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The Effect of Dual Language Book Page Layout on L2 Vocabulary Gains: An Eye Tracking Study

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Abstract

Dual language books (DLBs) present the target language along with L1 translation without following a standard page structure. Hence, the arrangement of L2 content and its L1 equivalents in the page layout depends on the publisher. This study aimed to examine how different L1-L2 layouts affect L2 reading experience and L2 vocabulary gains by using eye tracking and semi-structured interviews. A total of twenty-seven EFL learners enrolled in an ELT department aged between 19–21 read three homogeneous DLB samples with three different layouts, containing non-words designed for research purposes while their eye movements were recorded. After each DLB sample, the participants took a vocabulary post-test and attended the semi-structured interview about their reading experience. The results showed that layout type had no effect on vocabulary post-test scores. However, the eye tracking results indicated that total fixation duration, fixation count, and revisits were significantly higher for the layout in which L1 and L2 were presented on the same page in a 2-column setting. The layout in which L1 and L2 were presented in two facing-pages was found to be more efficient and demanded less attentional resources. These findings were also supported by the qualitative findings. The results were discussed in terms of cognitive effort, L2 reading experience, and column setting in reading.

1. Introduction

Popularly used in language learning, dual language books (DLBs) provide the same texts in two different languages (Naqvi et al., 2010). DLBs are versatile; they can be integrated in dual language learning programs and assist people aiming to master a particular language with a wide range of linguistic duality. Reportedly, DLBs affect literacy development (Domke, 2023; Simoncini et al., 2019), motivation (Kenner et al., 2008; Ma, 2008), and reading comprehension (Galloway et al., 2020). DLBs also foster readers' critical consciousness and raise their awareness of the discourses about languages and language practices that predominate a particular language over some others (Domke, 2023). From a general perspective, DLBs are specifically designed to focus on reading comprehension and vocabulary learning across divergent language pairs (Si'ilata et al., 2023; Read et al., 2021; Simoncini et al., 2019; Teng, 2019). They can be integrated into cultural education (Si'ilate et al., 2023; Simoncini et al., 2019) to foster bilingual education, literacy, and cultural understanding, especially supporting young learners to navigate between their host and their heritage languages (Ma, 2008). Alongside its cultural aspect, DLBs can foster any learner who wants proficiency in an additional language. DLBs are significant reading resources that foster multilingualism, enhance text comprehension, promote noticing, and support differentiated instruction while emphasizing their role in bridging linguistic practices across two languages (Domke, 2023; Knabe et al., 2024; Ma, 2008; Read et al., 2021; Galloway et al., 2020).

In addition to the fact that these books are offered in different versions, it is worthwhile to consider the layout of the books- how the languages are ordered and aligned within the content. The formats of DLBs can vary to suit diverse learner needs, providing flexibility for the learners to engage with the text. The target language and the L1 translation are generally aligned in 3 different formats as on the same page in parallel fashion (i.e., Grimms' fairy tales: Dual language: German-English-2015 [Grimm & Grimm,

2015]); on different facing pages (Short stories in Japanese: New Penguin parallel text-2011), or stacked, one below the other on the same page, (Bilingual fairy tales in Spanish and English: 2015 [My Daily Spanish, 2022]).

Column settings are different in the three layout types. The parallel same-page (SP) layout has 2 columns on the same page; the target language and its L1 translation are located side by side on a single page. In the different-page layout (DP), each page has a single column in a traditional layout; the target language is presented on the left - hand page in a single column while the corresponding L1 translation appears on the right-hand page. The stacked layout (ST) has a single column; however, the target language is placed at the top of the page while the L1 translation is positioned directly below it on the same page. The layouts vary depending on the publisher, yet the reason for a specific page layout type is not clear. Given that layout may have an impact on processing information and vocabulary acquisition, the current research aimed to reveal any processing and vocabulary learning differences regarding three different page layout types in the EFL context.

1.1. Previous Research on DLBs

Several recent studies have explored the multifaceted role of DLBs in educational contexts, particularly for EFL learners coupled with different language pairs (Domke, 2023; Guiberson, 2021; Knabe et al., 2024; Read et al., 2021). DLBs are also spotlighted for the examination of their content suitability and translation accuracy across different languages (Dillon et al., 2018) and of cultural consistency to enhance literacy (Guiberson, 2021). Research has underlined the role of DLBs in improving English comprehension (Galloway et al., 2020), integrating culturally relevant content (Simoncini et al., 2019), challenging language ideologies (Przymus & Lindo, 2021), and supporting children's cultural and linguistic identities through community-based approaches (Si'ilata et al., 2023). The study by Simoncini et al. (2019) explored the role of cultural relevancy of DLBs in five primary schools to develop literacy and agricultural education in Papua New Guinea. The findings highlighted both the potential of culturally relevant dual-language materials to enhance literacy and the need for improved distribution strategies to maximize their impact on communities. In another study examining how Spanish and English academic language skills affect text comprehension among middle-grade dual language learners, Galloway et al. (2020) assessed students' academic language proficiency and its relationship with reading comprehension. Emphasizing cross-linguistic transfer, their findings reported a contribution of academic language skills to text comprehension for dual language learners. Further, Si'ilata et al. (2023) investigated the role of DLBs in supporting cultural literacies and heritage languages in early childhood settings. Data were collected over eight years using reading records and vocabulary tests in the Pacific and English languages. The results demonstrated that more than 86% of Pasifika children improved their reading skills, highlighting the effectiveness of DLBs in promoting language development, cultural identity, and critical thinking.

Adopting a different lens, Przymus and Lindo (2021) directed attention to the sequencing and positioning of DLBs. They argued that positioning, separation, or integration of languages in DLBs often reflects underlying ideologies about language dominance, power, and cultural value. Hence, their study advocates for a more deliberate design of DLBs regarding text representation and consideration of the social and cultural implications of the target and source languages. In light of these studies, the widespread use of bilingual storybooks designed for EFL learners plays a key role in fostering early literacy, vocabulary acquisition, and comprehension across diverse dual language forms. Although previous research yielded practical results, no research was conducted by using eye tracking technology, which may reveal processing differences due to different layout types of DLBs.

1.2. Column Settings and Line Length in Reading

Different types of layouts in DLBs naturally require different column and line length settings, which may potentially affect the reading experience and the target language learning process. Several L1 studies on text layout and reading have emphasized the effect of typographical elements such as column setting and line length on reading performance. Some early related research demonstrated that reading speed was slightly faster with two-column and three-column layouts, with improved comprehension (Creed et al., 1987; Dyson & Kipping, 1997). In a recent EEG research, Al-Samarraie et. Al. (2019) supported this notion, proposing that the two-column layout provided a better reading experience since this layout improved the cognitive functions related to the way information is displayed. On the other hand, a number of later studies yielded contradictory results. Dyson (2004) emphasized that most readers are familiar with single-column formats, which have a positive effect on reading speed and comprehension. For example, Kurniawan and Zaphiris (2001) and Ganayim and Ibrahim (2013) demonstrated that single-column formats with typically longer lines resulted in shorter reading times, reporting that simpler and more familiar formats might support the reading experience. In an e-book study, Yi et al. (2011) suggested that readers found single-column settings more satisfactory, along with better readability, comprehension, and reading speed. One column with 1.5 multiple lines spacing of font size achieved the best result. Harley et al. (2013) examined r eading speed with different numbers of columns and reported that reading multi-page layouts took longer to complete due to demanding visual search. In a recent eye-tracking study, Al-Samarraie et al. (2017) examined the reading experience in repeated and n on- repeated conditions arranged in a multi-column layout. They reported that the readers performed best in a three-column layout for repeated reading, and with a single column for normal reading. For normal reading, fixation duration was found to be higher with multiple columns when compared to a single column layout.

The processing differences between single and multiple columns can also be related to line length since it is a major variant in column settings. Using multiple columns enables shorter lines to maintain a similar text density, while a single column setting consists of longer lines. Bouma (1980) stated that

readers might find lengthy lines challenging, particularly due to difficulties in locating the start of a new line after long eye movements affecting return sweeps. Similarly, Dyson and Haselgrove (2001) found that longer line lengths could disrupt a reader's ability to quickly locate the beginning of a new line after a return sweep. Problems in return sweeps may cause higher fixation count in long lines since readers may not process much information during each fixation, leading to shorter saccade lengths (Inhoff et al., 1989). However, some studies suggest that longer lines are faster to read (Duchnicky & Kolers, 1983; Dyson & Kipping, 1998), while others propose that medium to short line lengths may contribute to reading comprehension (Bruijn et al., 1992; Chaparro et al., 2004). In sum, previous related research showed that different column settings and line lengths offer different reading experiences.

The studies mentioned above were in the context of L1 and traditional reading. Related second language (L2) research still lacks a study on different layouts and DLBs. Regarding the effect of different layouts and typography on reading experience, we hypothesized that different column settings in DLBs may yield different processing times and EFL vocabulary learning. Several empirical studies have shown that eye tracking reflects moment-by-moment cognitive processing during reading (e.g., Liversedge & Findlay, 2000; Starr & Rayner, 2001). Additionally, major eye tracking measures (fixation duration and count) are related to cognitive effort (Rondón et al., 2021; Wang et. Al., 2014). Since the three-page layout types mentioned above (Same page, different pages and stacked) would require learners to employ different eye movement patterns and fixation durations, there may be an effect of text layout on cognitive effort and target language vocabulary gains. By using eye tracking technology, the current study sought answers to the following research questions:

1. Is there an effect of SP, DP and ST layouts on L2 vocabulary learning gains?

2. Is there an effect of SP, DP and ST layouts on eye movements (total fixation duration, fixation count and revisits)?

3. What are the opinions of the EFL learners regarding the reading experience of SP, DP and ST layouts?

2. Methods

2.1. Design

The study adopts a mixed-methods research design. An explanatory sequential design, which is one of the core designs, was employed in the study. The aim of this design is to use qualitative findings to explain the quantitative results (Creswell, 2021). Firstly, quantitative data were collected in the study. After that, qualitative data were gathered. Since the qualitative data were used to explain and support the quantitative findings, the study was structured in accordance with this design.

2.2. Participants

27 sophomore EFL learners (7 males and 20 females) in an ELT department at an age range of 19 to 21 (M=19.5; SD=,57) voluntarily participated in this research and received course credit for their participation. A purposive sampling procedure was adopted to obtain reliable data. To be elected as a participant, the volunteers were required to have successfully completed a 1-year preparatory class with a minimum score of 65 out of 100 (M=72.8; SD=6.97), which officially corresponded to a B1+ level. Participants are also required to have no eye sight problems. All participants had the same L1 background (Turkish).

2.3. Reading Text

To control any negative interference of comprehension on vocabulary learning, a short stage 1 novel with 400 headwords called “Goodbye Mr. Hollywood” was chosen as the reading stimulus. The same story book by Oxford Bookworms was also used by previous related research by Mohamed (2018). The text was cut down to around 2000 words. After AI-generated short sentences, including pseudowords, were added, the final length of the text was 2120 words. The text was then translated into Turkish and double-checked with another researcher teaching translation courses in an ELT department. The final version of the translation was also reviewed together with 10 senior students to avoid any translation-related issues.

Reading the whole story at one sitting, along with the translated parts, would cause fatigue during eye-tracking experiments. Moreover, vocabulary retention would be challenging in longer eye-tracking sessions. So, the translated text along with the original text was then cut into three homogenous sequential parts as part 1 (beginning of the story-1207 words), part 2 (mid-story-1242 words), and part 3 (Final-1187 words). Vocabulary tests and comprehension check was given after each part and calibration was applied before starting each part. To avoid carryover effects and provide counterbalance, each part was reformatted into 3 different page layouts as DP (different page), SP (similar page) and ST (stacked). In this way, 3 different conditions were created as C1, C2 and C3 as shown in Table 1 below:

Table 1 *Structure of the Test stimuli*

Condition	N	Part 1	Part 2	Part 3
C1	9	DP	SP	ST
C2	9	SP	ST	DP
C3	9	ST	DP	SP

Each student was assigned a condition in the eye-tracking sessions. For example, student A attended C1 and started the story with DP layout, went on with ST layout, and finally read SP layout. On the other hand, student B in C3 started the story in ST layout, then read DP layout and ended with SP layout. By doing so, we aimed to counterbalance each layout during eye-tracking experiments to obtain more reliable data.

2.4. Pseudowords as target words

Being quite common in experimental vocabulary studies, a pseudoword is a word- like unit that seems and is pronounced like a real word while it has no meaning. In the current research, 24 different short pseudowords were generated as target words through UniPseudo (http://www.lexique.org/?page_id=582) by New et al. (2024). All pseudowords were nouns. The list of pseudowords with with their translated meanings for each part of the story is given in Table 2 below.

Table 2 *List of pseudowords with translated meanings for each part of the story*

Part 1	Part 2	Part 3
Dow (Yol)	Hax (Otobüs)	Sim (Kalem)
Bup (İş)	Fip (Kedi)	Hud (Köpek)
Flin (Havuz)	Tros (Yıldız)	Tave (Göl)
Cunk (Yüzük)	Cawn (Kek)	Jord (Kapı)
Thoic (Dünya)	Spush (Sandalye)	Brels (Çim)
Spick (Yer)	Glamp (Ekmek)	Floom (Telefon)
Dablet (Vadi)	Coftey (Çember)	Wasert (Ceket)
Withor (Çaba)	Hoppet (Çarşı)	Pollet (Bilet)

Since eye movements are sensitive to word length in reading (Rayner et al., 2011; Barton et al., 2014; Hautala & Loberg, 2015), all pseudowords in each part were balanced as 3 to 6 letters equally. Instead of randomly substituting words in the original text with pseudowords, we preferred to add simple AI-generated short sentences, including pseudowords, into the text. For this purpose, ChatGPT was utilized and asked to add a short, simple sentence to a given paragraph, including a word (i.e., road) without distorting the meaning (see Appendix 2 for a sample). After choosing a proper sentence, the word “road” was substituted with its pseudoword equivalent (dow). In each part, related pseudowords occurred once. For 24 pseudowords, 24 sentences were generated. The sentences were embedded in the text in a way that the participants met 2 pseudowords in a two-page layout in full-screen mode. Each part had a total of 8 pages in experimental mode.

2.5. Vocabulary Tests and Comprehension Check

Vocabulary tests were given after reading each part and consisted of 3 tests: form recognition, meaning recall, and meaning recognition. In the form recognition test, the participants were asked to circle the pseudowords they saw during reading (a maximum of 8 pseudowords) out of 24, of which 16 were distractors. In the meaning recall section, the participants were required to make predictions on the Turkish meanings of 8 pseudowords. In the meaning recognition test, the participants were required to choose the correct Turkish meaning of 8 pseudowords among multiple options. For each reading part, the maximum score to be acquired was 24. The participants took the vocabulary tests in the following order to avoid transfer effects: form recognition, meaning recall, and meaning recognition. The testing duration for a participant was limited to 3 minutes for each test. The maximum points to acquire were 72 for the whole test procedure. A comprehension check was given right after the vocabulary tests to avoid blind reading. The test included five simple multiple-choice questions along with 5 true/false items about the content of the part that was read. The vocabulary tests and and complerehnsion check is given in Appendices 4 and 5.

2.6. Semi-Structured Interview

The qualitative data were collected through a semi-structured interview form. During the development phase of the form, firstly, the relevant literature was reviewed. Subsequently, a draft version of the interview form was prepared. This draft was submitted for review to two faculty members who are experts in the field. Based on their feedback, two additional questions were incorporated into the form. Then, the revised form was evaluated by an expert in the field of native language education, and language adjustments were made in accordance with the expert's suggestions. Before using the form, we conducted a pilot with two undergraduate students by asking them the questions included in the form and minor linguistic revisions were made to enhance clarity and ensure better comprehensibility. As a result, the semi-structured interview form was finalized. The form consists of a total of nine main questions along with corresponding follow-up prompts.

2.7. Apparatus

A remote gazepoint GP3 device with 60hz refresh rate was utilized for this research. The device had 0.5 – 1 degree of visual angle accuracy and allowed 25cm (horizontal)- 11cm (vertical) head movement with ±15 cm range of depth.

2.8. Procedure

27 participants were equally divided into 3 different conditions (C1-C2-C3) and attended eye tracking sessions individually. Before the sessions, each participant was informed about the procedure and signed the consent form. After 9-point calibration with a 19-inch LED monitor, the participant was asked to read the given first part silently for comprehension and vocabulary learning purposes. On the monitor

screen, the stimuli seemed similar to the authentic DLB format. Each part was 8 pages, and the participants could process 2 pages at once in full-screen mode. They were also able to turn over pages with the spacebar. After reading the first part, the participant immediately took the vocabulary tests and a short comprehension check test. After the first test procedure, the participant sat for the second reading part and recalibration. After reading the second part, the participant took the second vocabulary test session and comprehension check. The same procedure was applied for the third eye-tracking session and tests. Finally, the participant was taken for an immediate semi-structured interview to another room. For an average participant, eye tracking, reading, and testing sessions lasted around 30 minutes and 15 minutes for the semi-structured interview. The interviews were conducted directly by the researchers. Each interview was audio-recorded using a voice recorder. Prior to data analysis, all audio recordings were transcribed verbatim. For statements that were unclear or raised doubts, member checking was employed to ensure accuracy. Furthermore, the interviews were conducted immediately following the intervention. Thus, we aimed to obtain more reliable qualitative data.

2.9. Data analysis

Areas of interest (AOIs) are shapes (mostly rectangular or square shapes) drawn by the researchers to analyze the obtained eye-tracking data. The desired eye-tracking measures can be analyzed through dedicated software. In this research, the AOIs were the original version (English) and the translated version (Turkish) as shown in Appendix 3.

In these AOIs, two eye-tracking measures were used for the eye-tracking data analysis: Total fixation duration and revisit. Total fixation duration refers to the total time spent on a given area of interest. While short duration visual search (i.e., participants are required to make quick decisions in a limited time constraint) in which total fixation duration may indicate attention, alertness or focus (Byrne et. Al., 1999), total fixation duration in longer tasks (i.e., language processing/reading) may represent a comprehensive range of underlying constructs including effortful processing (Rayner, 1998). In this research, we assumed that longer total fixation durations may indicate effortful processing among different types of layouts.

A revisit can be described as leaving an area of interest after fixation(s) and re- entering the same area after some time. Dual language texts are quite suitable for this metric since readers are expected to go between the original text and the translated version on the same page for information processing. Our assumption was that higher revisits may indicate effortful processing since revisits also inflate total fixation duration in a given area.

The vocabulary tests were scored traditionally; each correct answer was 1 point. The maximum total score for each part was 24 points, and the complete maximum score for all parts was 72. Comprehension scores were scored over 100 as each question stood for 10 points. Since all participants were exposed to all layout types, repeated measures ANOVA was adopted to examine any differences between DP, SP, and ST vocabulary scores. Total fixation duration (as milliseconds) and revisit counts

(how many times revisits were employed) on the related AOI were extracted through the eye tracking software (Gazepoint Analysis Professional Edition). To examine within-subject differences among DP, SP, and ST layouts, repeated measures ANOVA was adopted since all participants were tested under 3 different conditions as DP, SP, and ST layouts. As dependent variables, total fixation duration and revisits for each AOI were compared through repeated measures to examine any difference.

In the analysis of the qualitative data, we employed the content analysis technique. Additionally, direct quotations were included (to support the findings). Pseudonyms were used for the participants (e.g., P1, P2, Pn) to ensure confidentiality. The content analysis was conducted following the approach proposed by Dey (1993). Accordingly, the data were first coded, and then categories were generated based on the relationships among the codes. In order to assess inter-coder reliability, the Cohen's Kappa coefficient was calculated. At this stage, approximately half of the dataset coded by the researchers was independently coded by another expert in the field. The resulting agreement coefficient was .80, indicating a satisfactory level of inter-coder reliability (Miles & Huberman, 1994).

3. Findings

3.1. Finding 1: Comprehension and Vocabulary Test Results

A descriptive analysis was conducted for comprehension scores to examine any comprehension difficulty that may interfere with the vocabulary learning process. The results showed that the scores ranged from 70.00 to 93.33 (M = 79.57, SD = 8.32), based on 27 valid responses. The overall score was satisfying, and no comprehension interference was assumed. No further detailed analysis was made since the focus of the study was vocabulary learning only.

A repeated measures ANOVA was applied to examine any effect of layout type on vocabulary test scores. Descriptive statistics showed that the mean score for the DP exam (M = 11.33, SD = 4.20) was slightly lower than for the SP exam (M = 12.37, SD = 4.80) and the ST exam (M = 12.31, SD = 4.33). No significant effect was found across the 3 types of layout at the $p<.05$ level. Depending on these findings, the type of layout has no significant effect on EFL vocabulary learning gains.

3.2. Finding 2: Eye Tracking Results

Repeated measures ANOVA was applied to examine total fixation duration, fixation count, and revisits over AOIs as Turkish (L1) and English (L2) parts. Mean values were given in Table 3 below.

Table 3 *Descriptives for Eye Tracking Data*

Total Fixation Duration (seconds)				Fixation Count (Count)		Revisits (Count)	
Layout Type	**AOIs**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
DP	English Part	191.7	51.4	421.4	115.8	-	-
	Turkish Part	19.3	11.5	58.2	34.7	10.1	7.1
	English Part	198.6	47.8	457.3	125.8	-	-
SP	Turkish Part	25.4	12.9	75.8	40.2	21.4	12.5
	English Part	194.4	47	436.5	98.1	-	-
ST	Turkish Part	20.7	9.9	59.7	29.8	11.8	9.13

3.2.1. Fixation Duration (seconds)

For the English part, the highest mean fixation duration was observed in the SP layout type (M = 198.6, SD = 47.8), followed by ST (M = 194.4, SD = 47.0) and DP (M = 191.7, SD = 51.4). This difference was not significant at p> .05 level. The total fixation duration for the Turkish part was much lower. The participants spent the least time in the DP layout type (M = 19.3, SD = 11.5), while they paid the highest attention to the SP layout (M = 25.4, SD = 12.9). Total attention on the Turkish part in the ST layout was around 20 seconds (SD=9.9). This difference was found to be significant, $F(2, 52) = 3.60$, $p = .034$, with the assumption of sphericity met ($W = .380$, $p > .05$). Overall, while total fixation duration was similar in the English part, the participants significantly spent more time in processing the Turkish parts in SP layout when compared to DP and ST layouts.

3.2.2. Fixation Count (count)

In the English part, participants employed the highest number of fixations on the SP layout (M = 457.3, SD = 125.8). It was followed by ST (M = 436.5, SD = 98.1) and DP (M= 421.4, SD = 115.8). This difference was found to be significant, $F(2, 52) = 3.97$, $p = .025$, with the assumption of sphericity met ($W = .922$, $p > .05$).For the Turkish part, fixation counts were notably lower than those for the English part. The participants spent the highest number of fixations in the SP layout (M = 75.8, SD= 40.2), followed by ST (M = 59.7, SD = 29.8) and DP (M = 58.2, SD = 34.7). These

differences were found to be significant, $F (2, 52) = 3.91$, $p = .026$, with the assumption of sphericity met ($W = .250$, $p > .05$). In sum, the participants employed more fixations in SP layout in both Turkish and English parts.

3.2.3. Revisits (count)

No revisits were recorded for the English part of any layout type as explained in the method section. In contrast, revisits were recorded for the Turkish part. The participants revisited the Turkish part in the SP layout most (M = 21.4, SD = 12.5), followed by the ST layout type (M = 11.8, SD = 9.13). DP layout attracted the least revisits (M=10.1, SD=7.1). This difference was found to be significant, $F(1.64, 42.63) = 22.20$, $p < .000$ with the Greenhouse-Geisser correction (W=.045).

Overall, the eye-tracking findings showed that there is a considerable effect of layout type on total fixation duration on the Turkish part, fixation count in both the English and Turkish parts, along with revisits on the Turkish part. Especially, SP layout was found to be consuming a higher amount of attentional resources when compared to DP and ST layout types, while vocabulary learning gains stayed the same across all layout types.

3.3. Finding 3: Semi-Structured Interviews

The qualitative findings obtained in the study were used to explain and elaborate on the quantitative results. The generated codes were united under two main categories as advantages and disadvantages. The codes and categories are presented in Table 4.

Table 4 *Categories and Codes*

Category	Code
Time	duration
	time management
	difficulty
	take the easy route
Challenges/opportunities	stress
	concentration and focus
	holistic perception.
	cognitive load
Cognitive and sensory factors	word retain
	word comprehension
	motivation

In the ‘time’ category, participants' most prominent views were about the duration of the tasks and time management. P27 stated “*I spent the most time on the translation task while using the same page application. Since the text was narrower, it took more time to locate the words.*”. This suggests that participants spent more time searching for words when using the same page application. Similarly, P24

commented, "*One of the advantages of the same page was being able to see unfamiliar words in close proximity. However, since fewer lines fit on a single page, I believe I spent more time on each page. Additionally, I lost time due to the possibility of a word shifting to the next or a lower line. I think that I was not able to manage my time efficiently*." This indicates that the participant experienced difficulties with time management in the same page application. In contrast, P1's remark regarding the different page application—"*It was more advantageous in terms of both finding words and selecting lines. Seeing the English equivalent directly aligned on the same line below made it easier. This prevented time loss and allowed me to grasp the meaning more clearly.*"—implies that this application offered a time management advantage for the participant.

One of the prominent codes in the category of challenges/opportunities is *difficulty*. P6 stated, "*I think the same page was more challenging due to the difficulty in following the text. You may be able to find the word easily, but constantly going back and forth makes it hard to track the text. I didn't have much difficulty with the different page since the line length increased. If I were to rank them in terms of difficulty or text tracking, the most difficult was the same page, followed by the stack. However, the most efficient was the different page*." This statement indicates that the participant experienced difficulty with the same page application, while the stack and different page applications were found to be more advantageous. Additionally, P11's remark about the same page application—"*The translation is right next to the text. Sometimes I even looked up the meaning of words I already knew. However, if I had tried to infer the meaning of the word from the context of the sentence, perhaps I would have remembered it more easily. But as I said, I kept taking the easy way out*"—reveals that the participant chose the easier route and used the application in a way that did not align with its intended purpose. Some participants also reported that certain text types caused them stress. For instance, P2 noted, "*I experienced stress while searching for words on the same and stack pages. Especially on the same page, the word could sometimes shift to the next line because the lines are very narrow. The same goes for the stack. Look down, then look up. This time I felt I was having trouble with time and became stressed.*" This statement exemplifies how certain formatting features could contribute to increased stress. The majority of participants emphasized that the same-page application was disadvantageous in terms of distraction and maintaining focus, whereas the different-page application was perceived as more beneficial in this regard. Selected excerpts from participants' responses are presented below.

P3 stated, "In the same page application, the sentences are more compressed and narrower. There are too many columns. This creates a visual search difficulty. You lose more time and experience distraction". Similarly, P18 commented, "In the different page application, I did not experience any problems with focus since the page is not overly divided and the lines are longer. I cannot say the same for the same page application, as I was highly distracted."

Some participants (P4, P7) indicated that, the most advantageous text type was the *stack* format in terms of minimizing distraction and enhancing focus. They justified this view by stating that scanning with eye movements—particularly up and down—was easier with this format. These ideas expressed by only two participants, can more appropriately be interpreted as a matter of individual difference.

Because, both participants highlighted that they had certain vision-related issues. The final code identified under this category relates to *holistic perception*. P14 remarked, "*Same and stack page formats are more focused on individual words. In those formats, it can be difficult to locate the target word. In the same page application, the fact that the sentences are broken up at short intervals is a major disadvantage. In contrast, the different page application presents paragraphs more holistically, allowing me to see complete sentences. In other words, I was able to take a more holistic view.*" This suggests that the different page application offers a significant advantage over the other formats in terms of enabling the user to perceive and comprehend the text as a whole.

The final category emerging from the analysis pertains to *cognitive and sensory factors*. P23 conveyed, "*In terms of cognitive load, the most advantageous was the different page application. The others had a higher number of lines. I had to constantly go back and forth. Also, when returning to the text, trying to find where I had left off became a burden for me.*" This statement suggests that the different page application was more beneficial in terms of reducing cognitive load. P12 supported this finding by asserting, "*I think the highest cognitive load occurred with the same page application because the words and sentences were too intertwined, and the number of lines was greater*". However, some participants expressed the exact opposite view, indicating that the different page application imposed a *higher* cognitive load. For example, P25 commented, "*It feels like there is more to read. Visually, it looks larger. Psychologically, it gives a greater sense of needing to focus. That's why I think the different page application created more cognitive load*". The majority of participants reported that the *different page* application was more effective for *word recall.* Some illustrative responses are provided below:

P20: "*For example, in the different page application, after finding the meaning of a word, I spent more time trying to relocate my position in the text. During this time, I kept repeating the word and its meaning. Maybe that's why I remembered the words better in the different page format*."

P25: "*In terms of remembering words, the best was the different page. In the same page application, I noticed I focused more on the individual words, which distracted me. But in the different page application, as I focused on the sentence, the meaning of the word became more lasting. I think since it provided me with a view of the whole text, remembering the words was easier*".

In light of the views presented above, P20 transformed what might be perceived as a disadvantage (the need to relocate text position) into an opportunity for reinforcement and better retention. Meanwhile, P25 expressed that focusing too heavily on individual words in the same page format actually hindered word recall. With regard to *word comprehension,* P8 remarked, "*In terms of locating words, the same page was slightly more advantageous. However, I had difficulty with word comprehension in the same page application. Since sentences didn't fully fit the lines and there were too many lines, the coherence of meaning was disrupted*." This reflects that some participants emphasize the disadvantage of the same page format in semantic processing. The final code identified relates to *learning motivation.* P11 claimed, "*The different page application motivated my learning more. It didn't strain my eyes. The same page and stack page applications had too many lines and columns, which caused focus problems. I just wanted to*

finish quickly in those formats because I was tired. But I didn't have that problem with the different page". This suggests that the same page and stack page applications may have limitations in terms of sustaining learning motivation. The participant attributed this situation to visual fatigue and cognitive overload resulting from dense formatting.

4. Discussion

Our eye-tracking findings showed that layout type significantly influenced total fixation duration on the Turkish section, fixation count in both the English and Turkish sections, and the number of revisits to the Turkish part. In particular, while DP layout was most efficient to process in terms of attentional sources, the SP layout was found to be the most demanding. An inflated number of total fixation duration, fixation count, and revisits may indicate consumption of extra attentional sources that increased cognitive effort while vocabulary learning gains remained consistent across all layout types. This finding can be interpreted on the relationship between eye tracking measures and cognitive effort. Eye-tracking metrics used to assess cognitive load or cognitive activity typically rely on fixation data (Jarodzka et al., 2010; Laeng et al., 2011). When combined with learning performance measures, eye tracking also helps reveal where cognitive activity is concentrated and the degree of mental effort involved (Mayer, 2010). Indicators such as the total duration and number of fixations on relevant content, as well as the frequency of transitions between related text and images, are thought to reflect learners' cognitive engagement during information processing. This view is supported by several studies demonstrating a strong positive correlation between eye-tracking measures—particularly total fixation time—and cognitive load, where longer fixation durations suggest higher cognitive demands (Just & Carpenter, 1976; Rayner, 1998). Based on these findings, a dissociation between attentional engagement and learning outcomes can be deduced in vocabulary learning. The SP layout evinced more visual attention; learners' cognitive effort increased, without any increase in vocabulary test performance. This implies that drawing more attention by certain layout types, such as the SP format, visual salience, and excessive cognitive load, may not always enhance learning outcomes.

Our qualitative findings supported the eye-tracking and cognitive effort relationship. According to the qualitative data, participants experienced higher cognitive effort and attentional difficulty in the SP layout formats compared to the DP format. While navigating SP, the participants reported experiencing considerable time loss due to tracking difficulties and visual clutter. This finding aligns with Harley et al. (2013), who examined reading speed with different numbers of columns. Their study reported that the duration of reading multi-page layouts was longer to complete due to time loss caused by visual search. The dense and vertically arranged lines made it difficult for them to locate corresponding words, which contributed to a higher cognitive load.

The findings also suggested that the SP format, especially, may hinder vocabulary acquisition by imposing excessive mental demands on learners, probably because of its 2- column structure, which was not familiar. This format was also perceived as more tiring, and some participants expressed a desire to finish the task quickly due to cognitive fatigue, probably due to their compressed structure. As

for the ST layout, participants expressed similar concerns to those mentioned in SP, including stress, time constraints, and difficulties with locating words. These issues further highlight the cognitive and practical advantages of the DP format over the others. This finding supported Kurniawan and Zaphiris (2001) and Ganayim and Ibrahim (2013) who reported that simpler and more familiar formats would support learners' reading experiences. In contrast, the different Page (DP) format was more familiar and perceived as more advantageous regarding cognitive sources. Participants indicated that the linear arrangement of lines in DP made it easier to find target words, and they did not encounter the time loss or focus-related issues observed in SP. The DP format enabled a more holistic view of the text and was identified as the most efficient in terms of both cognitive load and learning productivity. Learners also reported better recall of vocabulary items in this format. Based on these insights, the DP format can be considered the most beneficial structure among the three. Furthermore, DP was described as more motivating and visually comfortable, minimizing eye strain, and promoting sustained engagement. This finding supported Dyson (2004) and Yi et al. (2011) who found that single-column layouts were mostly preferred by readers since they facilitated improved readability, comprehension, and reading speed. In a more recent study, Al-Samarraie et al. (2017) found that a single-column layout was more suitable for normal reading, in which the fixation duration was reported to be higher with multiple columns when compared to a single column layout, supporting our findings related to DP layout.

However, it should be noted that some L1 related studies suggested that longer lines (DP layout) are faster to read (Duchnicky & Kolers, 1983; Dyson & Kipping, 1998), while others propose that medium to short line lengths (i.e., SP and ST formats) may contribute reading comprehension (Bruijn et al., 1992; Chaparro et al., 2004). Although there is no consensus on this issue, dual language reading experience is different and more demanding since readers not only read but also are required to search for unknown word meanings while reading. Hence, it can be assumed that more complex structures, such as multiple columns, are more prone to make fewer L2 vocabulary gains. In light of the findings, the preference of the DP format may suggest that more thoughtfully sequenced and spatially separated formats provide both cognitive benefits and more equitable treatment of both languages, thanks to better organization, reduced distraction, and a spatially separated format that facilitates tracking the words or phrases in the dual texts. On the other hand, the increased stress, visual complexity of the reading text, and cognitive load experienced by participants in the SP and ST formats can be somehow attributed to the less supportive design of these layouts in terms of L2 vocabulary gains, which arguably fail to create a balanced or user-friendly bilingual reading experience.

5. Limitations & Further Research

While this study provides valuable insights on the importance of page layout of DLBs, there are some limitations that should be acknowledged. First, the analysis is limited to a selected sample of bilingual materials, and so the findings may not be generalizable to all DLBs produced in different contexts and designs. Second, the study focuses on the visual and spatial organization of target language and source language content, rather than examining learners' interaction with these layouts. Thirdly, potential contextual factors such as learners' language levels and their prior exposure to DLBs are not considered.

Relatedly, further research can include larger scale studies with more participants and readers from diverse age range and this can enhance the generalizability of the findings. Additionally, future research may explore the effect of the page layout of DLBs not only in vocabulary learning, but also in grammatical, discourse, or some other linguistic areas acroos two languages. Finally, designing a systematic framework for DLB layout can contribute to more effective and pedagogically informed material development for different targeted readers.

6. Conclusions and Pedagogical Implications

This study aimed to examine the effects of three distinct DLB layouts, namely SP, ST, and DP, on learners' reading performance and vocabulary retention by using eye tracking and semi-structured interviews. The findings suggested that layout showed an effect on L2 reading experience regarding eye movement measures. While the DP layout was found most reader-friendly with its familiar nature along with less fixations, SP was associated with increased distraction, higher cognitive load and fragmented concentration with higher fixation values. Despite the reading processing differences, the layout type had no effect on L2 vocabulary gains. To sum up, the study emphasized the role of layout choices of DLBs and demonstrated how the layout of this style of books affects learners' cognitive processing when reading dual text and vocabulary retention given in a dual language context.

Since DLBs are popular both for self-paced L2 study and classroom practice, enabling L2 learners to compare two languages, publishers may want to consider adopting the DP layout for a better L2 reading experience. Moreover, for a more concentrated reading, we also recommend readers to opt for DLB sources with DP layout to eliminate distraction and cognitive load. If the resources are to be made available for sale in digital format such as e-book, presenting them in a DP may also be effective. Assigning multiple columns on a single page may have some advantages regarding cost and marketing issues for publishers; however, our results do not advise such a practice since L2 learners may find it unfamiliar, compressed, and cognitively demanding.

Declarations

Compliance with Ethical Standards

Disclosure of Potential Conflicts of Interest:

The authors have no conflicts of interest, financial or non-financial, that could have appeared to influence the work reported in this paper.

Research involving Human Participants:

In this research, human participants were involved. Ethical standards of institutional, national research committee and 1964 Helsinki declaration and its later amendments were followed in all procedures performed on studies involving human participants.

Informed Consent:

All individual participants included in the study gave informed consent. Detailed information about aims of the research, procedures concerned and participant's rights including the right of withdrawal from the study at any point without any consequence was supplied to each participant.

Ethics approval and consent to participate:

This research was conducted in compliance with ethical standards for research involving human participants. All research procedures were carried out in accordance with relevant institutional and national ethical guidelines and regulations. The confidentiality of participants was upheld throughout the research process, and all data were anonymized to protect their identities. This study wasapproved by the Bayburt University Social and Human Sciences Scientific Research Ethics Committee (Meeting Date: 12/12/2024, Decision No: E- 79126184-050.99245466) and adheres to all ethical standards for research involving human participants. Relatedly, we confirm that scientific ethical approval for this study was obtained from Bayburt University, Turkiye, where the study was also conducted.

Consent for publication

We, Dr. (First Author), Dr. (Second Author), and Dr. (Third Author), the authors of the manuscript titled " ***The Effect of Dual Language Book Page Layout on L2 Vocabulary Gains: An Eye Tracking Study***", hereby provide our consent for the publication of the manuscript in the journal '*Plos One*'.

Availability of data and materials

The data supporting the findings of this study are not publicly available due to ethical and privacy considerations, as the dataset contains information that could potentially compromise participant confidentiality.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contribution

E.D.: Conceptualization, methodology, validation, data collection, formal analysis, data curation, writing—original draft preparation, project administration.F.K.: Literature review, investigation, resources, writing—

original draft preparation, writing—review and editing.İ.S.: Data collection, formal analysis, data curation.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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