, $F(5.84) = 3.274$, $p < .05$, $\eta^2 = .16$). Furthermore, the three-way interaction involving LOP $\times$ NDT $\times$ group

Table 1. Means and standard deviations by condition. Mean number of words and titles correctly retrieved out of 25 target words and 10 titles according to encoding conditions (levels of processing) for recall and retention.

Memory test	Design type	Levels of processing	Recall Mean	Recall SD	Retention Mean	Retention SD
Free recall	LPND	Shallow	7.07	4.17	5.27	2.76
		Medium	8.00	3.48	4.27	1.91
		Deep	10.60	2.82	7.73	3.37
	RPND	Shallow	4.13	2.10	3.87	2.10
		Medium	8.80	3.65	4.87	2.59
		Deep	12.40	2.59	7.93	2.87
Title recognition	LPND	Shallow	7.53	2.17	6.40	2.59
		Medium	7.60	2.06	5.47	2.59
		Deep	8.27	1.71	6.27	2.02
	RPND	Shallow	7.33	2.13	4.60	2.22
		Medium	6.93	1.98	4.27	3.08
		Deep	8.27	1.71	5.93	1.87
Location memory	LPND	Shallow	6.67	4.13	2.07	1.71
		Medium	6.73	1.98	2.93	2.46
		Deep	7.93	4.23	3.27	1.87
	RPND	Shallow	2.73	2.05	1.40	.91
		Medium	3.20	1.70	1.27	.80
		Deep	6.87	3.09	3.13	2.07

was also significant (Wilks' Lambda = .657, $F(10.166) = 3.878$, $p < .001$, $\eta^2 = .19$).

Two-way ANOVA results were significant for free recall and location memory in recall and retention tests. Free recall performance of both recall and retention tests was significant ($F(5.84) = 11.951, p = .000$; $F(5.84) = 6.662$, $p = .000$). However, groups' title recognition performances were not significant for recall ($F(5.84) = 1.077$, $p = .379$) and retention ($F(5.84) = 1.991$, $p = .88$). Location memory was also significant for recall ($F(5.84) = 7.577$, $p = .000$) and retention ($F(5.84) = 3.903, p = .003$) memory test scores. These results confirm the impact of LOP and NDT on free recall memory performances of recall and retention test scores as well as location memory performances. However, it is evident that there was no significant interaction effect of LOP and NDT on title recognition. The significance levels of free recall was found to be higher than those of location memory, revealing that LOP and NDT are more effective on participants' free recall memory performances than location memory performance. Table 1 demonstrates the means and standard deviations for the six groups on measures of memory performance (recall and retention) of free recall, title recognition and location memory with NDT and LOP.

Mean memory performances (mean of recall and retention scores of both of the NDTs) of free recall (shallow: $M = 5.09$, SD = 2.78; medium: $M = 6.48$, SD = 2.90; deep: $M = 9.66$, SD = 2.91), title recognition (shallow: $M = 6.46$, SD = 2.28; medium: $M = 6.06$, SD = 2.42; deep: $M = 7.18$, SD = 1.82) and location memory (shallow: $M = 3.21$, SD = 2.58; medium: $M = 3.53$, SD = 1.85; deep: $M = 5.3$, SD = 3.08) resulted in and indicated an increasing level of retrieval related to depth of processing.

LPND resulted in a higher accuracy, respectively, on free recall, title recognition and location memory ($M = 7.15$, SD = 3.08; $M = 6.92$, SD = 2.19; $M = 4.93$, SD = 2.73) than RPND ($M = 7.00$, SD = 2.65; $M = 6.22$, SD = 2.17; $M = 3.10$, SD = 2.11) according to the mean recall and retention performance scores. Significantly, the results demonstrated that greater memory performance was obtained in deeper levels of encoding as compared to medium and shallow levels (see Figures 4–6).

As expected, groups' recall performance decreased after two weeks of delay, overall. Frequency of decrease level of free recall (34%), title recognition (28%) and location memory (59%) is arguable. The highest level of recall performance decrease was seen in location memory. This result indicates that remembering an item together with its episodic features tended to build a more complex level of

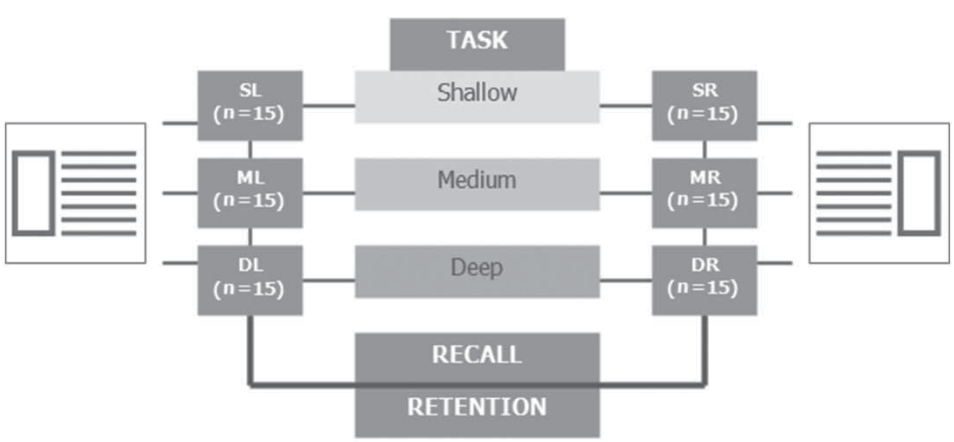

Figure 4. Task process and testing memory performance. (Group identification: group coding characters are the combinations of NDT and LOP. The code L in group names refers to usage of LPND type of e-learning environment and the code R refers to RPND type. Codes S, M and D indicate shallow, medium and deep processing levels.)

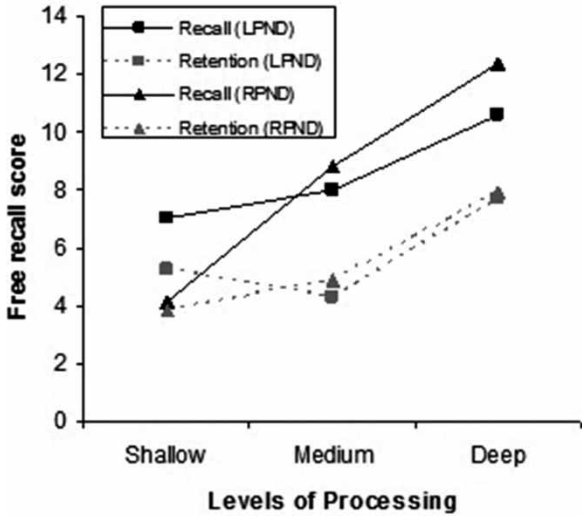

Figure 5. Free recall memory performances of recall and retention test scores in left and RPND types.

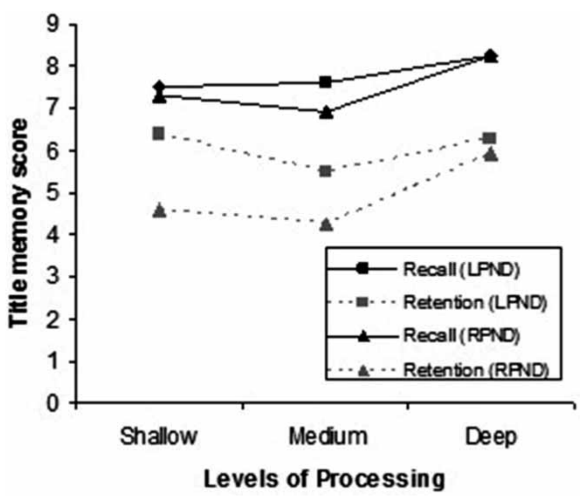

Figure 6. Title recognition performance of recall and retention test scores in left and RPND types.

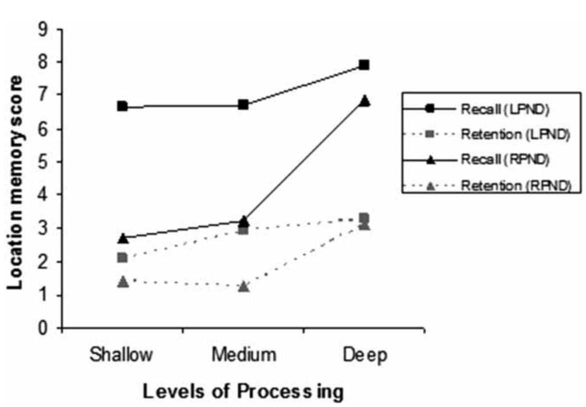

Figure 7. Location memory performances of recall and retention test scores in left and RPND types.

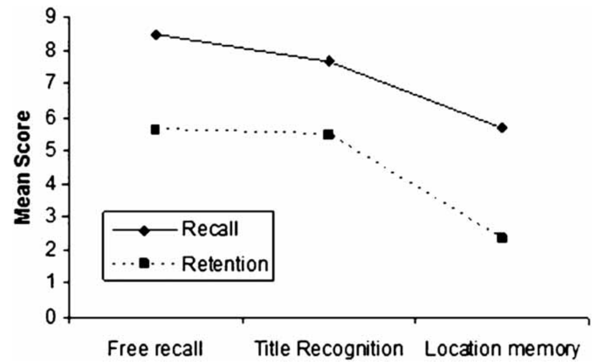

Figure 8. Decrease levels for free recall, title recognition and location memory in recall memory performance after two weeks of delay.

cognitive process, thus increasing the probability of failure in memory performance (see Figure 7).

A notable result in title recognition of the two groups' studying with the deep level task was the equal mean and standard deviations of immediate recall performances ($M = 8.27$, SD = 1. 71). Both in LPND and RPND, the groups' deep level title recognition resulted in equal memory performances of recall. However, after two weeks of delay, the recall memory performance equality for deep level title recognition disappeared, and retention memory performance was found to be better (4%) for the group members who studied with LPND (Figure 8).

4. Discussion and conclusion

In this study, the LOP framework was applied to e-learning environments within the context of NDT and instructional tasks. E-learning environments designed in two different NDTs were tested to examine whether participants' recall and retention memory performances of free recall, title recognition and location memory differ according to shallow, medium and deep levels of task.

The findings indicate that recall and retention MPT scores match with the basic idea of LOP (Craik 2002; Craik and Lockhart 1972; Lockhart and Craik 1990; Lockhart 2002). Mean scores tend to increase in accordance with the processing levels from shallow to deep, respectively. The main effects of NDT on recall and retention demonstrate that the main visual characteristics (DeStefano and LeFevre 2007) of the learning environment involving navigation design basics are good indicator elements of cognitive processes and memory performance during web interaction.

According to NDT, RPND was advantageous only in the free recall test's medium and deep levels of task. In contrast, left panel design type mediated better free recall mean scores for the groups studying with a shallow level of task, together with better performance of location memory scores in all processing levels. This finding pointed out left preference (Oulasvirta, Kärkkäinen, and Laarni 2005) in online reading activity during e-learning environment interaction. It is also a stable reality that reading occurred from left to right in this research, and it can be concluded that this might have an effect on left preference. This possible effect of reading direction should be taken into account in future research and attention research. In contrast to free recall and location memory performances, however, memory performances of recall and retention test scores for title recognition were similar in each of the shallow, medium and deep LOP. Moreover, the title recognition mean scores, regardless of LOP and NDT, indicated a better persistence level than free recall and location memory. In other words, the decrease level in recall performance for title memory was less than that of free recall and location memory performances. This result can be explained in two ways. First, the titles were constant on the screen layout in that they were seen repeatedly and processed in every page of the text from the beginning to the end of the reading activity. Secondly, participants processed a repeated action of clicking interactive title buttons in order to navigate between chapters. This clicking corresponded to an active process of using that web element. On the other hand, the target words could be seen on the screen and processed with a task only once during reading, unless the participants returned to the relevant page again. At this point a visuo-spatial memory (Baddeley and Hitch 1974) could be possible for participants' cognitive processes, due to repeated demonstrations of memory traces, implicit learning and episodic memory (Chun and Jiang 1998; Rittschof 2010). Memory retrieves the information with episodic and location features, which were encoded by visuo-spatial processes. According to Piolat, Roussey, and Thunin (1997), the page has a two-dimensional structure in reading that the encoding processes for location memory might be carried out in a context of two-dimensional axis (x,y) coordinate space. However, all the elements in a reading context are not encoded spatially, as there might be additional cognitive processes in order to provide a more effective way of encoding the location of those elements. Recent studies imply that encoding the target words from a screen or a printed document involves a surface type of encoding.

In this study, the testing effect is another dimension to be discussed, as repeated testing could give a cueing role for the first implemented test, immediate recall. Participants might have processed a new encoding process during testing sessions (Roediger and Karpicke 2006). After two weeks of delay, the encoded mental representations of the first test could be used by the participants as the material, as a cue provider, instead of the e-learning environment, in order to facilitate memory retention. Another point to underline here is that participants were not informed about the first and second experimental sessions' contextual details and were not aware that they were going to be tested later or right after the reading sessions so that the task implementing processes could be fitted into an incidental paradigm. Self-awareness and expectations (Oulasvirta et al. 2005) in memory research can alter the ways of encoding that knowing the difficulty level of an instructional task can influence participants' LOP (Agarwal and Roediger 2011) in which this argument corresponds to a criticism of LOP.

In answer to how NDT and LOP influence memory performance, the findings indicate that the reading activity in the context of an e-learning environment required readers to read from shallow to deep processing in terms of LOP. Reading processes were also manipulated by NDT. LOP and NDT, one by one and together, had significant effects on explaining memory performance in this study. It can be concluded that, in extending the findings of this study to e-learning, navigation design could be important for constructing new implications of design principles. E-learning designers might take into consideration that memory performances change in correlation with the environment's design characteristics (navigation, layout and content) and the learner's cognitive processes. The memory for navigation and the content are crucially important in designing e-learning environments. The way of encoding, storing and retrieving during implementing instructional tasks determines the level of memory performance in online interaction. For further research, readers' memory performances in different LOP and NDTs could be evaluated by including the search process for the effects of time spent on tasks, as well as learners' attention processes during encoding.

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