Journal of Theoretical Educational Science, 17(3), 592-615, July 2024
Kuramsal Eğitimbilim Dergisi, 17(3), 592-615, Temmuz 2024
[Online]: http://dergipark.org.tr/akukeg
DOI number: http://doi.org/10.30831/akukeg.1386249

The Role of Word Decoding Speed and Accuracy on Reading Comprehension in a Highly Transparent and Morphologically Complex Orthography

Sözcük Çözümleme Hızı ve Doğruluğunun Saydam ve Morfolojik Olarak Karmaşık Ortografideki Okuduğunu Anlama Üzerindeki Rolü

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Received: 5 November 2023 **Research Article** **Accepted:** 15 April 2024

ABSTRACT: This research aimed to investigate the impact of word decoding speed and accuracy on reading comprehension in Turkish, which is characterized by a highly transparent and morphologically complex orthographic system. The study involved 160 students, half of whom were identified as poor readers, while the other half were classified as good readers. These participants were selected from the second and fourth grades of public elementary schools. The assessment process involved evaluating participants' isolated word decoding skills using a task that measured their ability to decode both real words and pseudowords. Additionally, reading fluency and comprehension were measured using grade-level appropriate reading texts. The analysis included a series of MANOVAs as well as a mediation model (Model 7) employing Haye's PROCESS macro for SPSS. The findings indicated that the poor readers' limited reading comprehension abilities were primarily attributed to their overall deficiency in word decoding fluency, with a particular emphasis on their inadequate phonological decoding skills. These results are significant as they shed light on the challenges that children with reading comprehension difficulties may face in transparent orthographic systems. The attainment of proficient reading comprehension in such languages appears to be influenced by the specific aspects of word decoding fluency.

Keywords: Word decoding, reading fluency, reading comprehension, orthography, mediation model.

ÖZ: Bu araştırmanın amacı, oldukça saydam ve morfolojik olarak karmaşık bir ortografi sistemine sahip olan Türkçe'de kelime çözümleme hızı ve doğruluğunun okuduğunu anlama üzerindeki etkisini incelemektir. Çalışmaya, yarısı zayıf okuyucu, diğer yarısı ise iyi okuyucu olarak sınıflandırılan 160 öğrenci katılmıştır. Bu katılımcılar devlet ilkokullarının ikinci ve dördüncü sınıflarından seçilmiştir. Değerlendirme süreci, katılımcıların hem gerçek sözcükleri hem de sahte sözcükleri çözümleme becerilerini ölçen bir görev kullanarak sözcük çözümleme becerilerini değerlendirmeyi içermektedir. Ek olarak, okuma akıcılığı ve anlama, sınıf seviyesine uygun okuma metinleri kullanılarak ölçülmüştür. Analiz, bir dizi MANOVA'nın yanı sıra Haye'nin SPSS için PROCESS makrosunu kullanan bir aracılık modelini (Model 7) içermektedir. Bulgular, zayıf okuyucuların sınırlı okuduğunu anlama becerilerinin öncelikle sözcük çözümleme akıcılığındaki genel eksikliklerine atfedildiğini ve özellikle yetersiz fonolojik çözümleme becerilerine vurgu yapıldığını göstermiştir. Bu sonuçlar, okuduğunu anlama güçlüğü çeken çocukların saydam ortografik sistemlerde karşılaşabilecekleri zorluklara ışık tutması açısından önemlidir. Bu tür dillerde yeterli okuduğunu anlama becerisinin kazanılması, sözcük çözümleme akıcılığının belirli yönlerinden etkileniyor gibi görünmektedir.

Anahtar kelimeler: Sözcük çözümleme, okuma akıcılığı, okuduğunu anlama, ortografi, aracılık modeli.

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Citation Information
Kargın, T., Güldenoğlu, B., Gengeç, H., & Alatlı, R. (2024). The role of word decoding speed and accuracy on reading comprehension in a highly transparent and morphologically complex orthography. *Kuramsal Eğitimbilim Dergisi [Journal of Theoretical Educational Science], 17*(3), 592-615.

ISSN: 1308-1659

Reading is a multifaceted process that involves various cognitive and linguistic abilities (Tunmer, 2008). The Simple View of Reading (SVR-Gough & Tunmer, 1986) posits that reading comprehension relies on two essential components: decoding and oral language comprehension. Decoding, a crucial aspect of reading instruction, encompasses two dimensions: accuracy and fluency. Accuracy pertains to the ability to correctly produce the phonological representation of each word, while fluency concerns the speed of decoding. Extensive research emphasizes that the majority of young or inexperienced readers struggle primarily with word decoding speed and accuracy, which leads to significant difficulties in reading, including poor comprehension (e.g. Cutting & Scarborough, 2006; Kim et al.,2010; Price et al., 2016). These deficits can be attributed to insufficient grapheme-to-phoneme conversions or limitations in fluency, which refers to the inability to decode written materials at an appropriate pace.

The development of fluent decoding skills plays a vital role in the reading process. As decoding becomes automatic and more accurate, readers can allocate their cognitive resources toward understanding the meaning of the text (Fuchs et al., 2001; Wolf & Katzir-Cohen, 2001). Fuchs et al. (2001) emphasized the significance of word decoding fluency for proficient reading and suggested that instruction focused on fluency holds promise for enhancing the reading comprehension abilities of struggling readers. Overall, existing literature consistently agrees that fluent and automatic word decoding is a crucial factor in achieving reading comprehension. Various studies conducted in different orthographic systems have reported moderate to strong positive correlations between word decoding fluency and comprehension (e.g., Fernandes et al., 2017; Kim et al., 2014; Kuhn et al., 2010; Vaknin Nusbaum et al., 2020). For instance, a recent study investigating Hebrew found that reading fluency, assessed in terms of both speed and accuracy (excluding prosody), significantly related to the reading comprehension skills of second-grade students (Vaknin Nusbaum et al., 2020). Similarly, a study focusing on English-speaking students demonstrated a bidirectional positive relationship between word decoding fluency and reading comprehension skills (Klauda & Guthrie, 2008). Additionally, research conducted in a moderately deep orthography, Portuguese, indicated that efficiency in word decoding is foundational for the development of reading fluency (i.e., fast and accurate reading) and significantly contributes to reading comprehension (Fernandes et al., 2017). In a recent study conducted in Turkish, a highly transparent orthography, Turna and Guldenoglu (2019) investigated the phonological decoding and reading fluency of Turkish students across different grade levels (first, fourth, and eighth). They found a significant relationship between word decoding speed and accuracy and reading fluency, with deficits in this domain negatively impacting reading fluency across all grade levels. Taken together, these findings suggest that word decoding speed and accuracy are critical components of reading across orthographic systems, as they are closely associated with reading outcomes such as fluency and comprehension.

Various cognitive models have been developed to explain word decoding development, looking at the mechanistic routes by which efficient decoding is achieved (Coltheart, 2005; Frost 1998, 2006; Goswami &Ziegler, 2006; Ramus et al., 2003; Ziegler & Goswami, 2005). A widely accepted model for the principles of the word decoding mechanism is the Dual Route Cascaded (DRC) reading model (Coltheart, 2005; Coltheart et al., 2001). DRC assumes there are two distinct routes to get from a

primitive alphabetic-phonological stage to a more advanced orthographical one to decode words. The first is a phonological or non-lexical route that focuses on grapheme-to-phoneme conversions through phonological analysis, and the second route is known as the orthographical or lexical route, which involves the direct retrieval of written word forms from the reader's orthographic lexicon (Coltheart, 2005).The basic assumption of DRC is that the phonological route, mapping letters onto sounds, is the initial and causal mechanism of the word decoding procedure; it enables beginning readers to decode and blend sub-lexical parts of written words to build orthographic representations in their mental lexicons (Share, 2011). In this model, the orthographic route is often conceptualized in terms of automaticity (fluency) because it is rapid and requires minimal effort. As the automaticity approach also argues, an increased use of this route eventually increases the speed of decoding and allows the attention once required for the task of word decoding to be devoted to reading comprehension.

The Role of Orthographic Transparency in Reading

Extensive research has established that the orthographic transparency of a language significantly influences word decoding speed and accuracy (Seymour et al., 2003; Ziegler et al., 2010). Alphabetic orthographies vary widely in terms of the consistency of their grapheme-to-phoneme mappings. English, with its inconsistent grapheme-phoneme conversions, represents one end of the spectrum, while Turkish, characterized by perfect correspondence between graphemes and phonemes, exemplifies the other extreme. Seymour et al. (2003) conducted a study to illustrate these differences among orthographic systems. They developed a set of simple real words and non-words and administered them to first-grade students from 14 European countries. Readers of orthographically consistent languages (e.g., Greek, Finnish, German, Italian, Spanish) performed strongly in both real word and non-word reading, while English readers fared significantly worse, reflecting the inconsistency of the English language. Another cross-linguistic study comparing word decoding in English and Turkish yielded similar findings. Due to the orthographic transparency of the Turkish language, Turkish children demonstrated faster and more accurate word decoding skills than their English counterparts by the end of the first grade (Durgunoglu & Oney, 1999). These results underscore the impact of the orthographic characteristics of a language on word decoding speed and accuracy.

Turkish stands out as one of the few orthographic systems characterized by highly symmetric transparency in grapheme-to-phoneme conversions (Babayigit & Stainthorp, 2011; Durgunoglu, 2006; Durgunoglu & Oney, 1999, 2002; Oney & Goldman, 1984; Raman, 2006). The regular orthography of Turkish consistently produces one-to-one relationships between graphemes and their corresponding phonemes. Notably, a letter in the Turkish alphabet generally maintains the same pronunciation across all the words in which it appears (Babayigit & Stainthorp, 2010; Oney & Durgunoglu, 1997; Raman, 2006). However, it is important to recognize that while Turkish exhibits high orthographic transparency, it is also a morphologically complex agglutinative language, distinguishing it from other transparent languages such as German, Dutch, and Finnish. Turkish commonly employs suffixation, resulting in the formation of long words through the combination of numerous suffixes. This morphological complexity, with its iterative loops, allows for the potential creation of

words of infinite length through various combinations of suffixes. This intricate word formation process can impede the decoding process for readers, particularly those who are less experienced, and hinder their fluency in accessing decoded words from their orthographic lexicon. One can argue that this particular attribute of the Turkish language adds complexity to the word decoding process in reading, emphasizing the significance of proficient decoding abilities in facilitating reading comprehension.

In conclusion, the significance of word decoding speed and accuracy for reading comprehension may vary in highly transparent yet morphologically complex languages like Turkish compared to opaque languages like English. However, most studies have primarily focused on English-speaking children, and there is limited evidence from transparent orthographies. This restricts the generalizability of the findings, given that English possesses one of the most-opaque orthographic systems. Furthermore, the existing research on the association between word decoding speed and accuracy and reading comprehension in a language with unique linguistic characteristics, such as Turkish, has yielded inconclusive results. Since the relative importance of word decoding speed and accuracy may differ in impacting reading comprehension, it is important to investigate the relationship specifically in highly transparent orthographies that represent morphologically complex agglutinative languages like Turkish.

The Present Study

The objective of this research was to investigate the impact of word decoding speed and accuracy on reading comprehension in Turkish, an orthography characterized by high transparency and morphological complexity. The study aimed to provide valuable insights into the factors that contribute to reading comprehension difficulties in transparent orthographies in general, and to shed light on the relationship between word decoding speed and accuracy and reading comprehension in a highly transparent and morphologically complex orthography specifically. When the literature is examined, it is observed that there are studies investigating the relationship between word decoding speed and reading comprehension (Aytaç, 2017; Keskin, Baştuğ & Akyol, 2013; Baştuğ & Keskin, 2012; Güldenoğlu, Kargın & Miller, 2012; Kargın, Güldenoğlu, & Alatlı, 2023), as well as studies examining the relationship between word reading accuracy and reading comprehension (Arabacı, 2022; Güldenoğlu, et al., 2012). However, a study comparing the impact of word decoding speed and accuracy on reading comprehension between students with good and poor performance in reading could not be found. The study differs from other studies in the literature in that it examines the mediating effect of word reading speed and accuracy on reading comprehension.

Research Questions

1. Do deficiencies in word decoding speed and accuracy have a substantial association with the inability to comprehend text effectively in Turkish?

2. How are word decoding speed and accuracy related to reading comprehension in Turkish, a language characterized by high transparency and morphological complexity?

Method

This study, which aims to examine the mediating effect of word decoding speed and accuracy on reading comprehension of good and poor readers attending the 2nd and 4th grades, is in the relational screening model. Relational screening model is a screening approach that aims to determine the existence of co-variation between two or more variables. In the relational screening model, whether the variables change together or not; If there is a change, it is tried to determine how it happened (Karasar, 2006).

Participants

The participants consisted of 160 students (80of them were poor readers, 80 were good ones) recruited from the second and fourth grades in public elementary schools in Turkey (Table 1). The two samples were balanced with respect to grade levels and gender distribution. The participants in both samples came from socio-economically disadvantaged backgrounds and were enrolled in regular education classrooms. According to their school files:(a) poor readers consisted of students with lower reading comprehension performance in their classes, while good ones were average; (b) all participants included in the study were individuals who spoke Turkish as their native language, had normal vision or corrected-to-normal vision, and did not have any diagnosed cognitive disabilities (hearing impairments, intellectual disabilities, visual impairments, etc.); (c) good readers were educated in the same class as poor ones. In determining the participants, 2nd and 4th grade reading comprehension texts included in the Reading Skills Assessment Battery (RSAT) developed by Alatlı et all. (2022) were used.

Table 1

Demographic Distribution of Participants Based on Reader Profile, Gender, and Grade Level

Reader Profile	**Grade 2**		**Grade 4**		**Total**
	M	F	M	F	
Poor readers	23	17	26	14	80
Good readers	16	24	15	25	80
Total	39	41	41	39	160

To check the participants' reading profiles, we applied a reading comprehension assessment with grade level matched reading texts and multiple choice questions related to the texts (for details, see Measurements). We ran an ANOVA, with reader profile (poor readers (PR), good readers (TD)) and grade level (second and fourth grades) as between-subject factors. Results appear in Table 2.

Table 2

Means and Standard Deviations in Reading Comprehension Considering Reader Profile and Educational Level

Grade Level	PR	TD	Total
Grade 2	3.10 (1.31)	4.85 (.86)	3.97 (1.41)
Grade 4	3.42 (.98)	4.85 (.76)	4.13 (1.13)
All	3.26 (1.16)	4.85 (.81)	4.05 (1.27)

Note.(Maximum accuracy score= 6, PR : Poor readers, TD: Good readers)

The group comparison yielded a highly significant between-group effect, with TD readers demonstrating significantly higher reading comprehension rates compared to their poor reader counterparts ($F(1,159) = 99.79$, $p < .01$, $\eta 2 = .39$). The main effect of grade level was found to be statistically non-significant ($F(1,159) = 1.04$, $p > .05$, $\eta 2 = .00$), indicating that overall grade level did not have a significant impact on the classification of individuals as good or poor readers. Additionally, the interaction between grade level and reader profile was not statistically significant ($F(1,159) = 1.04$, $p > .05$, $\eta 2 = .00$), indicating that the reading comprehension differences between the two grade levels were similar for both groups (see Table 2).

Measurements

Isolated Word Decoding

We tested isolated word decoding performance using participants' reaction time and accuracy in an isolated word (a single word without a suffix) decoding task, with two different word statuses (real word and pseudoword). This task included 84 words (half were real words and the other half pseudowords) developed in a way that conformed to the Turkish language spelling rules and commonly used syllable structures (V, V+C, C+V, C+V+C, V+C+C, C+V+C+C), with one to four syllables. First, we determined if the real words were familiar to all participants. To test this issue, participants' teachers were asked to evaluate the relevance of the selected words to their students' level. They verified that each word used in the study fell within the active vocabulary of the youngest participants. Subsequently, they rearranged the letters of the real words to create pseudowords (e.g., the letters of “eldiven" (a real word) were displaced and “denilev” (a pseudoword/nonword) was created). We made sure the words were grammatically correct but had no meaning or use.

During the application of the paradigm, participants were asked to read aloud the words presented on a computer screen within five seconds. The items were presented one by one; if students gave no response within five seconds, the computer automatically passed to another word. We used D-MASTR software (http://www.u.arizona.edu/~kforster/dmastr/dmastr.htm)to present stimuli and collect data. This software is a computer-based application that enables the precise measurement of response latencies within the millisecond range. It records these latencies along with response accuracy, facilitating subsequent analysis.

Reading Fluency

The reading fluency of participants was calculated by the number of correct words read per minute (the formula of [total number of words read correctly X 60 / reading time (in seconds)]) from a grade level matched text. We used two narrative texts (one for second and the other for fourth graders). The texts used to determine the reading fluency of both 2nd grade and 4th grade participants are included in RSAT (Alatlı et al., 2022). The second-grade level text consists of 118 words and 14 sentences. The readability value is 57 (medium). The 4th grade level text consists of 267 words and 23 sentences. The readability value is 50 (medium).

Reading Comprehension

Reading comprehension was evaluated by the number of total correct responses to the multiple-choice questions on the text used to test reading fluency. Each text was accompanied by six multiple-choice questions (literal understanding (2 questions); reorganization (1); inference (1); prediction (1); evaluation (1); Day & Park, 2005) with one correct answer for each question. We performed an item analysis of the text questions and found the difficulty levels were average and the discrimination level was high.

Reliability

The reliability of the measurements was determined by Kuder Richardson (KR20) for word decoding and Cronbach Alpha reliability coefficient calculations for reading fluency and test-retest procedure for reading comprehension. To determine the reliability of the isolated word decoding task, we calculated the Kuder–Richardson Formula 20 (KR-20) on the basis of the grade levels; the results were.78 and .82 for the second and fourth grades, respectively. For reading fluency, we calculated the Cronbach Alpha coefficients and found .95 and .97 in each grade respectively. For the reliability analysis of the text questions, we applied the test-retest technique to 30 students in each grade with similar characteristics to our participants; the correlations between the two comprehension measurements were .80 and .70 for the second and fourth grade, respectively.

Procedure

Data were gathered during individual assessment sessions conducted in suitable settings within participants' schools. Prior to each session, participants received detailed information about the study's content, objectives, and procedures. The assessments were exclusively administered to participants who volunteered to take part. The duration of each session ranged from 25 to 30 minutes.

A standardized procedure was implemented across all assessment sessions, commencing with word decoding tasks and subsequently transitioning to text reading activities. Throughout the sessions, participants were instructed to read aloud, enabling the experimenter to record their audio. Upon completion of the applications, the total number of words read per minute was calculated for each participant using the appropriate formula. Following the completion of all independent tasks, the testing session concluded, and participants were expressively acknowledged for their participation.

Ethical Procedures

Participant recruitment adhered to the ethical guidelines outlined by the Turkish Academy of Sciences regarding research involving human subjects. This research was conducted with the permission of the ethics committee of Hasan Kalyoncu University, with the decision dated 20/07/2017.

Role of Researchers

In this study, where the relational screening method, one of the quantitative research methods, was used, the researchers have a doctorate degree in special education and have conducted research in the field of reading difficulties. Within the scope of this study, the role of researchers is limited to collecting data that can be expressed numerically using standardized measurement tools and explaining the results by analyzing these data statistically (Yıldırım & Şimşek, 2005; Walliman, 2017).

Results

Isolated Word Decoding

To examine the isolated word decoding abilities of the two groups, two multivariate analyses of variance (MANOVAs) were conducted. One MANOVA utilized reaction times (RT) as the dependent variable, while the other utilized decoding accuracy (accuracy rate). Both analyses incorporated the reader profile (poor readers (PR) and good readers (TD)) and grade level (second and fourth grades) as between-subject factors, and word status (WS) (real words and pseudowords) as a within-subject factor. The outcomes of these analyses are presented in Table 3 and visualized in Figures 1 and 2.

Reaction Time

The analysis revealed a significant effect of word status (WS) ($F(1,156) = 605.06$, $p < .01$, $\eta 2 = .79$), indicating that participants demonstrated faster decoding times for real words compared to pseudowords. Furthermore, there was a significant main effect of reader profile ($F(1,156) = 145.48$, $p < .01$, $\eta 2 = .48$), indicating that overall, TD readers exhibited faster word decoding abilities compared to their PR peers. Additionally, the main effect of grade level was statistically significant ($F(1,156) = 37.93$, $p < .01$, $\eta 2 = .19$), indicating that fourth graders demonstrated significantly faster word decoding times compared to second graders (see Table 3).

The observed significant interaction between grade level and reader profile ($F(1,156) = 5.54$, $p < .01$, $\eta 2 = .03$) indicated that the variations in word decoding speed between the two grade levels were not consistent for each group. To further elucidate this interaction, two separate ANOVAs were conducted, with word decoding speed as the dependent variable and grade level as the between-subject factor for each reader group. The analysis revealed a significant difference between the two groups in both the second and fourth grades ($p < .01$), but the disparities in word decoding speed between the two grade levels were more pronounced among PR participants compared to TD participants.

Table 3

Means and Standard Deviations in Word Decoding Considering Reader Profile and Educational Level

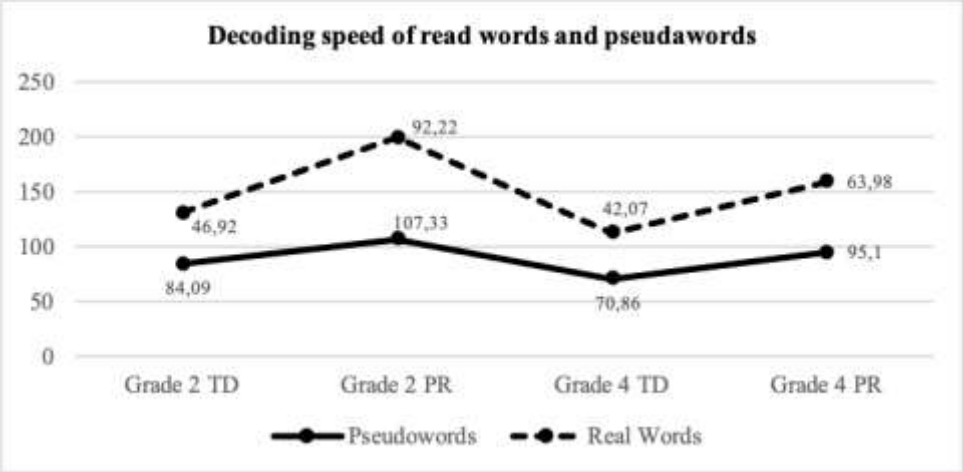
	Real words					
Grade Level	**Reaction Times**			**Accuracy Rates**		
	PR	**TD**	**Total**	**PR**	**TD**	**Total**
Grade 2	92.22 (27.71)	46.92 (9.99)	69.57 (30.79)	32.50 (9.28)	41.92 (.26)	37.21 (8.06)
Grade 4	63.98 (16.20)	42.07 (9.94)	53.02 (17.32)	41.12 (1.11)	41.92 (.47)	41.52 (.94)
All	78.10 (26.66)	44.49 (10.20)	61.30 (26.25)	36.81 (7.87)	41.92 (.38)	39.36 (6.11)
	Pseudowords					
Grade Level	**Reaction Times**			**Accuracy Rates**		
	PR	**TD**	**Total**	**PR**	**TD**	**Total**
Grade 2	107.33 (20.17)	84.09 (13.01)	95.71 (20.52)	22.42 (9.35)	39.27 (1.73)	30.85(10.79)
Grade 4	95.10 (14.51)	70.86 (14.39)	82.98 (18.84)	31.37 (6.31)	39.72 (2.51)	35.55 (6.36)
All	101.21 (18.51)	77.47 (15.17)	89.34 (20.65)	26.90 (9.12)	39.50 (2.15)	33.20 (9.14)
	Overall					
Grade Level	**Reaction Times**			**Accuracy Rates**		
	PR	**TD**	**Total**	**PR**	**TD**	**Total**
Grade 2	99.77 (22.48)	65.50 (10.11)	82.64 (24.44)	27.46 (8.74)	40.60 (.90)	34.03 (9.04)
Grade 4	79.54 (13.60)	56.46 (10.54)	68.00 (16.76)	36.25 (3.37)	40.82 (1.38)	38.53 (3.44)
All	89.66 (21.08)	60.98 (11.22)	75.32 (22.14)	31.85 (7.93)	40.71 (1.17)	36.28 (7.18)
	Word Status Effect					
Grade Level	**Reaction Times**			**Accuracy Rates**		
	PR	**TD**	**Total**	**PR**	**TD**	**Total**
Grade 2	15.10 (18.13)	37.17 (11.36)	26.13 (18.69)	10.07 (6.45)	2.65 (1.70)	6.36 (5.99)
Grade 4	31.11 (14.35)	28.9 (12.95)	29.95 (13.63)	9.75 (6.06)	2.20 (2.31)	5.97 (5.93)
All	23.11 (18.13)	32.98 (12.82)	28.04 (16.42)	9.91 (6.22)	2.42 (2.03)	6.16 (5.94)

Note. (RTs in seconds, Maximum accuracy score= 42 PR : Poor readers, TD: Good readers)

The analysis revealed a significant interaction between the word status (WS) effect and reader profile ($F(1,156) = 18.78$, $p < .01$, $\eta 2 = .10$), indicating that the reaction time differences related to word status were comparable for both reader groups. However, as presented in Table 3, the reaction time differences were more pronounced for TD readers compared to PR readers. The interaction between the WS effect and grade level was not statistically significant ($F(1,156) = 2.79$, $p > .05$, $\eta 2 = .01$), suggesting that the differences in word decoding speed between real words and pseudowords were similar across each grade level. Lastly, the three-way interaction between the WS effect, reader profile, and grade level was not statistically significant ($F(1,82) = .28$, $p > .05$, $\eta 2 = .00$), indicating that the reaction time differences resulting from word status disparities were not uniform for second and fourth graders (see Figure 1).

Figure 1

Reaction Time Means in Real Word and Pseudoword Decoding across Reader Profiles and Educational Levels



Accuracy

The analysis revealed a significant effect of word status (WS) ($F(1,156) = 281.19$, $p < .01$, $\eta 2 = .64$), indicating that participants demonstrated higher accuracy in decoding real words compared to pseudowords. Additionally, there was a significant main effect of reader profile ($F(1,156) = 138.48$, $p < .01$, $\eta 2 = .47$), suggesting that overall, TD readers exhibited greater accuracy in decoding words compared to PR readers. Furthermore, the main effect of grade level was statistically significant ($F(1,156) = 35.85$, $p < .01$, $\eta 2 = .18$), indicating that fourth graders demonstrated higher accuracy in decoding words compared to second graders (see Table 3).

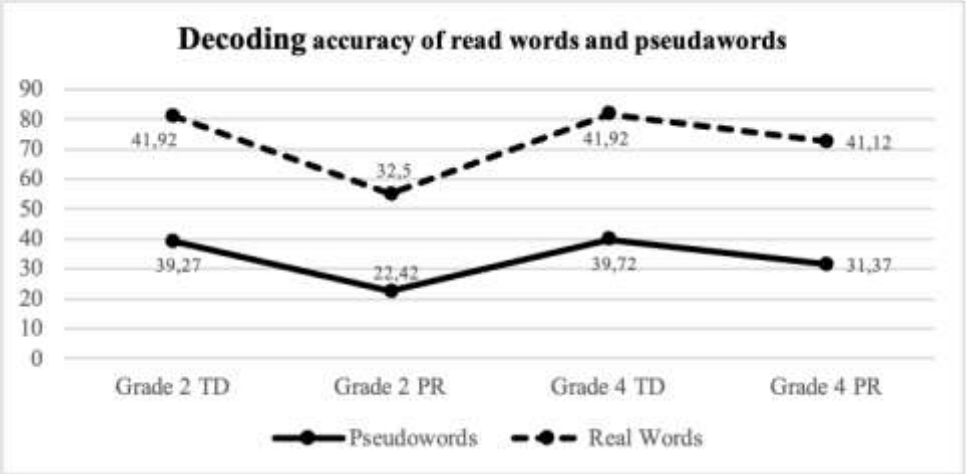
The observed significant interaction between grade level and reader profile ($F(1,156) = 32.36$, $p < .01$, $\eta 2 = .17$) indicated that the differences in word decoding accuracy between the two grade levels were not consistent for each group. To further elucidate this interaction, two separate ANOVAs were conducted, with word decoding accuracy as the dependent variable and grade level as the between-subject factor for each reader group. The analysis revealed a statistically significant difference between PRs in the second and fourth grades ($F(1,79) = 35.15$, $p < .01$), indicating a notable variation in word decoding accuracy. However, a similar difference did not emerge for

TDs (F(1,79) = .73, p > .05), suggesting a lack of significant variation in word decoding accuracy between the two grade levels within this group.

A significant interaction was observed between the word status (WS) effect and reader profile (F(1,156) = 103.56, p < .01, η2 = .39), indicating that the differences in accuracy rates for word decoding related to word status were comparable for both reader groups. The interaction between the WS effect and grade level was not statistically significant (F(1,156) = .27, p > .05, η2 = .00), suggesting that the disparities in word decoding accuracy rates between real words and pseudowords were similar across each grade level. Finally, the three-way interaction between the WS effect, reader profile, and grade level was not statistically significant (F(1,156) = .00, p > .05, η2 = .00), implying that the differences in accuracy rates between the two participant groups resulting from word status variations were consistent for both second and fourth graders (see Figure 2).

Figure 2

Accuracy Means in Real Word and Pseudoword Decoding across Reader Profiles and Educational Levels



Reading Fluency

To assess the reading fluency performance of the reader groups, a General Linear Model (GLM) ANOVA was employed, utilizing reader profile (poor readers (PR) and good readers (TD)) and grade level (second and fourth grades) as between-subject factors. The results of this analysis can be seen in Table 4.

Table 4

Means and Standard Deviations in Reading Fluency Considering Reader Profile and Educational Level

Number of words read per minute			
Grade Level	**PR**	**TD**	**Total**
Grade 2	43.74 (22.81)	108.31 (13.90)	76.02 (37.52)
Grade 4	62.41 (16.70)	110.00 (8.47)	86.21 (27.32)

All	53.07 (21.97)	109.15 (11.47)	81.11 (33.11)

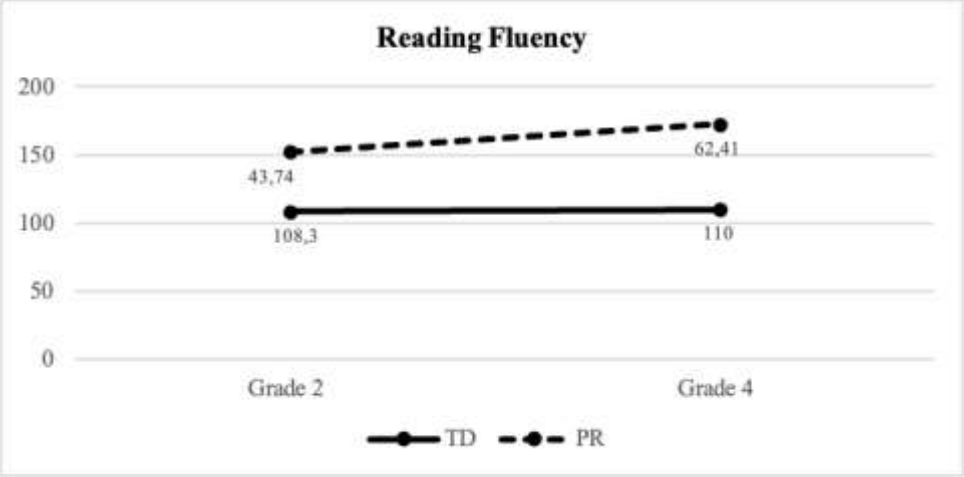
Note. (PR : Poor readers, TD: Good readers)

The main effect of reader profile was found to be statistically significant ($F(1,159) = 472.50$, $p < .01$, $\eta 2 = .75$), indicating that PR participants exhibited lower reading fluency rates compared to their TD peers. Additionally, the main effect of grade level was also statistically significant ($F(1,159) = 15.58$, $p < .01$, $\eta 2 = .09$), suggesting that fourth graders demonstrated higher reading fluency rates than third graders (see Table 4).

The observed significant interaction between grade level and reader profile ($F(1,159) = 10.83$, $p < .01$, $\eta 2 = .06$) indicated that the differences in fluency rates between the two grade levels were not consistent for each group. To further elucidate this interaction, two separate ANOVAs were conducted, with reading fluency as the dependent variable and grade level as the between-subject factor for each reader group. The analysis revealed a statistically significant difference between second- and fourth-grade PRs ($F(1,79) = 17.46$, $p < .01$), suggesting notable variations in reading fluency rates. However, a similar difference did not emerge between second- and fourth-grade TDs ($F(1,79) = .43$, $p > .05$), indicating a lack of significant variation in reading fluency rates between the two grade levels within this group (see Figure 3).

Figure 3

Means of Reading Fluency across Reader Profiles and Educational Levels

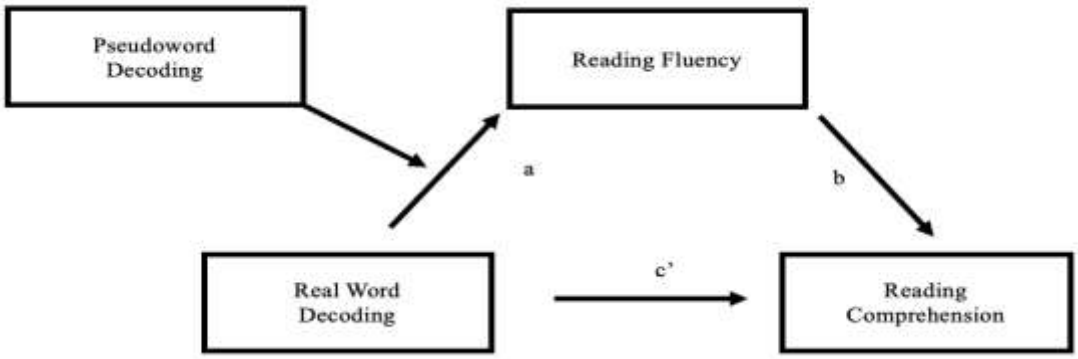


Relationship Between Word Decoding Fluency and Reading Comprehension

To clarify the relationship between word decoding fluency and reading comprehension in a highly transparent orthography, we tested the theoretical framework using a moderated mediation model (Figure 4).

Figure 4

Theoretical Framework for Moderated Mediation Analysis



Before conducting the moderated mediation analysis, we tested the interrelations of the measured variables via Pearson correlation coefficients. Findings revealed positive and significant relationships between all measured variables (Table 5).

Table 5

Correlations Between Variables

Variables	**RWD**	**PWD**	**RF**	**RC**
Real word decoding (RWD)	-			
Pseudoword decoding (PWD)	.766**	-		
Reading fluency (RF)	.652**	.808**	-	
Reading comprehension (RC)	.445**	.584**	.631**	-

The mediating role of reading fluency in the theoretical framework was evaluated with the help of a mediation model (Model 7) using Haye's PROCESS macro for SPSS. This model allows the assessment of the mediation effect with multiple regressions in a single analysis (Hayes, 2018). Results are visualized in Figure 5 and summarized in Table 6.

Figure 5

Multiple Moderated Mediation Analysis (Model 7 by Hayes, 2018)

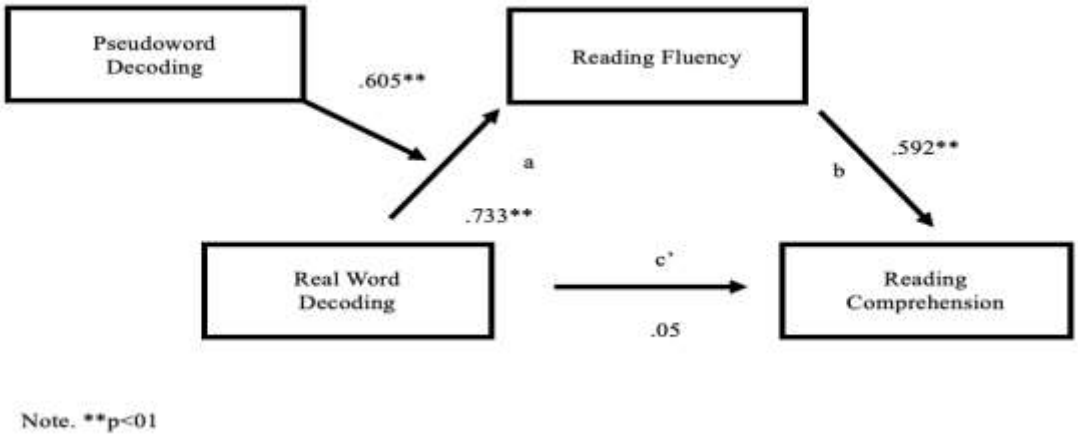


Table 6

Results for Moderated Mediation Analysis

	coeff	**se**	**t**	**p**	**LLCI**	**ULCI**
RWD on RF	.733	.176	4.150	.000	.384	1.082
PWD on RF	.605	.077	7.767	.000	.451	.759
Moderation of PWD	.287	.0714	4.025	.000	.146	.428
RF on RC	.592	.081	7.272	.000	.431	.753
RWD on RC	.058	.081	.714	.475	-.102	.219

Note. (LLCI = lower limit confidence interval; ULCI = upper limit confidence intervalRWD: real word decoding, PWD: pseudoword decoding, RF: reading fluency, RC: reading comprehension)

The direct effect of reading fluency on reading comprehension was also positive and significant (b=.592, s.e.=.081, p<.01), suggesting fluent readers were better comprehenders than non-fluent ones. Finally, when the mediator (reading fluency) was added to the model, a nonsignificant direct effect emerged for real word decoding on reading comprehension (b=.058, s.e.=.081, p>.01). Overall, this evidence suggests reading fluency fully mediates the relationship between phonological decoding and reading comprehension and supports pseudoword decoding as a moderator of the relationship between real word decoding and reading fluency (Table 6). In this model, we tested the mediation (indirect effect) using non-parametric bootstrapping. The lower and upper bound of the 95% confidence interval indicated that the indirect effect was statistically significant (Table 7). Finally, we tested the mediation effect using the Sobel test. Results were statistically significant (p<.01); reading fluency fully mediated the relationship between real word decoding and reading comprehension.

Table 7

Conditional Indirect Effects of Real Word Decoding on Reading Comprehension

Value group	**Effect**	**BootSE**	**BootLLCI**	**BootULCI**
Low	.264	.070	.139	.412
Medium	.434	.106	.250	.663
High	.598	.143	.353	.912
Index of moderated moderation				
Mediator	**Index**	**BootSE**	**BootLLCI**	**BootULCI**
Reading fluency	.170	.040	.104	.261

Note. (LLCI = lower level of confidence interval; ULCI = upper level of confidence interval.)

Discussion and Conclusion

This study aimed to investigate the impact of word decoding speed and accuracy on reading comprehension in Turkish, which possesses a highly transparent and morphologically complex orthography. To achieve this objective, a comparison was made between poor and good readers in a sample comprising second and fourth-grade students. Two tasks were utilized to evaluate word decoding speed and accuracy at both the isolated word and text levels. The isolated word decoding task focused on participants' ability to decode single real words and pseudowords, while the reading fluency task involved determining the number of words read correctly per minute in a grade-level reading text.

According to the Simple View of Reading (SVR - Tunmer & Greaney, 2010), reading comprehension relies on two key components: decoding and oral language comprehension. Decoding refers to the efficient extraction of meaning from printed text, encompassing accuracy and fluency in reading isolated words or nonwords (Lonigan et al., 2018). On the other hand, oral language comprehension involves understanding the linguistic aspects of written materials, such as vocabulary diversity, content, and linguistic structures (Tunmer & Chapman, 2012). These two dimensions are mutually dependent on successful reading, and achieving proficiency in both is crucial for the reading process. In this study, we tested the role of word decoding fluency in reading comprehension based on two research hypotheses by controlling the factors (e.g., vocabulary diversity and content; for details, see Measurements) affecting oral language comprehension.

Our initial hypothesis predicted that poor readers would demonstrate slower and less accurate performance in both isolated word decoding and reading fluency compared to their good reader counterparts. To test this hypothesis, we first evaluated the isolated word decoding abilities of all participants. The results revealed that poor readers exhibited significantly lower proficiency in isolated word decoding efficiency compared to the good readers. This pattern was also observed for decoding speed and accuracy. Consequently, our findings strongly support the first hypothesis, indicating a direct relationship between participants' performance in isolated word decoding speed and accuracy and their reading comprehension abilities.

Upon further examination of the analyses, it became evident that decoding the word stimulus took more time under the pseudoword condition. This observation suggests that participants employed distinct strategies to decode the words in the two experimental conditions. The extended reaction times observed in the pseudoword condition likely signify the engagement of phonological conversion processes in the absence of established orthographic representations. Because they were unknown sequences of letters for the readers, they had only one solution for decoding the pseudowords – to follow the phonological decoding route. However, when the word decoding reaction times are considered separately by group, we see each group took a different decoding route, especially in the decoding of real words. Specifically, the difference in word decoding speed for real words vs pseudowords with the same syllable structure and length in good readers suggested each grade level used different strategies for decoding each word category. Considering that they had only one way to decode the pseudowords, it is clear that the TD group decoded the real words using the orthographic route. This is an important finding; even the second graders had reached the orthographic decoding level when decoding the words. However, PRs were stuck on the phonological decoding route for both word statuses in the second grade; they reached the orthographic decoding level for real words only in the fourth grade but were still significantly slower than their TD peers. From these findings, at first glance, it seems PRs had some difficulties decoding words efficiently.

The results for word decoding speed only were not sufficient to determine isolated word decoding efficiency. Therefore, it was necessary to review them together with the results for the isolated word decoding accuracy. Results for accuracy rates suggested good readers were significantly more accurate (almost at the ceiling level) than PRs in all word categories. In contrast, the word decoding accuracy of PRs was as low as their word decoding speed. Taking the word decoding speed and accuracy results together, it seems PRs lacked a fundamental phonological decoding capacity. The main factor leading us to this conclusion was that PRs lagged significantly behind their TD peers in word decoding speed and accuracy in each grade level whenever they tried to use their phonological decoding skills.

In sum, findings on isolated word decoding speed and accuracy revealed that the word decoding capacity of readers was parallel to their reading comprehension. From this point of view, word decoding efficiency seemed to be a factor in reading comprehension. However, at this stage, the argument was a very preliminary one. For this reason, in the second analysis of the study, we examined the word decoding fluency in the context of the reading fluency performance of reader groups at the text level.

We tested reading fluency based on the number of correct words read per minute. Our findings revealed that having more skill in reading fluency had an impact on participants' reading comprehension skills. More specifically, regardless of the grade levels, good readers read approximately two times more correct words per minute than PRs. It is well established in the literature that efficient word decoding is one of the most important indicators of fluent reading, an important prerequisite for proper reading comprehension (Shaywitz & Shaywitz, 2005). From this perspective, the marked word decoding deficits in PRs may have caused them to perform much more poorly in reading comprehension. In addition, it should be noted that fluency needs to reach an acceptable level in order to contribute to reading comprehension; once the mechanics of

fluency (decoding speed and accuracy) reach a certain level of proficiency, they cease to constrain the comprehension processes (Babayiğit & Stainthorp, 2011; Vaknin-Nusbaum et al., 2020). Consider our PRs, although they increased their fluency rates by nearly 50 % from the second grade to the fourth grade, they were still only half as fluent as their good peers (see Figure 3), and the increase was not enough to contribute to their reading comprehension performance (see Table 2).

We should mention that the orthographical and morphological characteristics of Turkish may have influenced the participants' reading fluency results. As stated in the introduction, Turkish is an entirely shallow orthography. The consistency of grapheme-to-phoneme is perfect; readers only learn 29 correspondences and, in this way, they can decode all words. However, the most interesting aspect of Turkish is its morphological form, notably its agglutinative features. Turkish is characterized by a prevalent agglutinating structure, whereby word formation predominantly relies on suffixation. This linguistic feature leads to the generation of lengthy word forms in Turkish, which may pose challenges for decoding and hinder the transfer of the word into the reader's orthographic lexicon. Consequently, the complexity introduced by the agglutinating nature of Turkish compounds the decoding process and impedes its integration into the reader's existing orthographic knowledge. For this reason, even if they are experienced, in the course of fluent reading, readers frequently require the phonological route based on the process of converting graphemes to their corresponding phonemes. Although Turkish readers deal with an extremely transparent orthography, this situation reduces the reading fluency of those with poor phonological decoding skills, and this, in turn, negatively affects their reading comprehension performance. Thus, even if the entropy of letter to sound is minimum, fluent phonological decoding becomes denser. Nothing is arbitrary in Turkish orthography. The combination of extreme transparency and suffixation requires Turkish readers to have an optimal ratio of phonological decoding capacity to decode the written stimuli fluently.

An interesting question is how word decoding fluency and reading comprehension are affected by the relationship between the excessively agglutinative aspect of the Turkish language and the complete transparency of the orthographic system. Taking this point together with the previous results on isolated word decoding, the disadvantages of PRs in terms of reading fluency make more sense: their lower reading fluency and reading comprehension may have originated in their inefficient phonological word decoding fluency.

The general consensus in the reading literature is that success in reading comprehension depends on a reader’s ability to decode written words accurately and fluently (e.g., Garcia & Cain, 2014; Lonigan et al., 2018; Steensel et al., 2016; Tunmer, 2008; Tunmer & Hoover, 2019). Moreover, there is a reciprocal relationship between them, creating a “chicken and egg” situation, whereby better decoders comprehend the text better, and better comprehenders are more willing to read and thus increase their decoding efficiency. Recent research has also found that automaticity in word decoding has the largest share in reading comprehension performance (e.g., Alvarez-Canizo et al., 2020; Garcia & Cain, 2014; Vaknin-Nusbaum, et al., 2020; Roembke et al., 2019). Given these findings, to clarify the role of word decoding fluency in reading comprehension in a highly transparent orthography, our second hypothesis argued that

reading fluency would act as a bridge between isolated word decoding and reading comprehension.

The results of the regression analyses provided strong evidence supporting the significance of word decoding fluency as a predictor of reading comprehension in Turkish. Furthermore, reading fluency was found to fully mediate the relationship between isolated word decoding and reading comprehension, confirming our second hypothesis and highlighting the role of fluency as a bridge between decoding and comprehension levels. This finding aligns with previous research, which has consistently reported moderate to high positive correlations between word decoding fluency and comprehension in various studies (e.g.,Alvarez-Canizo et al., 2020; Vaknin-Nusbaum et al., 2020; Price et al.,2016; Roembke et al., 2019; Spear-Swerling, 2006; Stevens et al., 2017). The automaticity approach further supports this relationship, suggesting that as decoding fluency improves in terms of speed and accuracy, cognitive resources previously dedicated to decoding can be allocated to comprehension, leading to a more proficient understanding of the text. Importantly, our mediation analysis results align closely with the existing literature. It is worth noting the intriguing finding of the mediation role of phonological decoding, particularly in the context of pseudoword decoding, in real word decoding and reading fluency in Turkish, a highly transparent orthography known for its relatively straightforward phonological transformations. This finding suggests that the complex morphological structure of Turkish plays a crucial role in efficient word decoding, even in an orthography that is considered highly transparent.

Taking all the findings together, it seems the limited reading comprehension of PRs was due to their weakness in word decoding fluency in general and their impoverished phonological decoding abilities in particular. In summary, our findings indicate that word decoding fluency serves as a critical factor in reading fluency and ultimately contributes to reading comprehension, even in a highly transparent orthography like Turkish. This conclusion has implications for understanding the challenges faced by children with reading comprehension difficulties in transparent orthographies.

Based on the aforementioned perspectives, several practical implications can be drawn. Firstly, proficient phonological word decoding skills are crucial for reading comprehension, regardless of whether the orthography is transparent or opaque. Secondly, despite the comparatively easier and faster progress in decoding skills observed in transparent orthographies like Turkish, teachers should prioritize the development of word decoding fluency to enhance the reading comprehension abilities of students with reading difficulties. Thirdly, irrespective of the advantage offered by transparent orthographies, early implementation of a reading curriculum that emphasizes intensive phonological decoding knowledge would greatly benefit the long-term reading comprehension of students with reading difficulties in transparent orthographies.

The study acknowledged certain limitations. Firstly, its exploratory nature constrained the sample size to 160 elementary students, thereby limiting the generalizability of the findings. To enhance the validity and generalizability of the results, future research should aim to expand the sample size and adopt a longitudinal approach. Secondly, the study focused exclusively on the influence of word decoding

fluency on reading comprehension, neglecting other potential factors such as vocabulary, prosody, and cognitive abilities like working memory, rapid naming, and attention. It is recommended that future studies investigate the impacts of these factors across various levels of reading (e.g., word decoding, paragraph or text comprehension) to attain a comprehensive understanding of reading comprehension challenges and develop appropriate interventions.

Acknowledgements

This study was conducted as a component of a nationwide reading project funded by the Turkish Academy of Sciences (Project number: 117K976).

Statement of Responsibility

Therefore, we send an author contribution form to the authors, and authors are required to fill in this form. The form refers to a statement of responsibility in the manuscript that specifies the contribution of every author.

Conflicts of Interest

The authors declare no conflicts of interest to disclose in relation to this study.

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