OXFORD

Journal of Deaf Studies and Deaf Education, 2015, 147–162

doi:10.1093/deafed/enu044
Advance Access publication February 23, 2015
Empirical Manuscript

EMPIRICAL MANUSCRIPT

Deaf Native Signers Are Better Readers Than Nonnative Signers: Myth or Truth?

Paul Miller[*,1], Tevhide Kargin[2], Birkan Guldenoglu[2]

[1]University of Haifa and [2]University of Ankara

*Correspondence should be sent to Paul Miller, Faculty of Education, University of Haifa, Haifa 31905, Israel (e-mail: mpaul@construct.haifa.ac.il).

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

Abstract

The central aim of this study was to clarify whether sign language (SL) nativeness is a significant factor in determining prelingually deaf individuals' reading skills and whether its contribution is modified by the reader's orthographic background. A second aim was to elucidate similarities and differences between native and nonnative signers in processing written information at different processing levels in order to understand how SL nativeness sustains the reading process, if at all. Participants were 176 students with prelingual deafness recruited from two education levels (6th–7th graders and 9th–10th graders) and three orthographic backgrounds (Hebrew, German, and Turkish). Sixty-six students were native and the remainder nonnative signers. They were tested with a battery of eight experimental paradigms, each assessing their information processing skills in a specific reading-related or reading-unrelated domain. Findings corroborate SL nativeness enhancing the reading process in some regard. However, its contribution was not found to scaffold the structural processing of a written text to turn reading into a tool for learning. Rather, gains were restricted to facilitating processing written words from a perceptual to a conceptual level. Evidence suggests that compared with other determining factors, the contribution of SL nativeness to proficient reading may be rather marginal.

The ability to read fluently is undoubtedly key for proper adjustment to modern society, in which recent technological developments cause crucial information to be increasingly communicated in writing. Although reading is a highly complex skill requiring different types of knowledge and processing abilities (Frost, 2012; Moates, 2000; Vaughn & Linan-Thompson, 2004), most students succeed in mastering it in elementary school if adequately instructed. Yet the number of those who do not, unfortunately remains remarkably high (Catts, Compton, Tomblin, & Bridges, 2012; Fluss et al., 2008). This is particularly true for some populations where individuals with severe reading problems seem far to outnumber those without them.

Prelingually deaf individuals are an outstanding example of such a population. Research over the last 50 years on prelingually deaf individuals' reading comprehension (RC) and their mastery of other reading-related skills indeed suggests that the majority remain seriously underdeveloped in this regard, even after 12 years of formal schooling (Allen, 1986; Center for Assessment and Demographic Studies, 1993; Conrad, 1979; Gallaudet Research Institute, 2005; Holt, 1993; Holt, Traxler, & Allen, 1996; Miller, 2000, 2005a, 2010; Miller et al., 2012; Monreal & Hernandez, 2005; Padden & Hanson, 2000; Perfetti & Sandak, 2000; Traxler, 2000; Wauters, Van Bon, & Telling, 2006). This apparent failure is particularly puzzling given the notable progress in amplification technologies in this period, in conjunction with improved conceptualization of the reading process in general, and hypothesized causes underlying reading failure in particular. The failure of deaf education to convert such achievements into improved reading methods that successfully foster reading skills in such individuals should be a cause for great concern. It may indeed be possible that the wrong topics have been set by research and deaf education, and much crucial knowledge of the origins of their persistent reading deficits is still obscure (Luckner & Handley, 2008).

Received: August 20, 2014; **Revised:** October 17, 2014; **Accepted:** November 7, 2014

© The Author 2015. Published by Oxford University Press. All rights reserved. For Permissions, please e-mail: journals.permissions@oup.com.

The literature tends to highlight reading failure of the prelingually deaf; interestingly however, some evidence suggests that it may not be the necessary consequence of early profound hearing impairments: some prelingually deaf students eventually become highly competent in making sense of what they read. True, these are more the exception, yet the mere fact that they exist clearly indicates that prelingual deafness, per se, does not prevent individuals from becoming proficient readers (Conrad, 1979; Goldin-Meadow & Mayberry, 2001; Miller, 2010, 2013; Wauters, Van Bon, & Telling, 2006).

Undoubtedly, the above finding is encouraging, but regrettably, its underlying factors are far from satisfactorily understood. A clue may be findings that pinpoint deaf native signers as proportionally overrepresented among the more successful deaf readers (e.g., Chamberlain & Mayberry, 2000; Conrad, 1979; Goldin-Meadow & Mayberry, 2001; Meadow, 1968; Miller, 2010, 2013; Strong & Prinz, 1997). For example, evidence accruing from an international reading project testing 213 prelingually deaf signing students of different grade levels suggests that native signers are almost twice likely than nonnative signers to be among skilled deaf readers (Miller et al., 2012). Such superiority seems in line with a Linguistic Coding Differences Hypothesis (Sparks, Patton, & Ganschow, 2012), positing that high competency in sign language (SL)—the first language of the deaf—is expected to exert a positive influence on the acquisition and use of a second language, that is, spoken language. As written language represents spoken language, it is of course tempting to assign the advantage of native-signing deaf readers to the fact that they are likely to be more proficient signers as they grow up with a full-fledged SL and are in continuous interaction with competent SL models: their parents (e.g., Strong & Prinz, 1997). However, because some of the proficient deaf readers (e.g., Miller et al., 2012) were not native signers, such a straightforward conclusion may actually be an oversimplification.

But even if SL proficiency of native signers is indeed proven to promote this reading superiority, such evidence fails to disclose the level of processing at which SL proficiency contributes to better reading. Attempts systematically to trace the point at which native signers become distinct from nonnative signers in processing written text are strikingly absent from the literature. Nor is there sufficient understanding of whether differences between these two populations—if there are any—are restricted to the domain of reading or reflect variance at a more general cognitive ability level. The motivation of this study was to find this out.

RC is hypothesized to be the product of two central processes: word recognition (lexical processing level) and integration of the meaning of correctly recognized written words into a broader idea by means of partly rule-based knowledge (supra-lexical processing level, Frost, 2012; Hoover & Gough, 1990; Miller, 2013; Miller et al., 2012). Either process can be broken down into sub-processes that feed into higher processes. The most basic in word recognition is a perceptual process that interacts with conceptual knowledge to identify letter shapes as familiar entities. Letter recognition underlies the creation of an association between letter graphemes and their corresponding phonemes, based on a grapheme-to-phoneme conversion procedure: the indirect reading route (Jackson & Coltheart, 2001). Applied to written words, this procedure yields phonological forms the reader may recognize as legitimate entries in his/her phonological lexicon. The same letter recognition process is the foundation for directly accessing orthographic representations of written words in the reader's orthographic lexicon.

Phonological and orthographic representations alike serve as access units to written words' meanings. However, although the retrieval of such meanings is an essential step to RC, it is their integration by means of supra-lexical processes that provides a final understanding of the message conveyed by a sentence. Two distinct yet connected processes underlie this integration. The first is a top-down semantically based process that interprets the final meaning of sentences by mapping their content words into the reader's prior knowledge (Allington & Cunningham, 2007; Lesgold & Perfetti, 1978; Miller, 2000, 2013; Stanovich, 1980; Tarchi, 2010). This process provides reasonable understanding of text conveying information that reflects a reader's prior knowledge. The second process is a bottom-up elaboration of a sentence's meaning through the application of rule-based syntactic knowledge. In consequence, it principally sustains RC even in instances where the conveyed information cannot be readily mapped onto the reader's prior knowledge; that is, reading becomes a tool for learning. Note that in proficient readers, the above processes are assumed to operate in parallel, although the contribution of either to RC may vary according to the prior knowledge readers bring to the reading task or their mastery of the rules underlying the read language (Miller, 2013).

To understand how native and nonnative signers' reading skills differ, and whether SL proficiency makes this difference, a thorough study of all the foregoing processing levels is required. Investigations should also include experimental paradigms that track information processing skills in a context that does not involve reading. This study reflects an international effort to adhere to these requirements. For this purpose, we developed six experimental paradigms to elucidate differences between the two study groups at each processing level underlying RC. Two paradigms focused on processing letters, three on the lexical level manipulating depth of word processing, and one on the sentence level tracking participants' top-down and bottom-up processing skills. The study also included two experimental paradigms that tapped into more general cognitive skills that did not involve reading.

Research Questions and Hypotheses

This study's research questions were (a) are there meaningful differences between native and nonnative signers in reading-related processing domains? (b) at which level of text processing do such differences show? and (c) are such differences restricted to reading-related domains?

To provide satisfactory answers, we tested the following hypotheses:

1. In line with a Language Coding Deficit Hypothesis (LCDH; Sparks et al., 2012), native signers will have better RC skills than nonnative signers. This advantage will reflect the fact that the former, growing up in continuous interaction with competent language models, learn to read with a more fully developed first language: their SL. Although essentially different from the spoken code, SL nevertheless may provide a bridge to the acquisition of the spoken language's written form (e.g., Grosjean, 2001) as it provides deaf individuals with a deeper understanding of its rule-based structure. It also fosters efficient acquisition of general and domain-specific knowledge that underlies effective top-down processing of written text.
2. The advantage arising from SL proficiency will not transform into information processing that does not require the application of linguistic abilities or access to knowledge that is directly and effectively mediated by such linguistic abilities.

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

3. 3. The difference between native and nonnative signers will be restricted to levels of text processing that require access to semantic and structural knowledge. SL—if at all—is not expected to enhance the processing of text at the word level as the implementation of signs is based on the combination of principles (hand shape, movement, location, etc.) that cannot be reflected by the phonological rules underlying spoken words. This is in contrast to differences in the structure of spoken and signed sentences, which at least partly can be explicitly traced by comparison.

Method

Participants

The original participant sample comprised 216 prelingually deaf 6th–10th graders from three different countries with three different languages: Hebrew in Israel, German in Germany, and Turkish in Turkey.[1] All were prelingually deaf, with hearing losses measured at frequencies 0.5, 1.0, and 2.0 kHz, being 85 dBHL or higher in the better ear: ANSI (American National Standards Institute, 1989). All reported SL as their preferred mode of communication. Their vision was intact or corrected-to-normal. From knowledge of their students' personal files, their teachers and counselors confirmed that their intelligence was in the range considered normal and that none of them was diagnosed as having specific learning disabilities. Only students who volunteered were tested, after grant of permission from relevant authorities. All were rewarded with a small gift for their willingness to participate.

To supplement student-file-based teacher information about the participants' cognitive characteristics and to reduce possible variance in participants' study performance originating from general fine-motor slowness and/or attention deficits, we measured them with two baseline paradigms, in addition to the experimental paradigms used for testing our research hypotheses. From their performance on these baseline paradigms, 40 individuals who manifested psychomotor skills and/or ability to sustain attention that deviated two standard deviations from their grade level mean were excluded. Of these, eight were native signers (6% of the entire native signer sample) and 32 were nonnative signers (22% of the entire nonnative signer sample). The remaining 176 individuals, 66 of them native and 110 nonnative signers, constituted the final sample analyzed in this report. Table 1 shows participants' distribution by their orthographic background and SL nativeness.

All native signers were children of deaf parents who used SL as the primary communication means with their deaf child/ren from birth. All the nonnative signers were children of hearing parents who relied on some form of manual communication with their deaf child, such as a signed form of their spoken language. All participants were enrolled in deaf classes where teachers used spoken language in combination with some form of signing as a means of instruction. This included the Turkish participants, even though the Turkish Ministry of Education advocates an oral philosophy toward deaf education.

Design and Stimuli

The study used an experimental design that allowed examination of differences between native and nonnative signers at different levels of text processing and nonverbal processing. It developed six research paradigms, each to assess a particular processing skill. The processing skills were divided into five domains: (a) letter processing; (b) word processing; (c) semantic processing of word concepts; (d) sentence comprehension; and (e) nonverbal processing. The stimulus materials used in the different paradigms were either identical or prepared according to exactly the same criteria in the three tested languages. In the following, the experimental paradigms are presented in the order above.

Letter processing

To elucidate differences between native and nonnative signers at the letter processing level, we used an elaborated version of the Posner and Mitchell paradigm (1967). This paradigm asked participants to make rapid same/different judgments for a series letter pairs presented one after the other at the center of a computer display. A set of 60 letter pairs was used for stimulation. Half of the pairs (30) contained the same letter twice (b b), while the other half consisted of two different letters (b t). Participants were asked to press a key marked "YES" for pairs of identical letters and a key marked "NO" for pairs of nonidentical letters.

The paradigm was implemented in two versions, a perceptual letter (PL) processing version and a conceptual letter (CL) processing version. In the PL version, both letters in the pair were presented in the same script: either print or cursive. Consequently, in pairs comprised of the same letter twice, the letters were physically identical (b b or ) and shared the same name/sound. In nonidentical pairs, the letters were physically different and had different names/sounds, but were presented in the same script type (b r or  ). The basic assumption here was that letter identicalness in this paradigm could be processed on a purely perceptual basis, namely without the need to access some form of letter knowledge (e.g., Vaknin & Miller, 2012). In that case, no differences would be expected between native and nonnative signers.

In the CL version, one letter of the pair was always presented in print and the other in cursive script. Thus, in pairs comprised of the same letter twice, the two were no longer physically identical (b ), and in nonidentical letter pairs, each letter appeared in a different script type (b) and had different names. The basic assumption here was that letter identicalness in this paradigm could not be processed on a purely perceptual basis, namely to make satisfactory letter identicalness decisions, access to some form of letter knowledge (letter name, letter sound, abstract letter representation, etc.) was a prerequisite (Vaknin & Miller, 2012). Given that SL per se does not seem to bear properties that directly support the processing of isolated letters, no differences would be expected between native and nonnative signers.

Word processing

To elucidate differences between native and nonnative signers at the lexical (word) processing level, we used an elaborated version of the letter processing paradigm outlined above (see also Kargin et al., 2011). This paradigm asked participants to make rapid same/different judgments for a series word pairs presented one after the other at the center of a computer display. A set of 60 word pairs was used for stimulation. Half of the pairs contained the same word twice (napkin napkin), whereas the other half consisted of two different words (picture apple). Participants were asked to press a key marked "YES" for pairs of identical words and a key marked "NO" for pairs of nonidentical words.

The paradigm was implemented in two versions, a perceptual word (PW) processing version and a conceptual word (CW) processing version. In the PW version, both words in the pair were presented in the same script: print or cursive. Consequently, in pairs comprised of the same word twice, the

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

Table 1. Demographic characteristics of the participants

Orthography	Grade	Sign language nativeness		All	Portion within whole sample
		Native	Nonnative		
Hebrew	Junior	10	14	24	35%
	High	14	23	37	
	All	24	37	61	
German	Junior	12	18	30	36%
	High	13	21	34	
	All	25	39	64	
Turkish	Junior	10	18	28	29%
	High	7	16	23	
	All	17	34	51	
All	Junior	32	50	82	100%
	High	34	60	94	
	All	66	110	176	

Note. The Hebrew sample is all native-signing junior high and high school students attending deaf classes who could be identified in the Jewish sector in Israel; the Turkish sample is all such students identified in Ankara, the capital of Turkey, a city of 5 million; and the German sample is all such students identified in Hamburg, a city of 1.8 million, plus participants tested in deaf schools in other German cities.

words were physically identical (apple apple or ***apple apple***) and shared the same name/sound. In nonidentical pairs, the words were physically, phonologically, orthographically, and semantically different, but were presented in the same script type (honey rabbit or ***honey rabbit***). The basic assumption here was that word identicalness in this paradigm could be processed on a purely perceptual basis, namely without the need to access some form of word knowledge (e.g., Kargin et al., 2011). Taking this as true, no differences would be expected between native and nonnative signers.

In the CW version, one word of the pair was always presented in print and the other in cursive script. Thus, in pairs comprised of the same word twice, the two were no longer physically identical (honey ***honey***) yet still had the same phonological, orthographic, and semantic properties. In nonidentical word pairs, each word appeared in a different script type (honey ***rabbit***), and they had different names. The basic assumption here was that word identicalness in this paradigm could not be processed on a purely perceptual basis, namely to make satisfactory word identicalness decisions access to some form of the words' linguistic properties (phonology, abstract orthographic representations, word meaning, etc.) is a prerequisite (Kargin et al., 2012; Miller, 2004a, b, 2005b, 2006). On the assumption that SL does not directly support the processing of isolated words, no differences would be expected between native and nonnative signers.

Semantic processing of word concepts

To assess native and nonnative signers' written-word-based semantic processing skills, we used an experimental paradigm that required them to determine as fast as possible whether two words simultaneously presented on a computer display were semantically related and to indicate their decision by pressing a "YES" or "NO" key.

Stimulus materials were prepared according to the same criteria in all tested languages. Stimuli were 40 word pairs, each comprised of two high-frequency words (Appendix A). To control for the familiarity of the word stimuli to our participants, we asked three experts—two primary school teachers of the deaf and a speech/language therapist of the deaf—to indicate stimulus words they thought may not be familiar to deaf third and fourth graders, that is, students that were at least two grade levels below those tested in this study. Only words on which all raters concurred were used for stimulation.

The great majority of words used in the stimulus pairs were mono or bisyllabic, although a few had three syllables. In half of the pairs, the two words were clearly related semantically (e.g., "lock, key"), whereas in the remainder, they were semantically unrelated as widely as possible (e.g., "comb, city"). In all word pairs, it was ascertained that the two words were phonologically, orthographically, or visually dissimilar from each other. On the assumption that high proficiency in SL sustained effective internalization and organization of knowledge, we predicted deaf native signers would be faster and more accurate in making semantic-relatedness decisions.

Sentence comprehension

Participants' sentence comprehension—hereinafter RC—was examined by means of 16 active sentences built from basic vocabulary verified as familiar to participants. Using a forward-and-backward translation procedure, identical versions of the sentences were prepared in all three languages (Hebrew, German, and Turkish).

All sentences were syntactically complex. Half of them (8) had one subordinate and the remainder (8) two subordinates. Half of the sentences in each syntactic category conveyed a semantically plausible (SP) message (e.g., "The car that hit the train was totally destroyed."). The remainder conveyed a semantically implausible (SI) message (e.g., "The truck driver who hit the man was badly hurt." Appendix B presents additional test sentences). Each SI sentence was paralleled by a SP sentence by having exactly the same syntactic structure, a closely matched number of words and a vocabulary of similar difficulty. The aim of these matches was to control for the potential contribution of the above factors to RC variance.

The basic assumption underlying the sentence comprehension test was that for a proper understanding of SI sentences, semantic top-down processing is insufficient. Such processing, however, may generate proper understanding of SP sentences, provided the reader is in possession of adequate prior knowledge. In other words, mere semantic top-down processing generates sentence meaning according to the readers' prior knowledge only; a meaning which—for SI sentences—is incompatible with the one produced by their syntactic bottom-up processing. Therefore, poor comprehension of SI sentences, in

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

contrast to proper understanding of SP sentences, is presumed indicative of failure properly to process sentences' syntactic structure.

A short question, with two or three multiple-choice answers, was used to test the comprehension of each test sentence. Questions referenced either the subject or the object of the main or the subordinate clause. An additional set of four sentences was used for task explanation and practice. The 16 test sentences were mixed and presented randomly on an A4 sheet. Performance time was measured but not limited. Chance level performance was 42%. Internal test reliability (Cronbach's alpha), calculated from the 16 test sentences, was 0.72.

Six independent judges (university students) were asked to determine the semantic plausibility status of each sentence (SP or implausible content). For this purpose, pairs of test sentences were shown to each judge separately, one pair at the time. One sentence in each pair was assumed to depict a SP scenario, and the other, syntactically parallel, sentence to convey a SI scenario. Three of the six judges were instructed to indicate which of the two sentences in a pair described a scenario compatible with how things normally happen in real life. The other three judges were instructed to indicate which of the two sentences in a pair described a scenario not compatible with how things normally happen in real life. Sentences were used for experimentation only when their semantic plausibility status was confirmed in both ways.

Nonverbal processing

Differences between native and nonnative signers in nonverbal information processing skills were examined with two same/different paradigms: a nonverbal perceptual processing paradigm and a nonverbal semantic processing paradigm. Both were implemented as a paper and pencil task. The basic assumption underlying their development was that processing the stimulus materials used required linguistic knowledge in neither of them. Moreover, there was no reason to assume that possession of such knowledge would bear particular potential to enhance the processing of these materials.

Nonverbal perceptual processing

Bengali letter graphemes (Vrinda font) were used for stimulation. Because Bengali script was not a familiar orthography to our participants, making letter identicalness judgments for Bengali letter pairs was a purely perceptual processing task for them, regardless of their orthographic background.

Forty Bengali letter pairs randomly distributed in 40 rectangular fields and arranged in five equal rows on an A4 sheet served for stimulation. Half of the pairs were comprised of two identical Bengali letters (e.g., ঢ ঢ), the remainder of two distinct letters (e.g., জ ঢ). Participants were asked to decide as fast as possible whether the two Bengali letters in a pair were the same or not by rapidly marking identical pairs "√" and nonidentical pairs "×." Two additional rows of stimulus pairs were prepared on a separate sheet for task explanation and practice.

Nonverbal semantic processing

Forty pairs of schematic drawings of familiar objects were used for stimulation. The pairs were randomly distributed in 40 rectangular fields and arranged in five equal rows on an A4 sheet. Half of the pairs were comprised of perceptually very different drawings of the same object (e.g., ) and the remainder of two distinct objects (e.g., ). Participants were asked to decide as fast as possible whether the two drawings represented the same object or not by rapidly marking identical objects "√" and nonidentical "×." Two additional rows of stimulus pairs were prepared on a separate sheet for task explanation and practice.

Procedure

To guarantee the proper administration of the different experiments in all three countries, a detailed written procedural protocol translated into the three languages provided the basis for the training of research assistants. All of them, hearing and deaf, had to first learn, and then observe and practice, the experimental procedures. Only after they passed an exam ascertaining that they had mastered the knowledge required for the proper administration of the different experiments, were they considered ready for testing. Deaf research assistants received their training in SL.

All participants were tested individually in a quiet room by a trained research assistant. They were informed that they would not be graded and that their performance would be kept confidential. Instructions for the different experiments were translated into SL, supplemented when necessary by a physical demonstration of the task requirements.

The different experimental paradigms were administered in this order: (a) perceptual processing of letters; (b) conceptual processing of letters; (c) nonverbal perceptual processing; (d) perceptual processing of words; (e) conceptual processing of words; (f) sentence comprehension test; (g) semantic processing of word concepts; and (h) nonverbal semantic processing (drawings). In the following, the procedures used with the different experimental paradigms are presented in an order that refers to specific processing domains rather than according to the order in which they were administered to the participants.

Letter processing

DMDX experimental software developed by Forster and Forster (2003), set up on a laptop computer, was used to handle stimulus presentation and reaction time measurements. This technology measures response latencies following the presentation of the stimulus with exactitude of milliseconds and records them together with response accuracy for subsequent analysis. The laptop was placed at comfortable distance (about 60 cm) on an otherwise empty table in front of the participant. The experimenter told the participants that the experiment was to see how fast they could tell if two letters were the same or not. All participants were first given the PL-processing paradigm, followed immediately by the CL-processing paradigm. Instructions for the two paradigms were principally identical, except in the conceptual version the experimenter explicitly instructed the participants to ignore the fact that one letter in a pair appeared in cursive and the other in print.

The experiment was executed in two steps. In the first step, for explanation and practice, the experimenter presented a letter pair in the center of the laptop display and said: "You see here in the center of the screen there are two letters. Your task is to decide whether they are the same or different. If the two letters are the same, press the key marked YES (*experimenter points to the key marked 'YES'*). If the two letters are different, press the key marked NO (*experimenter points to the key marked 'NO'*)." The experimenter instructed the participant to put his/her index fingers on the two response keys and to press the appropriate one the moment the next two letters appeared; "YES" for two identical letters and "NO" for the different letters. Eight more warm-up trials were given before experimentation.

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

Prior to presenting a stimulus for the experiment, the experimenter told the participant that he/she would now be tested and that response time would be measured, so it was very important to work as quickly as possible. The participant was urged not to stop in case of error, but to continue without hesitation. All 60 stimulus pairs used in the perceptual and CL-processing paradigms were displayed in succession, with a filler mask (####) of 550 ms inserted between indication of the response and presentation of the next stimulus pair. When no response was given within 3,500 ms, presentation of the stimulus pair was aborted and marked by DMDX software as invalid; after a masked interval of 550 ms, the next item was presented. The display of "******" indicated the end of an experimental block.

Word processing

The experimental procedures for testing the perceptual and conceptual processing of written words were identical with those for testing the perceptual and conceptual processing of letters, except the experimenter told the participants that in this part of the experiment stimulus pairs were familiar words rather than isolated letters. A practice session using stimulus word pairs followed the task explanation.

Semantic processing of word concepts

The experimental procedure for testing participants' semantic processing of word concepts was generally identical with the one for testing the perceptual and conceptual processing of words, except the participants had to determine the relatedness rather than the identicalness of the words in a word stimulus pair. The experimenter informed the participants that word pairs presented on the laptop display would always consist of two different words; their task was to determine whether they are related or not by pressing "YES" for word pairs comprised of two related words and "NO" for word pairs comprised of two unrelated words. The experimenter explained the task with two examples: one showing an obvious relationship between the two words and the other with no noticeable relationship. The participants were then given eight additional trials to establish that they understood task requirements properly.

Sentence comprehension

Sentences used for task explanation and warm-up appeared separately on the first page of the test. The experimenter told the participants that the aim of the experiment was to learn how students read. They were then asked to read the first practice sentence and the following question carefully, and to answer by circling the choice they made. If participants did not understand the instructions, the experimenter provided the first answer and then asked participants to try to solve the other three practice sentences

Participants were told they could ask for help if they encountered an unfamiliar word. Only after the experimenter was confident that participants understood the test requirements did he or she tell them to solve the actual test sentences, reminding them once again to read both sentences and questions thoroughly before choosing an answer. There was no time limit.

Nonverbal processing

Both experimental paradigms assessing the participants' nonverbal processing skills were implemented as paper and pencil tasks. Unlike in the DMDX-based experimental paradigms, where time was measured per item, in the two paper and pencil tasks we recorded the time it took the participants to judge the 40 stimulus pairs presented on the test sheet and to mark them accordingly (or ×). Time was measured with a stopwatch to an exactitude of one tenth of a second. Performance accuracy was checked by positioning a transparent slide with the correct responses on the test sheet and counting the instances in which these did not overlap with those marked by the participant. Performance time and overall error rates were coded for further analysis.

Nonverbal perceptual processing

The experimenter placed the practice sheet on the table before the participant and said: "Here is a sheet of paper and on it are rows of rectangular squares (Appendix A). In each square are two items. The two are identical (e.g., ঠ ঠ) or distinct (e.g., ক ঠ). Your task is to mark squares containing two identical items with the sign '√' and squares with two different items with the sign '×'." The experimenter demonstrated the task by marking the first 4-item pairs presented in the first 4 rectangular squares. He or she then handed the pen to the participant and said: "Now go on marking this and the next row of squares according to the example I gave you. Please indicate your decision by marking the squares one after the other."

For experimentation, the experimenter replaced the practice sheet with the experimental sheet hidden by an empty coversheet, and said: "Beneath this empty sheet is another sheet with rows of squares, each containing two items. Remember, mark the squares with the sign '√' if they contain the same item twice and with the sign '×' if they contain two different items. This time I'll measure how long it takes you to mark all the squares, so it is important that you work as quickly as possible. Start from the top square on the left and go on row by row from left to the right. Try to avoid making mistakes, but if you do, don't correct it but go on marking because time is important."

The experimenter then told the participant to put his/her hand holding the pen near the upper left corner of the experimental sheet and to start working the moment he/she removed the coversheet; he or she was urged once more working as quickly as possible. He or she then removed the coversheet and started the stopwatch the moment the participant marked the first square. The experimenter stopped the stopwatch the moment the participant marked the last square.

Nonverbal conceptual processing

The procedure to examine participants' nonverbal conceptual processing skills was principally identical with the one for assessing their nonverbal perceptual processing skills, except they judged the identicalness of pairs of familiar objects (e.g.,  = √ or  = ×) rather than unfamiliar objects.

Results

Data analysis were conducted in four steps: (a) comparison of native and nonnative signers' overall sentence comprehension (RC) and the way it was biased by level of education and orthographic background; (b) comparison of the two study groups' processing skills on each of the different word processing paradigms; (c) comparison of their nonverbal processing skills; and (d) a detailed analysis of their syntactic and semantic RC skills.

Overall Sentence Comprehension

We conducted analysis of variance (ANOVA) as a general linear model (GLM) univariate analysis to compare the participant groups' overall RC. The analysis computed overall score on the sentence comprehension test as the dependent variable and SL

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

nativeness (native signer and nonnative signer), orthographic background (Hebrew, German, and Turkish), and grade level (5th–6th graders and 9th–10th graders) as three between-subject factors. The participant groups' overall RC scores, including standard deviations, with reference to their SL nativeness, their orthographic background, and their grade level, are presented in Table 2.

SL nativeness was revealed as a main effect of borderline significance, $F(1,175) = 2.95$, $p = .08$, $\eta^2 = .02$, pointing to a tendency of native signers to have somewhat better RC than their nonnative signing counterparts. The main effect originating from the participants' orthographic background proved statistically significant, $F(2,175) = 27.83$, $p < .001$, $\eta^2 = .25$. Tukey HSD post-hoc analysis to clarify the final significance of the orthography effect revealed that the RC of Hebrew participants was notably enhanced compared with their German and Turkish counterparts. By contrast, no marked difference between the latter two was evinced.

The main effect of grade level failed to reach statistical significance, $F(1,175) = .58$, $p > .05$, implying that overall, participants' RC did not markedly improve from junior high to high school. A statistically significant SL nativeness × grade level interaction, $F(1,175) = 4.70$, $p < .05$, $\eta^2 = .03$, was revealed, indicating that bias from SL nativeness on RC varied from junior high to high school (see Table 2). There was no significant SL nativeness × orthography interaction, $F(2,175) = 0.00$, $p > .05$, implying that bias from SL nativeness on RC was uniform across the tested orthographies. The absence of a significant triple SL nativeness × orthography × grade level interaction, $F(4,175) = 0.74$, $p > .05$, $\eta^2 = .02$, suggested this to be true regardless of the participants' grade level.

To clarify the final significance of the SL nativeness × grade level interaction, we compared native and nonnative signers' RC at junior high and high school level by one-way ANOVA. Findings pointed to a close-to-zero difference between the two groups at the junior high level, $F(1,81) = 0.01$, $p > .05$, and to a statistically marked difference between them at the high school level, $F(1,93) = 7.23$, $p < .01$.

Notably, the impact of grade level on participants' RC proved close to zero. This logically suggests that even if increase in years of education affected participants' ability to process written information at the lexical or sublexical level, this effect was not transferred to their RC. Taking this to be true, we decided to exclude grade level in subsequent analyses as a between-subject factor, and instead to compute it as a covariate that controls for possible variance from grade level on the participants' task performance.

Letter Processing

We conducted ANOVAs with a GLM univariate design to compare the participant groups' letter processing speed (RT) and accuracy (error rate). In all of them, SL nativeness (native and nonnative) and orthography (Hebrew, German, and Turkish) were computed as two between-subject factors. Grade level was entered as a covariate to account for potential variance in the participant groups' letter processing skills originating from their years of formal education. In the following, we present findings from this line of analysis for letter processing under perceptual and under conceptual conditions separately.

Perceptual processing of letters

The participant groups' average processing speed (in ms) and accuracy with reference to their SL nativeness and orthographic background are presented in Tables 3 and 4.

Table 2. Average reading comprehension scores (standard deviations in parentheses)

		Orthography			
Sign language nativeness	Grade	Hebrew	German	Turkish	All
Overall scores[a]					
Native	Junior	10.30 (2.79)	7.50 (3.55)	7.70 (2.21)	8.44 (3.13)
	High	12.57 (2.53)	8.31 (2.98)	8.29 (3.30)	10.06 (3.50)
	All	11.63 (2.83)	7.92 (3.23)	7.94 (2.63)	9.27 (3.40)
Nonnative	Junior	11.21 (3.47)	7.00 (2.40)	7.89 (2.45)	8.50 (3.21)
	High	10.09 (3.31)	7.29 (2.65)	6.56 (1.96)	8.17 (3.14)
	All	10.51 (3.37)	7.15 (2.51)	7.26 (2.30)	8.32 (3.16)
All	Junior	10.83 (3.17)	7.20 (2.87)	7.82 (2.33)	8.48 (3.16)
	High	11.03 (3.24)	7.68 (2.78)	7.09 (2.50)	8.85 (3.38)
	All	10.95 (3.19)	7.45(2.81)	7.49 (2.41)	8.68 (3.28)

Note. [a]Maximum score all sentences = 16.

Table 3. Mean RTs for the perceptual and conceptual processing of letters (standard deviations in parentheses)

	Orthography			
Sign language nativeness	Hebrew	German	Turkish	All
Perceptual processing of letters				
Native signers	682 (94)	624 (72)	818 (205)	695 (147)
Nonnative signers	730 (157)	699 (124)	809 (162)	743 (153)
All	711 (137)	670 (112)	812 (175)	725 (152)
Conceptual processing of letters				
Native signers	918 (137)	793 (121)	997 (211)	891 (173)
Nonnative signers	963 (183)	876 (186)	966 (186)	933 (188)
All	945 (167)	844 (168)	976 (193)	917 (183)

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

The main effect SL nativeness was statistically significant for speed of PL processing, $F(1,174) = 4.04$, $p < .05$, $\eta^2 = .02$, but not for processing accuracy, $F(1,174) = 0.33$, $p > .05$, implying that in the perceptual condition, deaf native signers process letter identicalness faster but not more accurately than their nonnative signing counterparts. The main effect originating from the participants' orthographic background was statistically marked with regard to processing speed, $F(2,174) = 15.43$, $p < .001$, $\eta^2 = .16$, but not with regard to processing accuracy, $F(2,174) = 0.91$, $p > .05$. We ran a Tukey HSD post-hoc procedure to clarify the final significance of the orthography-related speed of processing main effect. This analysis revealed that Turkish participants determined letter identicalness markedly slower than their Hebrew and German counterparts. There was, however, no evidence that distinguished Hebrew and German participants in this regard. Finally, the absence of a statistically significant interaction between participants' SL nativeness and their orthographic background, $F(2,174) = 1.24$, $p > .05$, suggests that processing-speed differences originating from participants' orthographic background were not further modified by their SL nativeness.

Conceptual processing of letters

The participant groups' average speed and accuracy of processing in respect of their SL nativeness and orthographic background are presented in Tables 3 and 4. The main effect SL nativeness was statistically not significant. This held for both processing speed and processing accuracy, $F(1,175) = 2.04$, $p > .05$; $F(1,175) = 0.03$, $p > .05$, respectively. The main effect of participants' orthographic background was significant for processing speed, $F(2,175) = 11.21$, $p < .001$, $\eta^2 = .12$, but not for processing accuracy, $F(2,174) = 0.91$, $p > .05$. We conducted Tukey HSD post-hoc analysis to clarify the final significance of the orthography-related speed of processing main effect. This analysis indicated that both Turkish and Hebrew participants determined letter identicalness markedly slower than their German counterparts. Hebrew and Turkish participants were not found to differ in this regard.

The SL nativeness × orthographic-background interaction failed to reach statistical significance in relation to both speed of processing, $F(2,175) = 1.48$, $p > .05$, and accuracy of processing, $F(2,175) = 0.75$, $p > .05$, suggesting that the participants' SL nativeness did not further modify speed of processing differences originating from their orthographic background.

Word Processing

To obtain a profound understanding of the participant groups' basic written word processing skills, we executed ANOVAs using a GLM univariate design, with processing speed (RT) and word processing accuracy (error rate) computed as the dependent variables and SL nativeness (native and nonnative) and orthography (Hebrew, German, and Turkish) as two between-subject factors. Grade level was entered as a covariate to control for impact of formal education on word processing. We first present findings from an analysis of the participant groups' PW processing skills, then an analysis of their CW processing skills. Group averages for word processing speed (in milliseconds) and accuracy for the two processing conditions, with reference to the participants' SL nativeness and orthographic background, are presented in Tables 5 and 6.

Perceptual processing of words

The main effect SL nativeness failed to reach statistical significance, which suggests that the ability of native and nonnative signers to process written words under conditions that did not require their conceptual processing was comparable. This proved true with regard to both speed of processing, $F(1,175) = 2.10$, $p > .05$, and processing accuracy, $F(1,174) = 0.47$, $p > .05$. The main

Table 4. Mean error rates for the perceptual and conceptual processing of letters (standard deviations in parentheses)

	Orthography			
Sign language nativeness	Hebrew	German	Turkish	All
Perceptual processing of letters[a]				
Native signers	2.00 (3.15)	2.76 (3.00)	4.18 (4.72)	2.86 (3.61)
Nonnative signers	2.65 (4.74)	2.69 (3.04)	2.56 (2.64)	2.64 (3.57)
All	2.40 (4.18)	2.72 (3.00)	3.10 (3.51)	2.72 (3.58)
Conceptual processing of letters[a]				
Native signers	3.67 (2.93)	5.80 (10.02)	6.65 (4.73)	5.24 (6.87)
Nonnative signers	5.30 (3.45)	5.38 (3.73)	5.88 (6.22)	5.51 (4.53)
All	4.66 (3.33)	5.55 (6.83)	6.14 (5.73)	5.41 (5.51)

Note. [a]Maximum error rate = 60.

Table 5. Mean RTs for the perceptual and conceptual processing of words (standard deviations in parentheses)

	Orthography			
Sign language nativeness	Hebrew	German	Turkish	All
Perceptual processing of words				
Native signers	718 (93)	726 (101)	968 (208)	786 (171)
Nonnative signers	735 (140)	814 (141)	948 (178)	829 (175)
All	728 (123)	780 (133)	955 (187)	813 (174)
Conceptual processing of words				
Native signers	832 (101)	823 (133)	1,020 (203)	877 (166)
Nonnative signers	847 (155)	913 (166)	1,081 (209)	943 (201)
All	841 (135)	877 (159)	1,061 (207)	918 (191)

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

effect originating from the participants' orthographic background was statistically significant with regard to processing speed, $F(2,175) = 34.00$, $p < .001$, $\eta^2 = .29$, but not with regard to processing accuracy, $F(2,174) = 0.93$, $p > .05$. Tukey HSD post-hoc procedure conducted to contrast the orthography-related speed of processing main effect revealed that Turkish participants were markedly slower in determining word identicalness than their Hebrew and German counterparts. Hebrew and German participants were indistinguishable in this regard. Notably, the absence of a statistically marked interaction between the main effects SL nativeness and orthographic background, $F(2,174) = 1.97$, $p > .05$, suggests that SL nativeness did not further modify speed of processing differences originating from the participants' orthographic background.

Conceptual processing of words

The effect of SL nativeness on the participants' word processing speed was statistically significant, $F(1,174) = 5.78$, $p < .05$, $\eta^2 = .03$. This suggests native signers' processing written words faster than nonnative signers in instances determining word identicalness requires the conceptual processing of the word stimuli. There was no evidence of such a difference in an analysis that focused on word processing accuracy, $F(1,174) = 0.08$, $p > .05$.

Analysis pinpointed the participants' orthographic background as a statistically marked main effect with regard to processing speed, $F(2,174) = 22.03$, $p < .001$, $\eta^2 = .21$, but not with regard to processing accuracy, $F(2,174) = 0.48$, $p > .05$. We used Tukey HSD as a post-hoc test to determine the final significance of the orthography-related speed of processing main effect. Turkish participants were found to process word identicalness in the conceptual condition markedly slower than their Hebrew and German counterparts. Hebrew and German participants were indistinguishable in this regard. The absence of a statistically marked interaction between SL nativeness and orthographic-background main effects, $F(2,174) = 0.87$, $p > .05$, further suggested that speed of processing differences originating from participants orthographic background were not further biased by their SL nativeness.

Semantic Processing of Word Concepts

The participant groups' processing speed (in milliseconds) and processing accuracy averages for the semantic processing of word concepts, with reference to SL nativeness and orthographic background, are presented in Table 7.

The effect of SL nativeness on participants' semantic processing of word concepts was statistically significant with regard to processing speed, $F(1,175) = 15.57$, $p < .001$, $\eta^2 = .08$, and processing accuracy, $F(1,175) = 5.63$, $p < .05$, $\eta^2 = .03$, implying that native signers possess marked advantages in determining the nature of the relationship between two word concepts. Further, participants' orthographic background was pinpointed as a statistically marked main effect with regard to processing speed, $F(2,175) = 27.88$, $p < .001$, $\eta^2 = .25$, and to processing accuracy, $F(2,175) = 80.85$, $p < .001$, $\eta^2 = .49$. The absence of a statistically marked interaction between the participants' SL nativeness and their orthographic background further suggests that the processing advantage of native signers over their nonnative signing counterparts was uniform across the three tested languages.

To determine the final significance of the orthography-related processing speed and processing accuracy main effects, we conducted two Tukey HSD post-hoc tests. The Turkish participants were shown to have severely impoverished semantic word concept processing skills, with regard to processing speed and processing accuracy alike. Hebrew and German participants were not found markedly to differ in this regard.

Table 6. Mean error rates for the perceptual and conceptual processing of words (standard deviations in parentheses)

	Orthography			
Sign language nativeness	Hebrew	German	Turkish	All
Perceptual processing of words[a]				
Native signers	2.38 (2.78)	1.60 (1.44)	2.06 (1.56)	2.00 (2.05)
Nonnative signers	2.46 (2.40)	2.56 (3.27)	1.71 (1.36)	2.26 (2.52)
All	2.43 (2.53)	2.19 (2.73)	1.82 (1.42)	2.16 (2.35)
Conceptual processing of words[a]				
Native signers	0.88 (0.95)	0.88 (1.17)	1.12 (0.86)	0.94 (1.01)
Nonnative signers	1.35 (1.36)	1.16 (2.19)	0.56 (0.79)	1.04 (1.60)
All	1.16 (1.23)	1.05 (1.84)	0.75 (0.85)	1.00 (1.40)

Note. [a]Maximum error rate = 60.

Table 7. Mean RTs and error rates for the semantic processing of words (standard deviations in parentheses)

	Orthography			
Sign language nativeness	Hebrew	German	Turkish	All
RTs for semantic processing of words				
Native signers	1,360 (248)	1,196 (212)	1,649 (350)	1,372 (317)
Nonnative signers	1,512 (322)	1,408 (249)	1,744 (328)	1,561 (334)
All	1,452 (302)	1,325 (255)	1,745 (328)	1,491 (339)
Error rates for semantic processing of words[a]				
Native signers	3.17 (2.48)	3.12 (2.26)	10.41 (3.45)	5.02 (4.29)
Nonnative signers	4.65 (3.08)	4.67 (2.84)	10.65 (3.11)	6.51 (4.14)
All	4.07 (3.08)	4.06 (2.72)	10.57 (3.20)	5.95 (4.19)

Note. [a]Maximum error rate = 30.

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

Nonverbal Processing

The participant groups' nonverbal processing skills were subjected to two ANOVAs conducted with a GLM univariate design, one focusing on their nonverbal perceptual processing, the other on their nonverbal semantic processing. In both analyses, SL nativeness (native and nonnative) and orthography (Hebrew, German, and Turkish) were computed as between-subject factors; grade level was entered as a covariate to control for variance originating from years of formal education. Given the low error rates found in relation to both processing domains (less than 5%), we restricted the analysis to performance time. Below we present the findings for participants' nonverbal perceptual processing skills, and then for their nonverbal semantic processing skills. Groups' mean performance time (in seconds) measured in relation to the nonverbal perceptual and conceptual processing paradigms, with reference to their SL nativeness and their orthographic background, are presented in Table 8.

Nonverbal perceptual processing

The effect of SL nativeness on the participants' nonverbal perceptual processing skills failed to reach statistical significance, $F(1,175) = 0.62$, $p > .05$, pointing to comparable performance by native and nonnative signers in this domain. In contrast, analysis pinpointed the participants' orthographic background as a statistically marked main effect, $F(2,174) = 34.47$, $p < .001$, $\eta^2 = .29$. The interaction between the participants' SL nativeness and their orthographic background was not statistically marked, suggesting that SL nativeness did not modify speed of processing differences originating from the participants' orthographic background. We conducted Tukey HSD post-hoc test to determine the final significance of the orthography-related main effect. Turkish participants were found to perform the nonverbal perceptual processing task significantly slower than their Hebrew and German counterparts, who did not differ in this regard.

Nonverbal conceptual processing

The effect of SL nativeness on participants' nonverbal conceptual processing of drawings failed to reach statistical significance, $F(1,175) = 0.08$, $p > .05$, pointing to comparable performance by native and nonnative signers in this domain. In contrast, analysis pinpointed the participants' orthographic background as a statistically marked main effect, $F(2,174) = 25.75$, $p < .001$, $\eta^2 = .24$. The interaction between the participants' SL nativeness and their orthographic background failed to reach statistical significance, $F(2,175) = 0.08$, $p > .05$, implying that speed of processing differences stemming from the participants' orthographic background were not biased by their SL nativeness. We conducted Tukey HSD post-hoc test to determine the final significance of the orthography-related main effect. Turkish participants' nonverbal conceptual information processing skills proved markedly underdeveloped compared with their Hebrew and German counterparts, who themselves did not differ in this regard.

Semantic and Syntactic RC Skills

As stated earlier, the sentence comprehension test comprised two distinct sentence categories: (a) SP sentences, which we assumed comprehensible through semantic top-down processing and (b) SI sentences, which required syntactic bottom-up processing for proper understanding (Miller, 2012). Mean RC scores for the two sentence categories, with reference to participants' SL nativeness, orthographic background, and grade levels, are presented in Table 9.

To elucidate how sentences' semantic plausibility (semantic plausibility effect) impacts participants' RC, and whether their SL nativeness and orthographic background further modify this impact, we conducted ANOVA with a GLM repeated measures design. Semantic plausibility (plausible and implausible) was entered into the procedure as a within-subject factor, and SL nativeness (native and nonnative), orthographic background (Hebrew, German, and Turkish), and grade level as three between-subject factors.

We have already presented statistics on the three between-subject main effects in relation to the primary analysis of participants' overall RC in the first subsection of the Results (see Overall sentence comprehension). So here we report only findings on the semantic plausibility within-subject main effect and how it interacted with the between-subject effects.

The semantic plausibility main effect was statistically significant, $F(1,164) = 71.43$, $p < .001$, $\eta^2 = .30$, suggesting that overall, participants understood SP sentences markedly better than SI sentences (Table 9). Nonsignificant interactions between semantic plausibility and grade level and semantic plausibility, grade level and SL nativeness suggested this to hold for all grade levels, and regardless of participants' SL nativeness.

The interaction between semantic plausibility and SL nativeness was close to zero, $F(1,164) = 0.01$, $p > .05$, implying that the impact of semantic plausibility on RC was similar for native and nonnative signers. A statistically marked interaction was found between the semantic plausibility effect and participants' orthographic background, $F(2,164) = 10.10$, $p < .001$, $\eta^2 = .11$, indicating that the size of the semantic plausibility effect was not the same for Hebrew, German, and Turkish participants.

To clarify the final significance of the semantic plausibility × orthographic-background interaction, we ran the one-way analysis of the semantic plausibility effect (the difference in comprehension of SP and implausible sentences) with orthography computed as a between-subject factor. The main effect

Table 8. Mean performance time in seconds for nonverbal perceptual and nonverbal conceptual processing (standard deviations in parentheses)

	Orthography			
Sign language nativeness	Hebrew	German	Turkish	All
Nonverbal perceptual processing				
Native signers	44.18 (7.06)	40.29 (7.59)	54.72 (12.02)	45.42 (10.39)
Nonnative signers	44.53 (10.80)	42.86 (10.12)	59.85 (10.83)	48.67 (12.91)
All	44.39 (9.44)	41.85 (9.24)	58.14 (11.38)	47.45 (12.10)
Nonverbal conceptual processing				
Native signers	46.59 (7.53)	44.35 (12.93)	61.81 (17.46)	49.66 (14.48)
Nonnative signers	47.30 (13.16)	46.13 (10.14)	61.13 (12.03)	51.24 (13.55)
All	47.02 (11.21)	45.44 (11.24)	61.52 (13.90)	50.65 (13.89)

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

Table 9. Average reading comprehension scores for semantically plausible and semantically implausible sentences (standard deviations in parentheses)

Sign language nativeness	Grade	Orthography			All
		Hebrew	German	Turkish	
Semantically plausible sentences[a]					
Native	Junior	6.30 (1.42)	4.33 (2.10)	3.90 (1.52)	4.81 (1.97)
	High	7.21 (0.97)	5.69 (1.32)	4.43 (2.22)	6.06 (1.76)
	All	6.83 (1.24)	5.04 (1.84)	4.12 (1.80)	5.45 (1.96)
Nonnative	Junior	6.71 (1.38)	4.50 (1.47)	4.28 (1.78)	5.04 (1.86)
	High	6.04 (1.40)	4.67 (1.56)	3.25 (1.959	4.82 (1.94)
	All	6.30 (1.41)	4.59 (1.50)	3.79 (1.90)	4.92 (1.90)
Semantically implausible sentences[a]					
Native	Junior	4.00 (1.94)	3.17 (2.25)	3.80 (1.32)	3.63 (1.88)
	High	5.36 (2.02)	2.62 (1.94)	3.86 (1.46)	4.00 (2.21)
	All	4.79 (2.06)	2.88 (2.07)	3.82 (1.33)	3.82 (2.05)
Nonnative	Junior	4.50 (2.62)	2.50 (1.65)	3.61 (2.03)	3.46 (2.21)
	High	4.04 (2.38)	2.62 (1.69)	3.31 (1.62)	3.35 (2.03)
	All	4.22 (2.45)	2.56 (1.65)	3.47 (1.83)	3.40 (2.10)

Note. [a]Maximum score per sentence category = 8.

orthography was statistically significant, $F(2,164) = 11.51$, $p < .001$. The Tukey HSD procedure indicated that the semantic plausibility effect exhibited by the Turkish participants was markedly smaller than that exhibited by the Hebrew and German participants, who did not differ in this regard (see Table 9).

Finally, in a series of paired *t*-tests, we compared participants of different orthographic background separately for comprehension differences between SP and implausible sentences. Hebrew and German participants were found to understand SP sentences significantly better than SI sentences, $t(61) = 7.91$, $p < .001$; $t(63) = 7.91$, $p < .001$, respectively. Notably, however, for the Turkish participants, there was no statistical evidence that understanding of the two sentence types differed, $t(63) = 0.87$, $p > .05$.

Discussion

We aimed to elucidate whether there are meaningful differences between native and nonnative signers in reading-related and other processing domains. The research hypotheses were driven by LCDH (Sparks et al., 2012), which suggests that level of competence in the first language contributes to acquisition and use of a second language, whether spoken or written. However, this theory was conceptualized on investigations with hearing learners who acquire a second-spoken language. A central question of this study was whether assumptions made by LCDH also hold when the first language is a SL, as is the case for deaf native signers. More specifically, we asked whether variance in SL proficiency (native signers vs. nonnative signers) leads to differences in RC. Findings from previous research indeed suggest that deaf native signers outscore nonnative signers in literacy-related domains (Chamberlain & Mayberry, 2000; Conrad, 1979; Goldin-Meadow & Mayberry, 2001; Meadow, 1968; Miller, 2010, 2013; Strong & Prinz, 1997). This is so despite the fact that SL is realized in a different modality, its lexemes are built of components of an essentially different nature (hand shape, movement, and location) than the phonemes used for the production of spoken words, and it is morphologically and syntactically structured in ways that in many instances have no parallels in spoken code.

Evidence of enhanced reading skills in deaf native signers has been interpreted as proof that SL proficiency enhances the acquisition and use of a spoken second language (e.g., Strong & Prinz, 1997; Traxler, Corina, Morford, Hafer, & Hoversten, 2014). Findings from our international reading study regarding participants' overall RC level fail to fully support the validity of this conclusion. In fact, our evidence indicates that the advantage in RC of native signers over their nonnative signing counterparts may be restricted to more advanced grade levels. This seems to imply that SL nativeness per se may not scaffold the acquisition of reading directly. To consider seriously the validity of this possibility, differences between native and nonnative signers should first be looked at more closely, with the focus on more specific processing domains. An initial step here is to consider findings obtained from the two nonverbal paradigms administered to our study groups.

We predicted that an advantage deriving from SL proficiency will not transfer to information processing that does not require the application of linguistic abilities (Paradigm 7: nonverbal perceptual processing). Nor was it expected to enhance information processing that does not involve access to knowledge directly and effectively mediated by such linguistic abilities (Paradigm 8: conceptual nonverbal processing). Our findings fully corroborate this hypothesis. They actually indicate that gains from SL proficiency—if such are found—may be restricted to cognitive tasks that directly or indirectly involve language as a mediator. Why both native and nonnative Turkish signers manifested marked processing-speed delays on nonverbal tasks, in contrast to their Hebrew and German counterparts, is not clear from this study. However, considering that the two Turkish groups were raised/educated according to oral philosophy, their slowness on the nonverbal tasks may reflect a hesitative response pattern originally developed in response to being compelled to rely on spoken code for communication. As such code is not fully accessible to the deaf, the risk of misunderstanding it may become associated with fear of providing a wrong response. Such fear is likely to be manifested as hesitation, which eventually becomes generalized also to tasks not directly related to language use.

Evidence from the two nonverbal tasks failed to unveil significant differences between native and nonnative signers. However, such uniformity may not exist when they have to process verbal

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

materials. This study tested this possibility by looking at different levels of processing verbal stimuli. As described earlier, at one level, we asked participants to process letters and words under conditions we assumed did not require access to linguistic knowledge, namely under perceptual processing conditions. We predicted that under those conditions native signers would not manifest markedly better processing skills than nonnative signers, even though they were processing materials that were in principle linguistic. This hypothesis was supported by the participants' performance with written words but not with decontextualized letters; the latter were processed by native signers significantly faster than by nonnative signers, but not more accurately. This may suggest that early exposure to native signing role models fosters processing skills that directly or indirectly also enhance the processing of letters' perceptual properties (Akamatsu, 1982; Padden, 2006).

Signs—like letters—are first and foremost visual stimuli that the perceiver has to subject to a thorough time-consuming perceptual analysis in order to bring them to a conceptual level. Some recent research with deaf signers suggests that deaf individuals' nativeness in SL determines the efficiency of such visual analysis to some degree, with native signers manifesting greater visual sensitivity to the components of signs than nonnative signers (Morford, Grieve-Smith, MacFarlane, Staley, & Waters, 2008). Provided the same sensitivity has the potential to speed up the perceptual processing of other familiar visual stimuli, such as letters, the advantage of deaf native over nonnative signers in the PL processing condition makes sense. It also explains why a similar advantage was not found in relation to the perceptual processing of the unfamiliar Hindi letters (nonverbal stimuli).

In line with our null difference hypothesis, PW processing speed and accuracy in these two signer groups were found comparable. This seems to indicate that—unlike the processing of decontextualized letters—early consistent exposure to SL does not foster visual skills that operate the perceptual processing of written words. A possible explanation for this apparent impotency is that for deaf readers, reading words and processing signs are two entirely different tasks, so they rely on skills that have evolved specifically for processing words. Such disparity in processing seems to make sense given that SL has no written form that urges its users to pay continuous attention to signs' formational components so as to map them onto the graphemes of such a system. This is in contrast to letters, which through the complementary system of fingerspelling are incorporated in SL (Padden, 2006).

Evidence regarding the performance of native and nonnative signers on the three perceptual processing paradigms seems to suggest that SL nativeness may benefit deaf individuals even when processing information under perceptual conditions. This benefit, however, seems restricted to instances where skills developed as part of SL competency are recognized as relevant for processing the information and suitable for sustaining it. To further ascertain this primary conclusion, a thorough consideration of the participants' processing skills under conceptual verbal processing conditions is required. Findings from two paradigms of this study—the conceptual processing of letters and the conceptual processing of familiar words—may yield deeper understanding in this regard.

As in the perceptual condition, processing letter or word stimuli in the conceptual condition required, as a first step, a perceptual visual analysis of the stimuli (see Jackson & Coltheart, 2001). However, making a same/different decision for two letters or words identical only conceptually (a a or apple ***apple***) required participants to go beyond this level and to access some form of conceptual knowledge (e.g., phonological, orthographic, and/or semantic representations) to resolve the visual incongruity. Interestingly, analysis of the participant groups' conceptual processing skills suggests that with regard to letters, native signing participants' advantage at the perceptual level was lost at the conceptual level. The exact reason why native signers lost their advantage is not sufficiently clear. However, it is worth investigating further the possibility that the two study groups accessed different types of representations (knowledge) to decide whether two letters were conventionally the same or not. For example, for native signers, letters may well become strongly associated with fingerspelling representations due to their use from early age in parental story reading (Padden, 1991, 2006). If this is the case, signers may have used such representations in this study for the mediation of identicalness of two conventionally identical yet visually dissimilar letters. By contrast, for nonnative signers, due to the absence of signing role models fingerspelling may be less internalized, therefore not fulfill a mediating role in processing decontextualized letters. Instead they may base such mediation on the retrieval of abstract orthographic or phonological letter knowledge, access to which is continuously practiced/automated during reading (e.g., orthographic or phonological). This is in contrast to fingerspelling, which—although used for literacy instruction in some Deaf curricula (e.g., Trezek, Wang, Woods, Gampp, & Paul, 2007)—does not seem to mediate rapid written word recognition in fluent reading (Mayberry & Waters, 1987; see also Musselman, 2000). In consequence, accessing its mental representations is not as practiced and as automated as is accessing abstract orthographic or phonological representations. Provided this scenario is true, the lost advantage of the native signers may actually reflect the price they pay for relying on a less practiced mediating strategy.

Unlike the conceptual processing of letters, which failed to distinguish native and nonnative signers, the conceptual processing of words did so in all three tested orthographies. This seems to suggest overall that processing written words down to a conceptual level is somehow enhanced by skills, knowledge, and/or experience associated with differences in SL nativeness. Most obvious in this regard may be that native signers as a group tend to enjoy better RC than nonnative signers (Chamberlain & Mayberry, 2000; Conrad, 1979; Goldin-Meadow & Mayberry, 2001; Meadow, 1968; Miller, 2010, 2013; Strong & Prinz, 1997). This superiority is likely to go together with increased motivation to engage in reading. Such an increase in reading experience, on the other hand, should sustain the native signing reader in automating his/her written word recognition skills. This may hold in particular for processing high-frequency words, such as those used as stimuli in the CW processing task of this experiment. Closer scrutiny of the analysis of participants' performance in the semantic word processing paradigm may help to further increase understanding of how SL nativeness contributes to reading at the lexical level.

The CW processing paradigm required participants to process the word stimuli beyond a perceptual level, namely to access some form of knowledge to successfully process whether two words were the same or not. However, such a decision did not necessarily lead them to process the word stimuli down to their semantics. Moreover, making such same/different decisions did not involve retrieval of world knowledge, an issue considered fundamental in trying to make sense of written connected text (a phrase, sentence, etc.). In this study, to make a semantic decision successfully (the semantic processing paradigm), the participants were required to do both: process the word stimuli down to their meaning and activate prior/world knowledge to determine their relatedness. More specifically, the semantic processing paradigm has the potential to disclose differences in the participant groups' reading skills at the lexical level in direct relation to requirements that must be considered essential for proficient reading of connected text as well.

As stated earlier, in line with LCDH (Sparks et al., 2012), we predicted that native signers would manifest more enhanced

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

semantic word processing skills than nonnative signing counterparts. This is because SL nativeness is assumed associated with high SL proficiency. Findings from this study corroborate this hypothesis with regard to both processing speed and processing accuracy. More specifically, native signers were markedly faster in determining the semantic relationship between two word concepts. In addition, they were overall less likely to make errors in this regard. This quantitative and qualitative superiority of the native signers inevitably raises the question of what exactly was gained by their SL nativeness. A closer look at the different processing stages involved in performing the conceptual, as opposed to the semantic, word processing paradigm seems to be a good starting point to answer this question satisfactorily.

Considering the two paradigms in depth, it becomes evident that some of the processing stages involved are identical, but others are not. First, in both paradigms, participants had to accomplish a thorough perceptual analysis of the words (letter strings) constituting the stimulus pairs. Secondly, they had to connect the outcome of this analysis to some form of representations/knowledge in order to make a same/different or related/not related decision. Given that significant differences between native and nonnative signers in the CW processing paradigm were restricted to speed of processing, it seems reasonable to assume that SL nativeness does not markedly enhance word recognition accuracy per se. A similar conclusion is warranted given the rather striking discrepancy in the number of errors both signer groups made in the semantic processing paradigm, its average being overall five to six times higher than that in the CW processing condition.

As stated above, unlike the CW processing paradigm, in which connecting the word stimuli to some form of linguistic representations was sufficient for making a same/different decision, in the semantic word processing paradigm participants had to go beyond this processing stage to make a decision. This assumption is directly supported by the markedly slower response times exhibited by the native and the nonnative signer groups when asked to determine the semantic relationship between two word concepts (1,491 ms) than when asked to indicate whether two words were identical or not (918 ms). It is also evident from a quite striking difference in the errors made in the CW processing condition (1.00 out of 60) as compared with the semantic (5.95 out of 40). Given the two groups' apparent equality in word recognition accuracy, in contrast to marked differences between them under conditions that required retrieval of prior/world knowledge and experience, the conclusion that SL nativeness somehow facilitates access to (speed of processing) and/or development of (processing accuracy) world knowledge, rather than sustains the encoding/processing of written words per se, seems tenable (see also Miller et al., 2012, 2013).

Language not only communicates information between people, it also seems to play an essential role in the way individuals internalize and integrate such information in long-term memory to sustain its effective retrieval when needed. Research indeed suggests that the efficiency of such processes is intrinsically linked to language proficiency, skilled language comprehenders' long-term memories being better integrated/organized, hence more easily and accurately retrievable, than those of less skilled counterparts (e.g., Zwaan & Brown, 1996). The above is likely to be true whether the language in which the information is assimilated into the individual's prior knowledge is spoken or sign. By this reasoning, the advantage of native over nonnative signers in a task that required referencing their prior knowledge makes sense. However, caution should be exercised against taking the power of SL nativeness to enhance deaf individuals' RC skills too far. As we will show later, its potency in this regard may actually be fairly marginal in the face of other much more influential factors.

An interesting question of course is whether benefits from SL nativeness found in determining a semantic relationship of decontextualized words become transferred to the processing of connected text (sentences). In particular, does SL nativeness benefit understanding SI sentences? As stated earlier, proper comprehension of this sentence category is contingent on the reader's ability properly to process the morpho-syntactic structure of spoken language, a structure that is essentially different from that of SL. In accordance with LCDH (Sparks et al., 2012), which assumes that mastery of a first language scaffolds the acquisition of a second, we predicted that native signers would manifest better sentence comprehension than nonnative signers. We further hypothesized this advantage to be particularly prominent in relation to SI sentences, the understanding of which requires their syntactic bottom-up processing.

As already stated, findings from this study corroborate that native indeed have somewhat better RC skills than nonnative signers. However, such advantages seem to appear only at more advanced grade levels. Particularly interesting is that gains from SL nativeness were not found to interact with the semantic plausibility of sentences. This actually indicates that SL does not scaffold the acquisition of structural knowledge in spoken language. Otherwise, differences between native and nonnative signers in comprehension would have proven more prominent with SI sentences than with SP sentences. It also implies that linguistic knowledge transfer predicted by LCDH (Cummins, 1979, 1989; Sparks et al., 2012) may not occur when the structural distance between languages is drastically widened due to substantial differences in the modalities of their realization (visual formational organization vs. phonological serial organization).

The above conclusion is further substantiated by evidence from a recent study (Rosenstein, Miller, & Meir, 2014) on the degree to which structural similarity between spoken Hebrew or Israeli Sign Language (ISL) and English facilitates native Hebrew speakers and prelingually deaf native ISL signers' understanding of English sentences. Findings from this study point to markedly enhanced RC in English in instances of structural similarity between Hebrew and English but not in instances of structural similarity between ISL and English.

By integrating findings yielded by the conceptual and the semantic word processing paradigm with those obtained from the RC paradigm, it becomes obvious that advantages of native over nonnative signing participants do not reflect variance originating from mastery of the structural level of spoken language. Several additional findings from this study corroborate this interpretation. Most prominent is the absence of a SL nativeness × orthographic-background interaction, suggesting that native signers are uniformly somewhat better readers in all three tested orthographies. This proved true whether they read SP or IP sentences, and despite the fact that their RC in some of the tested orthographies approached (Hebrew and Turkish) or even fell below (German) chance level. More specifically, native signers performed better than nonnative signers even when their performance—as a group—strongly suggested that they failed adequately to process the linguistic structure of the test sentences to comprehend what they read.

The focus of this paper is on the contribution of SL nativeness to deaf individuals' reading skills at different levels of processing. However, highly marked differences in performance originating from the participants' orthographic background clearly indicate that other much more dominant factors than SL nativeness have to be considered as well for a full understanding of deaf individuals' ability to process written and other types of information. This is clear from the finding that Turkish participants, native and nonnative signers alike, manifested strikingly less developed reading-related and other information processing skills than

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

participants from other orthographies. Deaf Hebrew readers, on the other hand, markedly outperformed German and Turkish counterparts in their ability to understand connected text; however, they were not more efficient in processing written information at the sublexical and lexical level. A thorough clarification of these orthography-related differences is beyond the scope of this paper. Whether their origins can be traced to features of the orthography (e.g., orthographic depth), to the syntactic complexity of the read language (e.g., German is syntactically more complex than Hebrew both with regard to word order and tense. Turkish differs markedly from Hebrew and German with regard to its morpho-syntactic structure as well as its dominant word order), or to the educational philosophy on which reading instruction is based (sign-supported or mere oral instruction), will have to be examined elsewhere (see Miller, Kargin, & Guldenoglu, 2012). Still, that the effect of SL nativeness was never found significantly to interact with the participants' orthographic background strongly suggests that these two factors contribute to reading skills in prelingually deaf individuals independently.

Conclusions, Implications, and Future Research

- Findings from this study corroborate that SL nativeness enhances the processing of written materials to some degree. Moreover, they show such gains to be independent of other factors that significantly determine prelingually deaf individuals' reading skills.
- Evidence further suggests that enhancements in reading-related skills rooted in SL nativeness do not reflect linguistic scaffolding that leads to a more effective processing of the structure of spoken language in connection to reading. Rather, such gains seem to become manifest in accelerated processing of written words from a perceptual (visual analysis) to a conceptual level (stored lexical and semantic knowledge). Whether such acceleration in the processing of written words gains from reliance on a neural structure developed in response to early extensive exposure to SL is not disclosed by findings from this study; this question should be the subject of future research.
- As SL nativeness does not seem to scaffold the structural processing of spoken language, its potential to sustain the development of proficient reading remains rather limited. This is obvious from the finding that comprehension of SI sentence by deaf native signers from all the examined orthographic backgrounds proved alarmingly poor.
- Evidence clearly indicates that deaf readers—whether native or nonnative signers—have to master the rule-based structure of spoken language to become proficient readers (Rosenstein et al., 2014). Such an achievement, however, may not be possible without systematic instruction that comprehensively externalizes spoken language's structural properties in conjunction with meaningful reading experience in order to turn reading into a tool for learning (Miller & Habib-Najjar, 2014).
- Differences between the native and nonnative signer samples at the lexical and supra-lexical reading level—although statistically significant—were far from striking. Moreover, they seemed to point to an enhanced ability of native signers to process prior knowledge but not the linguistic structure of the read language. One possibility to be considered here is that deaf native and nonnative signers alike lack metalinguistic awareness regarding the structure of SL as opposed to spoken code (C. Rathmann, personal communication, February 2014). As such awareness may not develop spontaneously, its potential to provide a gateway for the transfer of linguistic knowledge that sustains comprehension of the less dominant language is likely to be lost unless developed artificially by instruction (see Moiseyev, 2008).
- Development of metalinguistic awareness regarding the structure of SL as opposed to spoken code may lead to fuller exploitation of the potential of SL nativeness to sustain the lexical and structural processing of spoken language, in both its spoken and its written form. To determine whether this is indeed the case is a challenge for future research.

Note

1. The participants included in this study were tested within a large-scale NSF-funded international reading project that examined the reading process of different reader groups in five different orthographies.

Funding

This manuscript was prepared with the support of SLC on Visual Language and Visual Learning (VL2), NSF Grant (SBE-0541953).

Acknowledgment

We wish to thank Christian Rathmann (Hamburg University, Germany) for contributing analyzed German data.

Conflicts of Interest

No conflicts of interest were reported.

References

Akamatsu, C. T. (1982). The acquisition of fingerspelling in preschool children (UMI Dissertations Publishing, 8221594, ProQuest). The University of Rochester, New York.

Allen, T. E. (1986). Patterns of academic achievement among hearing impaired students: 1974 and 1983. In A. N. Schildroth & M. A. Karchmer (Eds.), *Deaf children in America* (pp. 161–206). Boston, MA: College-Hill.

Allington, R., & Cunningham, P. (2007). *Schools that work: Where all children read and write* (3rd Ed.). Boston, MA: Pearson.

American National Standards Institute. (1989). *Specifications for audiometers* (ANSI S3.6 - 1989). New York: ANSI.

Catts, H. W., Compton, D., Tomblin, J. B., & Bridges, M. S. (2012). Prevalence and nature of late-emerging poor readers. *Journal of Educational Psychology*, 104, 166–181.

Center for Assessment and Demographic Studies. (1993). *Data from the 1992–93 annual survey of hearing impaired children and youth*. Washington, DC: Gallaudet University.

Chamberlain, C., & Mayberry, R. I. (2000). Theorizing about the relation between ASL and reading. In C. Chamberlain, J. P. Morford & R. I. Mayberry (Eds.), *Language acquisition by eye* (pp. 221–259). Mahwah, NJ: Erlbaum.

Conrad, R. (1979). *The deaf school child*. London: Harper & Row.

Cummins, J. (1979). Linguistic interdependence and the educational development of bilingual children. *Review of Educational Research*, 49, 221–251.

Cummins, J. (1989). A theoretical framework for bilingual special education. *Exceptional Children*, 56, 111–119.

Fluss, J., Ziegler, J., Ecalle, J., Magnan, A., Warszawski, J., Ducot, B.,…Billard, C. (2008). Prevalence of reading disabilities in early elementary school: Impact of socioeconomic environment on reading development in 3 different educational zones. *Archives de Pédiatrie*, 15, 1049–1057. doi:10.1016/j.arcped.2008.02.012

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

Frost, R. (2012). Towards a universal model of reading. *The Behavioral and Brain Sciences*, 35, 263–329. doi:10.1017/S0140525X11001841

Froster, K. I., & Froster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments & Computers*, 35, 116–124. doi:10.3758/BF03195503

Gallaudet Research Institute. (2005). *Regional and national summary*. Washington, DC: Author.

Goldin-Meadow, S., & Mayberry, R. I. (2001). How do profoundly deaf children learn to read? *Learning Disabilities Research & Practice*, 16, 222–229. doi:10.1111/0938-8982.00022

Grosjean, F. (2001). The right of deaf child to grow up bilingual. *En Sign Language Studies*, 1, 110–115.

Holt, J. A. (1993). Stanford achievement test – 8th edition: Reading comprehension subgroup results. *American Annals of the Deaf*, 138, 172–175.

Holt, J. A., Traxler, C. B., & Allen, T. E. (1996). Interpreting the scores: A user's guide to the 9th edition Stanford Achievement Test for educators of deaf and hard-of-hearing students (Unpublished manuscript). Gallaudet University, Washington, DC.

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal*, 2, 127–160.

Jackson, N. E., & Coltheart, M. (2001). *Routes to reading success and failure: Toward an integrated cognitive psychology of atypical reading*. Philadelphia, PA: Psychology.

Kargin, T., Guldenoglu, I. B., Miller, P., Hauser, P., Rathmann, C., Kubus, O., & Superegon, E. (2011). Differences in word processing skills of deaf and hearing individuals reading in different orthographies. *Journal of Developmental and Physical Disabilities*, 24, 64–83. doi:10.1007/ s10882-011-9255-z

Kargin, T., Guldenoglu, I. B., Miller, P., Hauser, P., Rathmann, C., Kubus, O., & Superegon, E. (2012). Differences in word processing skills of deaf and hearing individuals reading in different orthographies. *Journal of Developmental and Physical Disabilities*, 24, 65.

Lesgold, A. M., & Perfetti, C. A. (1978). Interactive processes in reading comprehension. *Discourse Processes*, 1, 323–336.

Luckner, J. L., & Handley, C. M. (2008). A summary of the reading comprehension research undertaken with students who are deaf or hard of hearing. *American Annals of the Deaf*, 153, 6–36.

Mayberry. R. I., & Waters, G. (1987, April). Deaf children's recognition of written words: Is fingerspelling the basis? Paper presented to the Society for Research in Child Development, Boston, MD.

Meadow, K. P. (1968). Early manual communication in relation to the deaf child's intellectual, social, and communicative functioning. *American Annals of the Deaf*, 113, 29–41.

Miller, P. (2000). Syntactic and semantic processing in Hebrew readers with prelingual deafness. *American Annals of the Deaf*, 145, 436–451.

Miller, P. (2004a). Processing of written words by individuals with prelingual deafness. *Journal of Speech, Language, and Hearing Research*, 47, 979–989.

Miller, P. (2004b). Processing of written word and non-word visual information by individuals with prelingual deafness. *Journal of Speech, Language, and Hearing Research*, 47, 990–1000.

Miller, P. (2005a). Reading comprehension and its relation to the quality of functional hearing: Evidence from readers with different functional hearing abilities. *American Annals of the Deaf*, 150, 305–323.

Miller, P. (2005b). What the word recognition skills of prelingually deafened readers tell about the roots of dyslexia. *Journal of Development & Physical Disabilities*, 17, 369–393.

Miller, P. (2010). Phonological, orthographic, and syntactic awareness and their relation to reading comprehension in prelingually deaf individuals: What can we learn from skilled readers? *Journal of Development and Physical Disabilities*, 22, 549–561.

Miller, P. (2013). Similarities and differences in the processing of written text by skilled and less skilled readers with prelingual deafness. *Journal of Special Education*, 46, 233–244. doi:10.1177/0022466910386790

Miller, P., & Habib-Najjar, L. (2014, July). The development of syntactic processing skills in deaf pupils: Visualization of syntactic structures within a computerized learning environment. Paper presented at the 8th Literacy and Language Conference, University of Haifa, Haifa, Israel.

Miller, P., Kargin, T., & Guldenoglu, B. (2012). Differences in the reading of shallow and deep orthography: Developmental evidence from Hebrew and Turkish readers. *Journal of Research in Reading*, 1–24. doi:10.1111/j.1467-9817.2012.01540.x

Miller, P., Kargin, T., Guldenoglu, I. B., Hauser, P., Rathmann, C., Kubus, O., & Superegon, E. (2012). Factors distinguishing skilled and less skilled deaf readers: Evidence from four orthographies. *Journal of Deaf Studies and Deaf Education*, 17, 439–462.

Moates, L. C. (2000). *Speech to print: Language essentials for teachers*. Baltimore, MD: Brookes.

Moiseyev, E. (2008). Sign language as a bridge to literacy: A bilingual-bicultural study [in Hebrew] (Doctoral dissertation). University of Haifa, Israel.

Monreal, S. T., & Hernandez, R. S. (2005). Reading levels of Spanish deaf students. *American Annals of the Deaf*, 150, 379–387.

Morford, J. P., Grieve-Smith, A. B., MacFarlane, J., Staley, J., & Waters, G. (2008). Effects of language experience on the perception of American sign language. *Cognition*, 109, 41–53. doi:10.1016/j.cognition.2008.07.016

Musselman, C. (2000). How do children who can't hear learn to read an alphabetic script? A review of the literature on reading and deafness. *Journal of Deaf Studies and Deaf Education*, 5, 9–31.

Padden, C. (1991). The acquisition of fingerspelling by deaf children. In P. Siple & S. Fischer (Eds.), *Theoretical issues in sign language research, Volume 2: Psychology* (pp. 193–210). Chicago, IL: University of Chicago Press.

Padden, C. (2006). Learning fingerspelling twice: Young signing children's acquisition of fingerspelling. In M. Marschark, B. Schick & P. Spencer (Eds.), *Advances in sign language development by deaf children*. New York, NY: Oxford University Press.

Padden, C., & Hanson, V. L. (2000). Search for the missing link: The development of skilled reading in deaf children. In K. Emmorey & H. Lane (Eds.), *The signs of language revisited* (pp. 435–447). Mahwah, NJ: Erlbaum.

Perfetti, C. A., & Sandak, R. (2000). Reading optimally builds on spoken language: Implications for deaf readers. *Journal of Deaf Studies and Deaf Education*, 5, 32–50.

Posner, M. I., & Mitchell, R. F. (1967). Chronometric analysis of classification. *Psychological Review*, 158, 13–139.

Rosenstein, O., Miller, P., & Meir, I. (2014). Learning to read English as a third language without access to its spoken form: The case of deaf students in Israel. Paper presented at the 8th Literacy and Language Conference, University of Haifa, Haifa, Israel.

Sparks, R. L., Patton, J., & Ganschow, L. (2012). Profiles of more and less successful L2 learners: A cluster analysis study. *Learning and Individual Differences*, 22, 463–472. doi:10.1016/j.lindif.2012.03.009

Stanovich, K. E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly*, 16, 32–71.

Strong, M., & Prinz, P. (1997). A study of the relationship between American sign language and English literacy. *Journal of Deaf Studies and Deaf Education*, 2, 37–46.

Tarchi, C. (2010). Reading comprehension of informative texts in secondary school: A focus on direct and indirect effects of reader's prior knowledge. *Learning & Individual Differences*, 20, 415–420. doi:10.1016/j.lindif.2010.04.002

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021

Traxler, C. (2000). The Stanford achievement test, 9th edition: National norming and performance standards for deaf and hard-of-hearing students. *Journal of Deaf Studies and Deaf Education*, 5, 337–348.

Traxler, M. J., Corina, D. P., Morford, J. P., Hafer, S., & Hoversten, L. J. (2014). Deaf readers' response to syntactic complexity: Evidence from self-paced reading. *Memory & Cognition*, 42, 97–111.

Trezek, B. J., Wang, Y., Woods, D. G., Gampp, T. L., & Paul, P. V. (2007). Using visual phonics to supplement beginning reading instruction for students who are deaf or hard of hearing. *Journal of Deaf Studies and Deaf Education*, 12, 373–384.

Vaknin, V., & Miller, P. (2012). The importance of vowel diacritics for the temporary retention of high and low frequency Hebrew words of varying syllabic length. *Memory & Cognition*, 39, 516–526. doi:10.3758/s13421-010-0026-3

Vaughn, S., & Linan-Thompson, S. (2004). *Research-based methods of reading instruction, grades K-3*. Alexandria, VA: Association for Supervision and Curriculum Development.

Wauters, L. N., Van Bon, W. H. J., & Telling, A. E. J. M. (2006). The reading comprehension of Dutch deaf children. *Reading and Writing*, 19, 49–76.

Zwaan, R. A., & Brown, C. M. (1996). The influence of language proficiency and comprehension skill on situation-model construction. *Discourse Processes*, 21, 289–327. doi:10.1080/01638539609544960

Appendix A

Stimulus list of semantically related and unrelated word concepts—English version

Related				Unrelated			
lock	key	vegetable	potato	bug	once	net	nose
popcorn	movie	ball	play	comb	city	computer	crocodile
pudding	dessert	sand	box	sad	bone	water	office
tree	green	boy	girl	orange	mitten	hair	dream
video	camera	sticky	honey	melon	pencil	street	grape
water	cup	toe	nail	cow	hope	winter	laundry
cotton	candy	button	jacket	apple	glue	table	yellow
ski	snow	sky	blue	tent	pants	pink	cat
birthday	balloon	happy	people	thunder	parrot	paper	actor
good	news	track	train	wind	cake	truck	ear

For experimentation, the semantically related and the semantically unrelated word pairs were presented randomly mixed.

Appendix B

Examples of test sentences

Semantically plausible	Semantically implausible
One subordinate clause	
The teacher who caught Sara copying homework left the classroom.	The boy who saw the policeman stealing gum escaped through the window.
Who copied homework?	Who stole the gum?
a.Sara	a.the policeman
b.the teacher	b.the boy
The kindergarten teacher told the girl to climb the ladder in the playground.	The patient told the doctor to lie on the bed in the operating room.
Who was told to climb the ladder?	Who was told to lie on the bed?
a.the girl	a.the patient
b.the kindergarten teacher	b.the doctor
Two subordinate clauses	
The student who teased the teacher who was sitting in the park was punished by the principal.	The baby who was watching the babysitter playing in the crib got money from the mother.
Who was punished?	Who got money?
a.the principal	a.the babysitter
b.the student	b.the mother
The woman who was walking down the street gave some chocolate to the girl who helped her grandmother.	The mother who returned home gave a drink of milk to the babysitter who was watching the baby.
Who got the chocolate?	Who got the milk?
a.the woman	a.the baby
b.the girl	b.the mother
c.the grandmother	c.the babysitter

Downloaded from https://academic.oup.com/jdsde/article/20/2/147/363248 by ANKARA user on 11 December 2021