

Writing Units or Decades First in Two Digit Numbers Dictation Tasks: The Case of Arabic an Inverted Language [†]

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Abstract: This study uses the Arabic language numerical system, which differs in important ways from most other numerical systems. The numerical syntactic structure of two-digit numbers in Arabic differs mainly in its order of units and decades. In Arabic, two-digit numbers are read from right to left, i.e., the unit digit precedes the decade digit (24 = four and twenty) in accordance with direction for reading and writing text but opposite to the direction for reading and writing numbers (left to right). The current study investigated the effect of educational level and of the syntactic representation of numbers in Arabic on the task of transcoding two-digit numbers from dictation. For this purpose, it used the paradigm of writing two-digit numbers from dictation. The study participants were primary, junior-high, and high school pupils and higher education students. All spoke Arabic as their first language. They performed a transcoding task, namely writing two-digit numbers from dictation. Units first \ decades first writing patterns were collected depending on the differential syntactic structures of the two-digit number dictated (Teen numbers: units first; Identical units and decades: units first, Whole tens: decades first; Remaining two-digit numbers: units first). The findings of the current study reveal that in general Arabic speakers adopt a decades-first writing pattern for two-digit numbers especially when it is consistent with the syntactic structure of two-digit numbers as in whole-tens numbers. This decade-first writing pattern becomes more evident and consistent, in junior-high school, high school and higher education than in primary school due to improvement in mathematical skills and in second and third languages. However, this pattern is modulated by the syntactic complexity of the unit- decade structure. This complexity is more pronounced in two-digit numbers whose processing is more dependent on numerical syntax. Thus, whole-tens numbers (e.g., 40, 50), teen numbers, and identical-decade-unit numbers (e.g., 33, 44) are less complex than the remaining two-digit numbers (32, 61, 86. etc.)

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Introduction

Numbers may be presented in different ways; for example, Arabic numerals (01234567893) are distinct from number words (e.g., one, two, three) that themselves vary by language. These diverse representations evoke various mental processes that are involved in the understanding, production and calculation of Arabic numerals and verbal numbers (number words) (Dehaene, 1992).

All educated adults can shift from one notational system (number symbol) to another without substantial difficulty. They can write an Arabic numeral according to dictation or read an Arabic numeral aloud; for example, 4 is equal to ארבע in Hebrew, أربعة in Arabic, and four in English. This step of translating numbers from one context to another is called

“transcoding” or “conversion” and is considered a basic aspect of the development of number processing.

Transcoding is involved in many daily activities, such as specifying the time, reading a price, or registering telephone numbers, and it is also a prerequisite for arithmetical calculations. However, transcoding processes are not as easy as they might initially seem to be. The difficulty of transcoding is apparent in children, who require several years of practice to acquire the relevant skills (Brizuela & Cayton, 2008; Cayton & Brizuela, 2007; Noel & Turconi, 1999; Power & Dal Martello, 1990; 1997; Scheuer, Sinclair, Merlo de Rivas, & Tieche-Christinat, 2000; Seron & Fayol, 1994; Zhou, Wang, Wang, & Wang, 2006). It also occurs as a deficit in some adults with brain damage (Deloche & Seron, 1982a, b; Seron & Deloche, 1984; Seron & Noel, 1995).

Children learn the verbal number system long before they learn to read or write Arabic numerals, and this acquisition order seems to impact the transcoding process. According to the Sapir-Whorf hypothesis, language influences mechanisms of thinking. Few people nowadays accept the strong Whorfian hypothesis that language completely determines and constrains thought; but there is significant evidence for a weaker version, whereby language has some influence on certain aspects of cognition, including mechanisms of number processing (Butterworth, Reeve, Reynolds, & Lloyd, 2008; De Cruz, 2009). The structure of the verbal counting system appears to affect the difficulty of understanding numbers and using them in mathematical operations. Thus, the linguistic structure of number words, such as the order of units and decades in two-digit numbers, may influence how numbers are processed, in tasks such as in deciding which number is larger (Whorf, 1956). Therefore, recent studies of number processing have centered on how and to what degree language affects number processing (Brysbaert, Fias, & Noel, 1998; Nuerk, Weger, & Willmes, 2005).

There are many types of numerical systems around the world with different internal structures. They vary both in their lexical structure, i.e., the system of words used to represent numbers (Arabic: واحد, اثنان, ثلاثة; Hebrew: אחד, שניים, שלוש; English: one, two, three), and in their syntactic structure, i.e., how individual lexical units are composed in order to generate a larger verbal number (Comrie, 2005). In addition to the verbal number systems, there are digit number systems that also vary in their internal structure. They differ in their syntactic structure, or the order of units, decades, and hundreds, etc. Thus, the transcoding of numbers from one system (verbal or digits) to another requires control of the coding mechanisms of these verbal and digit systems. Bilinguals and multilinguals must control these transcoding processes in more than one language, which increases the complexity for them, especially when the transcoding processes differ between their languages.

The purpose of the present study is to study Arabic speakers’ transcoding from the verbal system to the digits system, in Arabic. It investigates this topic with regard to the numerical system of the Arabic language, which has several distinctive characteristics. In particular, this numerical system combines two somewhat unusual features: writing numbers in a different direction (left to right) from writing text (right to left in Arabic) and presenting tens and units in different orders in the spoken and written number systems (the inversion feature).

Cross-linguistic studies of transcoding

Different languages have different transcoding systems for numbers. Studies on transcoding between languages have provided significant insights into how language influences the acquisition of number transcoding. Although researchers have examined the transcoding system in various European and East Asian languages, very few have explored transcoding in the Arabic language. The existing research does suggest that language influences the nature and difficulty of transcoding and indicates the importance of studying transcoding in a wider variety of languages. Seron and Fayol (1994) carried out an important early study of transcoding in different languages. They tested

French and Belgian children, who had different systems of writing numbers from dictation. For example, in French, 70 and 90 are written as a complex “60 + 10,” “soixante-dix,” and “10+ (2 0 × 4)” “quatre-vingt-dix”. In Belgium, they are more transparent: “septante” and “nonante.” However, 80 is read as “4 × 20” or “quatre-vingt” in the two countries. The study found that French children made significantly more transcoding errors. Notably, these composite structures were often not combined lexically. On the contrary, the errors were often mistaking of partial lexicalization of each of the elements that comprise the decade; for example, writing the number eighty-two as 4202, 422, or 802. These errors demonstrate the strong influence of language on the acquisition of a digit number system. The task was completed through transcoding tasks that investigated the possible confounding effect of the understanding of verbal and written numbers. The results indicate that errors in transcoding tasks were significantly more likely, which was due to errors concerning the relation between the word number and digit rather than errors in reading comprehension.

Van Rinsveld & Schiltz, (2016) compared French- and English-speaking fifth-grade (10-year-old) children’s performance in number transcoding. Whereas English two-digit number names follow the decimal structure (base 10), the structure of French two-digit number words over 60 follow a vigesimal structure (base 20). Children undertook two number transcoding tasks. While children were generally successful at the tasks, English-speaking children significantly outperformed French-speaking children for numbers following a vigesimal structure in French compared to a decimal structure in English (i.e., numbers >60). These findings show that verbal number name structures influence children’s performance in numerical tasks, even though fifth-grade children have well passed the initial stage of acquiring transcoding skills for two-digit numbers. These findings highlight the importance of language specificities in number transcoding.

To date, no systematic developmental study has been published on transcoding in Arabic. However, there have been several studies of transcoding by children speaking European languages with the inversion feature, such as German and Dutch. However, in a comparison of the transcoding performance of children who speak German and French in Austria and Belgium, the error rate was higher among German-speaking children, and their types of errors were clearly related to the inversion feature in German for two-digit numbers. Additionally, German children needed more time to learn to write two-digit numbers correctly from dictation. The researchers discovered that German children have developed a unique strategy to overcome this problem: reversing the digit numbers in writing from right to left (Lochy, 2003). Transcoding is affected not only by general rules but also by linguistic characteristics (Pixner, Moeller, Hermanova et al, 2011; Zuber, Pixner, Moeller, & Nuerk, 2009). In the German language, where the unit digit precedes the decade digit, more substitution errors have been found (Zuber et al., 2009; see also Blanken, Dorn, & Sinn, 1997; Proios, Weniger, & Willmes, 2002). In contrast, fewer substitution errors were found in Japanese since its number system is highly transparent compared to that of German (Nuerk, Olsen, and Willmes, 2005). In a transcoding study in the Czech language, in which numbers can be represented as either “units-decades” or “decades-units,” this order of number words affected the number transcoding errors (Pixner et al, 2011). These findings clearly indicate that specific linguistic structures, such as the complex structure of two-digit numbers in French and the inversion feature for two-digit numbers in German, can influence number transcoding.

Imbo, Vanden Bulcke, De Brauwier, & Fias (2014) asked child speakers of Dutch (an inverted number language) and French (a non-inverted number language) to write Arabic digits to dictation. They were also given tests of language and working memory. Although the number of change errors (e.g., hearing 46 but writing 56) was equal in both groups, the number of substitution errors (e.g., hearing 46 but writing 64) was significantly higher in Dutch-speaking than in French-speaking children. Regression analyses confirmed that language was the only significant predictor of substitution errors. By contrast, aspects of

working memory components, in contrast, were the only significant predictors of change errors.

Van der Ven, Klaiber, and Van der Maas (2017) have analyzed the interaction between transcoding, math performance and working memory ability in a large sample of over 25,000 Dutch children, from kindergarten to the end of primary school, who responded to transcoding items using a computer adaptive system. Inversion errors declined with age, but did not disappear completely, even for those in the final year of primary school.

Clayton, Copper, Steiner et al (2020) investigated the writing of two-digit numbers in 5–7-year-old English- and German-speaking children during their first year of formal education. They were interested in the influence of number word inversion at the item level on number writing. As in previous studies, they found that German-speaking children made more inversion errors for numbers larger than 20 than English-speaking children. Though English-speaking children were less likely than inversion errors in English-speaking children. These errors occurred more often for number words that are inverted at the item level, i.e., teen numbers. Thus, inversion errors are commoner for inverted spoken number words, even in a language where most number words are not inverted:

Transcoding and models of number processing

One aim of the present study was to investigate whether the participants' performance was compatible with any or all of several models of transcoding and number processing, which had been developed with regard to speakers of European languages. These models are listed in Table 1 and will be briefly described here. Dehaene, Dupoux, and Mehler (1990) proposed the *triple code model*, which posits that transcoding employs auditory-verbal representation. This model includes a direct route between different numerical representations; thus, verbal and Arabic numerals can activate phonological representation of the words directly without the semantic mediation or indirectly through semantic mediation (Dehaene, 1989; Dehaene et al., 1990; Dehaene et al., 1993).

McCloskey (1992) proposed the abstract modular model, which consists of two systems – one of number production and the other of comprehension (verbal format and numerical format) – in addition to the central abstract representation of numbers, wherein the quantity is represented by a set of position and value consisting of the exponents of 10. According to this model, the first step in producing a verbal number is the creation of a syntactic pattern of the number from its semantic representation.

Campbell (1994; Campbell and Clark, 1992) proposed the encoding complex model, whereby specific codes of the format and modality represent the numbers (see Table 1). Noel and Seron (1997) proposed the existence of intermediate representations (IR) that relate to the lexical representations of numbers and their numeric representation (see Table 1). For example, 24 activates the IR of (4 + 20, four-and-twenty) in Arabic and (20 + 4, twenty-four) in English and Hebrew.

Power and Dal Martello (1990), on the basis of their study of number transcoding by Italian primary school children, proposed a Lexical-Semantic model, based on verbal input for writing numbers from dictation. The model includes a comprehension stage for numbers, which converts the perceived verbal number into semantic representation, followed by a production phase. They postulated that this semantic representation reflects the structure of the verbal number and the number's basic components (e.g., units and decades) in an embedded number sum. This semantic representation then becomes the appropriate digit numeral in the production phase.

The two remaining models are asemantic. In contrast to semantic models, asemantic transcoding models do not require a magnitude representation when transcoding from one numerical notation to another. Deloche and Seron (1987) proposed a model in which the transcoding of digit numbers into verbal numbers can occur through a direct route without the mediation of abstract representation. The model distinguishes between four stages of processing. First, the analysis of the digit number starts from the right. Then,

the process of categorization specifies the necessary parameters to implement the rules of transcoding, i.e., those related to the group and the position of the lexical numerical elements. Then, the transcoding process itself assumes the order of the numbers from the right place to fill the frame with slots with digits. Finally, at the production stage, a full number is stated.

Barrouillet, Camos, Perruchet, and Seron (2004) proposed an asemantic procedural transcoding model called ADAPT, wherein the transcoding of verbal numbers into digit numbers is initially performed with algorithmic strategies that are later replaced by the direct memory retrieval of numerical forms. When a person hears a verbal number, this string is stored in the database of phonological working memory. Then, the number string is divided into units so that each unit is the largest unit that is accessible in the long-term memory that fits its input. These units are subsequently processed sequentially through the production system. This transcoding process creates no semantic representation. Lexical errors are the result of difficulties in retrieving correct digit numbers from the long-term memory depending on the number of fetches that are required. By contrast, syntactic errors involve incorrect placement and ordering of the digits, e.g. reversal of tens and units.

Table 1. Summary of number processing models and their predicted units first \ decades first writing patterns in two-digit numbers transcoding to dictation.

Number processing Model	Number representations, Formats, Codes, elements	Semantic representation	Format dependent (verbal, numeric)	Transcoding process	Expected units first \ decades first writing patterns
The Triple Code	Auditory-Verbal Numeric-Verbal Analog	No	No	Direct	Units First
Deloche and Seron	Analysis Categorization Implementation Production	No	Yes	Direct	Units First
ADAPT	Memory	No	Yes	Direct	Units First
Abstract Modular	Comprehension Production	Yes	No	Abstract representation	Decades First
The Encoding Complex	Verbal Non-verbal	No	Yes	Reading dependent	Units First
Intermediate Representations-IR	Lexical Syntactic	Yes	Yes	Intermediate representation dependent	Units First
Power and Dal Martello	Comprehension Production	Yes	No	Lexical-semantic representation	Units First

Characteristics of the number system in Arabic

Arabic uses a digit system for writing numbers: most commonly with Hindi rather than Arabic digits. The written numeral system (Arabic-Hindi digits: ٠١٢٣٤٥٦٧٨٩ and Arabic-Arabic digit numerals: 0123456789) is a variant of the base-ten number system used in most literate countries and considered to be highly effective for representing numbers (Butterworth, 1999, Nuerk & Willmes, 2004, Zhang & Norman, 1995) because it uses a single base dimension and the dimension of power. The base dimension is represented by the shape of the 10 digits, and the power dimension refers to the position of the digit in the number that affects its value (Zhang and Norman, 1995). The 10- numbers from 0 to 9 are easy to learn. For example, the number 4 can relate to the magnitude of "four" (4), "forty" (40), or "four hundred" (400). Understanding the position-value system in the digit number system is essential to engage with multi-digit numbers, and it is part of one representation of the extended version of the triple code model (Nuerk, Graf, & Willmes, 2006). Therefore, the system of digit numbers has not only a small lexicon but also an effective and simple syntax, which together enable the representation of numbers both quickly and clearly and simplify calculations.

According to the number taxonomy that Deloche and Seron (1982) have proposed, word numbers in Arabic include lexical elements that are arranged in groups of units, tens, hundreds, and multiples "مئة" or "ميه" (one hundred) and " ألف " (thousand) to represent the values of a number by its syntax. In two-digit numbers, lexical elements are organized in a name-value system: a digit number receives its value according to its name rather than its position in the acoustic sequence. For example, the digit number 5, which is in the fifth place in different groups, is known as "خمسة" (five) as a unit and as "خمسين" (fifty) as a decade. In 15, it belongs to another group and is called "خمسة عشر - خمستعش" (fifteen). To represent all possible numbers, these elements are combined or multiplied by addition, e.g., "خمسة عشر" (خمستعش) (fifteen) corresponds to "خمسة + عشرة" (five + teen), or multiplication, e.g., "خمسة مئة" (خمسمية) (five hundred) corresponds to "خمسة × مئة". As with many other number systems, children who are beginning to count must memorize the words of one-digit numbers from one to nine and, subsequently, the number words for 10, 11, and 12. The word numbers for 13 to 19 can be derived from the one-digit word numbers, whereas the word numbers for 11 and 12 are not consistent, e.g. "11-أحد عشر" "1-واحد" "2-إثنين" (تنين اثنين) "but -12-إثنا عشر" (تناش اتنا عش) and "11-أحد عشر" (حداش احد عش). This inconsistency is probably due to the historical 12-based number system, and it tends to cause difficulties for young children who are learning to count numbers of tens. This is also a feature of other Middle Eastern and most European number systems, whereas Chinese and other East Asian number systems are more transparent from 10 onwards (Miller & Stigler, 1987).

After learning the teens (11-19), Arabic-speaking children must also memorize the names of whole tens (20, 30, 40...) that are identical or similar to one-digit word numbers adding the suffixes "ون \ ين" at the end (6=ستة, 60=ستة+ين = ستين \ ستة+ون = ستون). Moreover, the order of unit and decade word numbers in two-digit numbers is reversed in Arabic; for example, 18 is called "ثمانية عشر" (ثمانية عشر \ ثمان عش) and 27 is called "سبعة وعشرين". German word numbers have the same feature of inversion as Dutch, Danish, and sometimes Norwegian and Czech.

Hence, the sequence of number words affects the way in which the numbers are processed. Another complexity is that this inversion feature is inconsistent and differently affects the reading direction of two-digit and multi-digit numbers. Three- and four-digit numbers are read from the left-most digit (thousands or hundreds) to the unit digit and then and finally to the decade (e.g., 524 is read in Arabic as "five-four-hundred-and-twenty" ("خمسة مئة وأربعة وعشرين \ خمسمية وأربعة وعشرين"). Therefore, the name-value system of two-digit numbers of changes into a position-name-value system, which on the one hand is more consistent with position-value system digit numbers but on the other hand also complicates the understanding of the whole numerical system. For numbers with five

digits, the first two digits are reversed again. This inversion feature is especially confusing for young children, and German first graders sometimes perform inappropriate inversion overgeneralization to multi-digit numbers, which leads to substitution errors (Zuber et al., 2009).

The present study

As discussed above, many linguistic differences have emerged for various numerical tasks, but only a few number processing studies have engaged with the Arabic language (Everett, 2005; Nuerk, Weger & Willmes, 2005). The present study investigates the special Arabic numerical system, wherein numbers in general and two-digit numbers in particular differ syntactically from the numerical systems of most other languages. The syntactic structure of numbers in Arabic mainly differs in terms of the order of units and decades. In Arabic, two-digit numbers are read from right to left, i.e., the first digit is the units and the second is the decades (24 = four and twenty) but maybe written from right to left, i.e., the first digit is the units and the second is the decades or reverse from left to right, i.e., the first digit is the decades and the second is the units. Reversing the order of units and decades in Arabic is a basic, inherent feature for two-digit and multi-digit numbers (Ganayim & Ibrahim, 2014; Ganayim & Ibrahim, 2015). Notably, in Arabic, this inverted order of units and decades (Right to Left) occurs in the same direction of the reading and writing of words (Right to Left). In other languages, such as Hebrew and German, the direction of reading words (Hebrew: Right to Left, German: Left to Right) and two-digit numbers is the opposite (Hebrew: Left to Right, German: Right to Left), and in English, they both occur from left to right. Shaki, Fisher, and Petrusic (2009) have claimed that the language and the reading direction of words and numbers in particular can affect the spatial mapping of the number line.

Objectives and hypotheses

This study investigates the effect of the syntactic representation of numbers in Arabic on the task of transcoding two-digit numbers from dictation. For this purpose, it uses the paradigm of writing two-digit numbers from dictation (Brizuela & Cayton, 2008; Cayton & Brizuela, 2007; Power & Dal Martello, 1990; Scheuer, Sinclair, Merlo de Rivas, & Tieche-Christinat, 2000; Zhou, Wang, Wang, & Wang, 2006). The study participants were primary, junior-high, and high school pupils and higher education students with Arabic as their first language. They carried out a transcoding task, namely writing two-digit numbers from dictation. The two-digit numbers were in four categories: whole-tens numbers (e.g., 40, 50); teen numbers (e.g., 13, 15), identical-decade-unit numbers (e.g., 33, 44) and the remaining two-digit numbers (32, 61, 86. etc.).

We predict firstly that, for at least some numbers, participants will use a units-first writing pattern for numerals, rather than the standard tens-first for at least some numbers. This has previously been found for another language, German, with the inversion feature (Lochy, 2003); and might be expected to be even stronger in Arabic because of the right-to-left writing direction for text in general and number words in particular. Secondly, we predict that the syntactic complexity of the structure of the number words will influence the likelihood of participants using the decades-first versus the units-first writing direction. Thus, participants should predominantly use the decades-first order for whole-tens numbers but may use the units-first strategy for other numbers and are particularly likely to do so for the 'remaining two-digit number' category of numbers that are neither whole-tens numbers, teen numbers nor identical-decade-unit numbers.

Thirdly, we predict a developmental shift. such that older participants will be increasingly more consistent in using decades-first writing strategies, and in particular, that primary school pupils will be more likely to use units-first strategies, especially for numbers in the 'remaining two-digit number' category, than those in junior high school, high school, and higher education. This is both due to the fact that, with increasing exposure

to number reading and writing as people progress through education, the standard decades-first writing strategy is likely to become more automatized, and because working memory increases with age. It is likely that the decades-first writing strategy demands place a significant load on working memory, due both to the inconsistency between expected number writing and text writing patterns, and to the inversion feature. Therefore, younger participants with lower working memory are likely to find it more difficult to use and may therefore be more likely than older participants to adopt the units-first strategy.

We also hope that the results may contribute to assessing the validity of different models, summarized above, and listed in Table 1. The table gives the predicted writing order for writing decades and units, according to the different models. The task here may not in fact be highly sensitive to most differences between the models, as most models would predict similar results: however, it can discriminate successfully between McCloskey's (1992) abstract modular model and the rest.

Most of the models would predict a decades-first strategy for whole-tens words and a units-first strategy for the other categories. This would be expected to be the case for Dehaene, Dupoux, and Mehler's triple-code model (1990), since the transcoding process occurs in a direct route according to the phonological activation, with no need for a semantic representation; for Campbell & Clark's (1992) encoding complex model, and Noel & Seron's (1997) IR model, since in both the latter cases, since the transcoding process depends on the specific (verbal or numerical) codes of the format and modality Power & Dal Martello's (1990) model predicts the same, despite being format-independent, since the transcoding process occurs within a semantic representation that reflects the structure of the verbal number and its basic components (e.g., units and decades).. The same is true of Deloche and Seron's (1987) model, since the transcoding process occurs through a direct route with no need for a semantic representation and of the ADAPT model of Barrouillet, Camos, Perruchet, and Seron (2004), since the transcoding process depends on the accessibility of word numbers and digit numbers in long-term memory. The one model that would predict a consistent decades-first writing pattern is McCloskey's (1992) abstract modular model of McCloskey (1992) since it is independent of the number format (verbal, numeric) and the semantic representation of numbers is created from left to right according to the exponent of 10.

Method

Participants: There were 287 participants in total. They included 77 pupils (56 male, 21 female) from primary school, 66 pupils (52 male, 14 female) from junior high school, 72 pupils (45 male, 27 female) from high school and 72 students (38 male, 34 female) from higher education. The primary school children included four children from grade 1, 11 from grade 2, 12 from grade 3, 18 from grade 4, 23 from grade 5 and 9 from grade 6. The junior high pupils included 16 from grade 7, 28 from grade 8 and 22 from grade 9. The high school pupils included 24 from grade 10, 18 from grade 11 and 30 from grade 12. In the Israeli school system, school begins at age 6 so grade 1 pupils are aged 6 to 7, grade 2 pupils aged 7 to 8, and so on until grade 12, where pupils are aged 17 to 18.

All participants lived in Arab-majority areas of Israel and spoke Arabic as their first language (L1). According to teachers' and parents' reports, none of them suffered from specific difficulties in mathematics or other academic issues.

Materials and procedure

Task: The transcoding tasks consisted of the writing of digit numbers pre-recorded by the experimenter. Participants transcribed two-digit numbers from dictation. Numbers ranged from 12 to 99 100 and included 8 numbers from each of four two-digit number categories: (1) Teen-numbers: 12-13-14-15-16-17-18-19, (2) Identical-units-decade numbers:

22-33-44-55-66-77-88-99, (3) Whole-tens numbers-20-30-40-50-60-70-80-90 and (4) The remaining two-digit numbers: 26-37-48-59-61-72-83-94. The order in which numbers were presented was random for each participant.

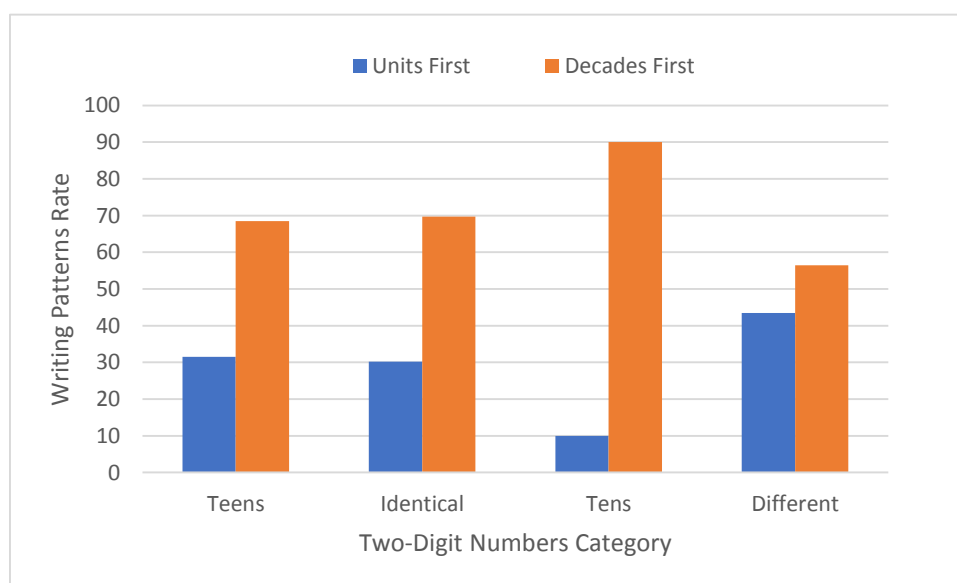
Procedure: The experimenter tested each participant individually in a quiet room. Participants and the experimenter were seated at a table so that participants could not read the comments that were written about their performance. Participants did not receive any feedback about their answers. They could request a short break during the test if they desired one.

For the transcoding task, participants were asked to write digit numbers from dictation. In this task, participants were asked to write numbers from dictation on a blank sheet of white paper (A4). A pre-recorded experimenter dictated one two-digit number at a time to the participants. If necessary, e.g., if the participant did not hear the number, the experimenter replayed the dictated number again. During the number writing task, the experimenter noticed whether the participant wrote the units first or decades first.

Results

The units first and decades first writing pattern rates were calculated according to the four number categories – teen numbers, identical-unit-decade numbers, whole-tens numbers and the remaining two-digit numbers – as a function of educational level -primary, junior high, high, and higher education. A mixed-repeated measures analysis of variance (Mixed-RM-ANOVA) was conducted for the units first and decades first writing pattern rates, with number category as the within-subject variable and educational level as the between-subject variable.

There was a significant main effect of number category was observed ($F [3,849] = 46.85, MSE = 5.47, p < 0.0001$). In a post-hoc analysis of paired comparisons for the units first (right to left) writing pattern rate, this pattern was more frequent for the remaining two-digit numbers than for teen numbers or identical decade-unit numbers, which did not differ significantly from one another in this respect, and in turn showed a higher units-first writing pattern rate than whole-tens two-digit numbers that elicited the lowest number of units-first responses (see Figure 1).



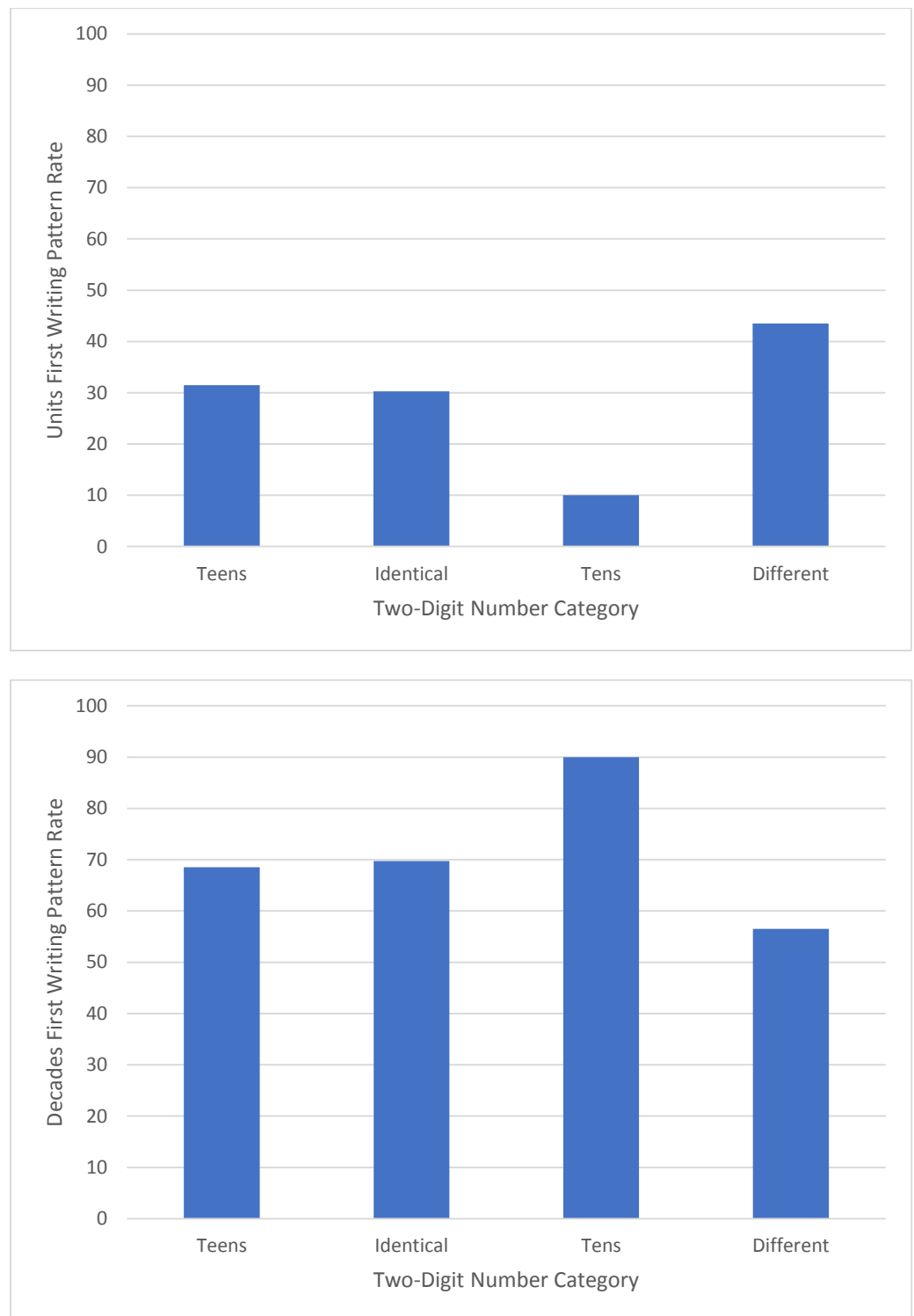


Figure 1.

There was a significant main effect of educational level: - ($F [3,283] = 262.4$, $MSE = 95.74$, $p < 0.0001$). In a post-hoc analysis of paired comparisons of the units first (right to left) writing pattern rate was higher for primary school pupils than for junior-high or high school pupils, who did not differ from one another, and showed higher rates than that for higher education students (see Figure 1).

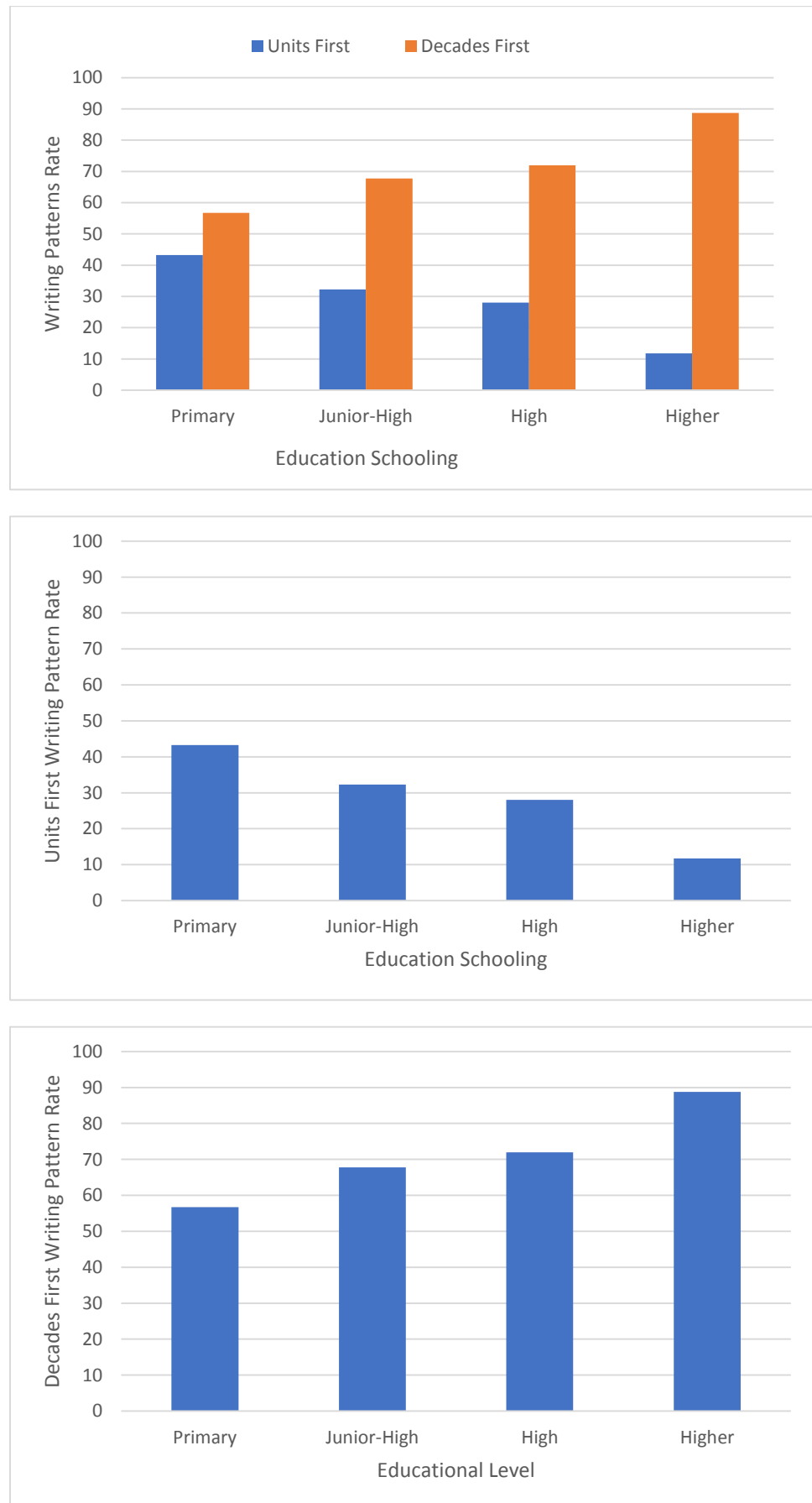


Figure 2.

Figure 3 shows a significant interaction between educational level -primary versus junior high versus high school versus higher education and number category – teen numbers versus identical-unit- decade numbers versus whole-tens numbers versus the remaining two-digit numbers ($F [9,849] = 2.23$, $MSE = 0.26$, $p < 0.05$). In a post-hoc analysis of paired comparisons of the units first (right to left) writing pattern rates in primary school pupils: the rate was higher for the remaining two-digit numbers than for teen numbers or identical- units- decade numbers, which did not differ significantly from one another, and showed higher rates than for whole-tens numbers (see Figure 3). Similar findings were obtained for higher education students. For both junior high and high school pupils, the units-first writing pattern rate did not differ significantly between teen numbers, identical-unit-decade numbers, and the remaining two-digit numbers; but was higher for each of these categories than for whole-tens numbers. .

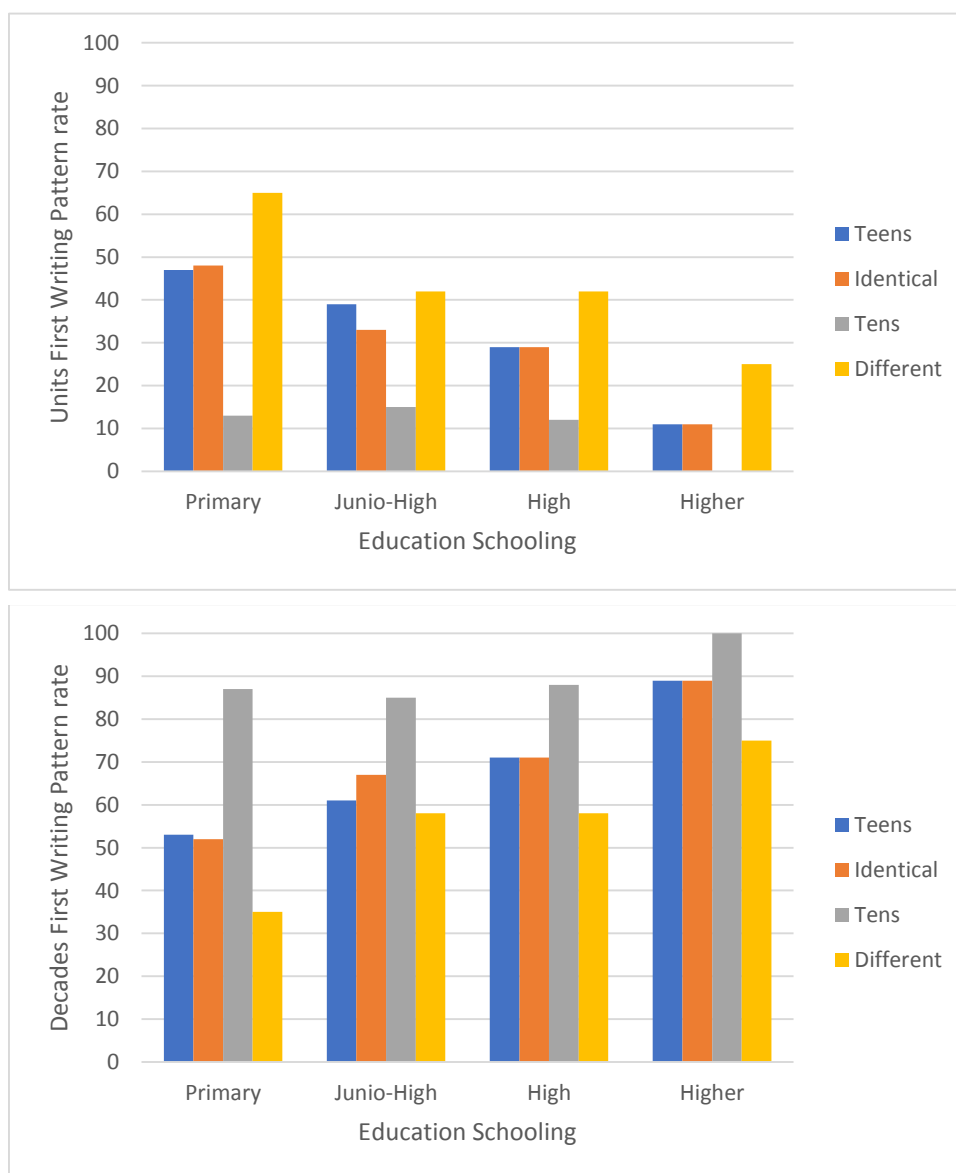


Figure 3.

Discussion

The current findings suggest that, in general, Arabic speakers adopt the decades-first writing pattern in most transcoding of two-digit numbers . They used the decades-first writing pattern for 78% of items and the units-first writing pattern for only 22% of items.

Thus, our first prediction was only partially supported. The participants did use the units-first pattern for a significant minority of items, which probably would not occur in most other languages for participants beyond the first year or two in primary school, though a direct comparison of different language groups on the same task would be desirable in future research. However, they used the decades-first pattern much more frequently,

This pattern is in line with a recent study by Hayek, Karni, & Eviatar, (2019), which showed that native speakers of Arabic performed better in a digit writing task requiring the transcoding of number-words into numerals, when the numbers were presented in the non-inverted format (HDU), a format that is nonstandard in Arabic, compared to transcoding numbers presented in the inverted, standard, format of Arabic (HUD). Hayek et al (2019) also showed that when the stimuli were presented (in both modalities) in the HDU format, speakers of Arabic made very few changes in the writing direction: writing the digits in the same order that they heard or saw them. However, when the number words were presented in the standard, inverted, format in Arabic (with units and decades reversed, HUD), only 14/46 participants consistently (in 95% or more of the trials) wrote the numbers in the order of hundreds, decades then units, in one or both modalities. Most speakers of Arabic tended (in 3 or more of the 23 trials of the test block) to write the hundreds, leave a space, write the units, and then enter the decades into the space. This form of writing multi-digit numbers was never observed in by native speakers of Hebrew (which lacks the inversion feature), even when presented with number words in the reverse-order HUD format (either in Hebrew or in English).

Our second prediction was supported: Number category – teen numbers, whole-tens numbers, identical-unit-decade numbers, or the remaining two-digit numbers – affected the direction of number writing. Units first (right to left) writing pattern rates were higher for the remaining two-digit number category than for teen numbers or identical-unit-decade numbers, which were in turn higher than for whole-tens numbers. Thus, that the syntactic structure of the numerical system (order of units and decades) of Arabic language especially of whole tens (decades first- ستون = ستة+ون = ستين \ ستة+ين = ستة=60, ستة=6) and remaining different two-digit numbers (units first- 40+6 = ستة واربعون) affects the transcoding process in the two-digit number writing from dictation task differentially. Since whole-tens numbers are dictated with decades first, even primary school pupils adopt the decades-first writing pattern (Left to Right) as in standard pattern for number writing but in the opposite direction to text writing (Right to Left) in Arabic. For the remaining two-digit number category, primary school pupils adopted the units first writing pattern (Right to Left) as in text writing but unlike the standard number-writing direction. Though older participants made predominant use of the decades-first strategy even for the remaining two-digit number category, junior-high pupils, high school pupils and even higher education students used the units-first writing pattern more frequently for this category than for the other categories.

There is a similarity between the performance of the participants in the current study and Arabic-Hebrew bilingual adults of a recent study by Ganayim, Ganayim, Dowker & Olkun (2020). In this recent study, the paradigm of reading and writing two-digit numbers from dictation, in both languages was used. Sixty university bilingual students were given two tasks in both Arabic and Hebrew: One task involved writing two-digit numbers to dictation, and the other involved reading two-digit numbers aloud. Reading times and the error rates were calculated in both languages according to type of error – total errors, substitution errors, change errors, and omission errors. The participants made some errors in reading and especially in writing two-digit numbers. Their commonest errors were substitution errors compared to change and omission errors. Such errors were commoner for numbers which require processing the numerical syntactic structure than for decade numbers, or numbers from 11 to 19, which require less attention to numerical syntax. The same was found in another recent study by Ganayim, Ganayim, Dowker & Olkun (in

press) with first graders suggesting particular difficulty with the syntactic rather than lexical aspects of the counting system. The syntactic aspects may be particularly difficult for Arabic-speaking children, due to the inversion feature of the Arabic counting system.

Our third prediction was also supported: there were differences between participants of different ages and educational levels. The rate of use of the units-first (right to left) writing pattern was highest for primary school pupils, who actually used it for a majority of items in the 'remaining two-digit number' category. Junior high and high-school pupils were similar to one another with regard to the rate of use of units-first and decades-first writing patterns, while higher education students were the most consistent in their use of the decades-first pattern and least likely to use the units-first pattern. It appeared that the older pupils and the higher education students were less readily influenced in their number writing by the syntactic structure of the particular numbers dictated, because of both greater mathematical proficiency, and greater flexibility in separating oral and written number patterns as a result of experience with a second language (Hebrew) and a third language (English), with different directions of number and text writing and different syntactic structures for number words. In Hebrew, as in Arabic, text writing is from right to left and the standard number writing pattern is from left to right, but, unlike Arabic, the inversion feature is not present and decades precede units in number words (except teen words). In English, unlike both Hebrew and Arabic, text writing is from left to right; as with both the other languages, the standard number writing pattern is from left to right; and, as in Hebrew but not Arabic, the inversion feature is not present, and decades precede units in number word (except teen words). This exposure to several different number representation systems may reduce the rigidity of associations between the syntax of number words and numeral combinations. Also, improvements in working memory may lead to greater proficiency, not only the ability to remember the lexical elements and their sequence, but also through the ability to manipulate the sequence of digits in multiple formats and verbal notations (Barrouillet & Lepine, 2005; Camos, 2008; Zuber et al., 2009). It has been proposed that in a transcoding task, when decades come after units and the order needs to be reversed, there are larger demands on working memory processes (Barrouillet et al., 2004).

Junior high school pupils, high school pupils and higher education students are more proficient than primary school pupils in mathematics, in their second language of Hebrew (where text is written from right to left, numbers are written from left to right, and there is a decades-units syntactic structure) and in their third language of English (where text is written from-left to right, numbers are written from left to right, and there is a decades-units syntactic structure). By this stage, they depend less on the syntactic structure of two-digit numbers (the order of units and decades) induced by dictation and are thus more likely to use decade-first writing patterns for all numbers. Thus, their writing patterns at this stage are consistent with McCloskey's (1992) abstract modular model, and inconsistent with the other models. These patterns require them not only to remember the lexical elements and their sequence, but also to manipulate the sequence of digits in multiple formats and verbal notations (Barrouillet & Lepine, 2005; Camos, 2008; Zuber et al., 2009). It has been proposed that such transcoding tasks, where decades come after units and the order needs to be reversed, place a greater load on working memory. (Barrouillet et al., 2004). Thus, the move with age to decades-first writing patterns may involve not only greater mathematical and linguistic expertise, but improvements in working memory. Further studies should investigate the relationships between unit- versus decade-first number-writing patterns and performance on working memory tasks; and also look at whether performance on transcoding tasks is influenced by interference with phonological working memory, for example through articulatory suppression (Hitch, 1978).

An interaction was observed between educational level -primary, junior high, high school or higher education and number category – teen numbers, whole-tens numbers, identical-unit-decade numbers . and the remaining two-digit numbers. In primary school

children, the units first (right to left) writing pattern rate was higher than for the remaining two-digit number category than for teen numbers or identical unit-decade numbers, and was higher for both than for whole-tens numbers. This was also true of the higher education students, though their overall rates of usage of the units-first strategy were much lower. For both junior high and high school pupils, the rate of use of the units-first strategy was higher for numbers in the remaining two-digit number category than for any of the other categories, which did not differ from one another.

One possible limitation of the study with regard to effects of differences in educational level is that the educational levels, especially primary school, were quite broadly defined and included a fairly wide age range within each level. Future studies should include a finer-grained investigation of primary school children's progress from age 6 to 12.

The results support the findings for European languages that indicate that transcoding is affected by not only general factors but also linguistic ones (Pixner et al, 2011; Zuber, et al 2009). The findings of the present study clearly indicate that the complicated linguistic structure of two-digit numbers in Arabic and its inversion feature affect the transcoding of numbers from one notational format to another (Van Rinsveld, and Schiltz, 2016).

The differential influence of the syntactic structure on the units first \ decades first writing pattern in the transcoding task (writing from dictation) is consistent with most of the proposed models, only ruling out the abstract modular model, which would predict a consistent decades-first response. More research needs to be done to compare the validity of the other models for different number systems.

To summarize, the findings of the current study indicate that in general Arabic speakers adopt a decades-first writing pattern for two-digit numbers. especially when this is consistent with syntactic structure of two-digit numbers. as in whole-- tens numbers. This decades-first writing pattern becomes more consistent as students more beyond primary school to junior-high school, high school, and higher education. However, this pattern is modulated by the complexity of the numerical syntactic structure and, we propose, by the working memory capacity that it requires. This complexity is less marked in whole-tens numbers, teen numbers and identical-decade-unit numbers than in the remaining two-digit numbers. The writing pattern in transcoding also seems to be influenced by the level of consistency between the reading direction for text, the reading direction for two-digit numbers and the taught direction for writing two-digit numbers.

These findings have some implications for mathematics education. They imply that educators should give attention to children's mastery of the transcoding of verbal word two-digit numbers into Arabic digits and especially to their writing patterns for two-digit numbers (decades-first or units-first) . This is especially true of languages with counting systems with the unit-decade inversion feature. The clear impact of the unit-decade inversion feature of two-digit number transcoding has implications for the planning of future mathematics curricula and textbooks.

The initial stage of teaching transcoding to Arabic-speaking children, and possibly other speakers of languages with inverted counting systems should begin with the whole-tens numbers, which elicit the decades-first writing pattern and require mainly just short-term memory rather than working memory. Pupils should then move to teen numbers and identical unit-decade numbers and then to the remaining two-digit numbers since the latter numbers make the greatest demands on working memory and on processing the numerical syntactic structure. We conclude that an earlier focus on two-digit number transcoding (starting in first and second grade) may have positive effects on the development of numeracy since it would give children an earlier start in grasping the difficult syntactic structure of two-digit numbers and might thereby improve their ability to deal more complex mathematical tasks involving two-digit and multi-digit numbers.

References

1. Barrouillet, P., Camos, V., Perruchet, P., & Seron, X. (2004). ADAPT: A developmental, asemantic and procedural model for transcoding from verbal to Arabic numerals. *Psychological Review*, *111*, 368-394.
2. Blanken, G., Dorn, M., & Sinn, H. (1997). Inversion errors in Arabic number reading: is there a nonsemantic route? *Brain and Cognition*, *34*, 404-423.
3. Brizuela, B. M., & Cayton, G. A. (2008, October). *Interpretación y producción de numeros en niños de 5 a 7 años de edad a través de diferentes sistemas de representación: análisis factoriales* [Interpretation and production of numbers in 5–7-year-old children through different representational systems: Factorial analyses]. Paper presented at the 4th International Conference on Writing, Speech, and Context. Querétaro, México.
4. Brysbaert, M., Fias, W., & Noel, M.P. (1998). The Whorfian hypothesis and numerical cognition: is „twenty-four“ processed in the same way as „four-and-twenty“? *Cognition*, *66*, 51-77.
5. Butterworth, B. (1999). *The mathematical brain*. McMillan, London.
6. Butterworth, B., Reeve, R., Reynolds, F., & Lloyd, D. (2008). *Numerical thought with and without words: Evidence from Indigenous Australian children*. Proceedings of the National Academy of Sciences of the USA, *105*, 13179–13184.
7. Campbell J. I. D. (1994). Architecture of numerical cognition. *Cognition*, *53*,1-44 .
8. Campbell J. I. D. & Clark J.M. (1992) . Cognitive Number processing: An Encoding – Complex Perspective. In J.I.D. Campbell (Ed.), *The nature and origin of mathematical skills* (pp:457-491) . Amsterdam: North Holland .
9. Cayton, G. A., & Brizuela, B. M. (2007). First graders' strategies for numerical notation, number reading and the number concept. In J.-H. Woo, H.-C. Lew, K.-S. Park, & D.- Y. Seo (Eds.), *Proceedings of the 31st Annual Meeting of the International Group for the Psychology of Mathematics Education* (vol.2, pp. 81-88). Seoul, Korea: Seoul National University.
10. Clayton, F. J., Copper, C., Steiner, A., Banfi, C., Finke, S., Landerl, K., & Göbel, S. M. (2020). Two-digit number writing and arithmetic in Year 1 children: does number word inversion matter? *Cognitive Development*, *56*, [100967]. <https://doi.org/10.1016/j.cogdev.2020.100967>
11. Comrie, B. (2005). Endangered numeral systems. In J. Wohlgemuth and T. Dirksmeyer (Eds.), *Bedrohte Vielfalt: Aspekte des Sprach(en)tods [Endangered diversity: Aspects of language death]*. Berlin: Weisensee Verlag.
12. Damian, M. F. (2004). Asymmetries in the processing of Arabic digits and number words. *Memory & Cognition*, *32*, 164-171.
13. De Cruz, H. (2009). Is linguistic determinism an empirically testable hypothesis? *Logique & Analyse*, *208*, 327-341.
14. Dehaene S. (1989) . The psychophysics of numerical comparison: A reexamination of apparently incompatible data. *Perception & Psychophysics*. *45*(6), 557-566.
15. Dehaene, S. (1992). Varieties of numerical abilities. *Cognition*, *44*, 1–42.
16. Dehaene S., Bossini, S., & Giraux, P.(1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: Learning ,Memory and Cognition*, *21*, 314-326.
17. Dehaene S. ,Dupoux E. & Mehler J. (1990) . Is numerical comparison digital? Analogical and symbolic effects in two-digit number comparison. *Journal of Experimental Psychology : Human Perception and Performance*. *16*(3), 626-641.
18. Deloche, G., & Seron, X. (1982a). From three to 3: a differential analysis of skill in transcoding quantities between patients with Broca's and Wernicke's aphasia. *Brain*, *105*, 715-733.
19. Deloche, G., & Seron, X. (1982b). From one to 1: An analysis of a transcoding process by means of neuropsychological data. *Cognition*, *12*, 119-149.
20. Deloche, G., & Seron, X. (1987). Numerical transcoding: A general production model. In G. Deloche & X. Seron (Eds.), *Mathematical disabilities: A cognitive neuropsychological perspective*. Hillsdale, NJ: Erlbaum, 137-179.
21. Dewaele, J. M. (2007). Predicting language learners' grades in the L1,L2,L3 and L4:The effect of some psychological and socio-cognitive variables. *International Journal of Multilingualism*, *4*, 169–197.
22. Everett, C. (2005). Independent cross-cultural data reveal linguistic effects on basic numerical cognition. *Language and Cognition*, *5*(1), 99-104.
23. Ganayim, D., & Ibrahim, R. (2014). Number processing of Arabic and Hebrew bilinguals: Evidence supporting the distance effect. *Japanese Psychological Research*, *56*(2), 153 – 167. DOI: 10.1111/jpr.12035
24. Ganayim, D., & Ibrahim, R. (2015). Number processing in Arabic and Hebrew bilinguals: Evidence supporting the compatibility effect. *Journal of Cross- Cultural Psychology*, *46*(4), 565-578. doi: 10.1177/0022022115573316
25. Ganayim, D., Ganayim, S., Dowker, A., & Olkun, S. (2020). Linguistic Effects on the Processing of Two-Digit Numbers. *Open Journal of Modern Linguistics*, *10*, 49-69. <https://doi.org/10.4236/ojml.2020.101004>
26. Ganayim, D., Ganayim, S., Dowker, A., & Olkun, S. (in press). Transcoding errors of two-digit numbers from Arabic digits into verbal numbers and from verbal numbers into Arabic digits by Arab first graders. *Journal of Cognitive Education and Psychology*.
27. Grana, A., Lochy, A., Girelli, L., Seron, X., & Semenza, C. (2003). Transcoding zeros with complex numerals. *Neuropsychologia*, *41*, 1611-1618.
28. Grosjean, F. (1997). Processing mixed language: Issues, findings, and models. In A. de Groot & J. Kroll (Eds.), *Tutorials in bilingualism: Psycholinguistic perspectives* (pp. 225–254). Hillsdale, NJ: Lawrence Erlbaum.
29. Fias, W., Lammertyn, J., Reynvoet, B., Dupont, P., & Orban, G. A. (2003). Parietal representation of symbolic and nonsymbolic magnitude. *Journal of Cognitive Neuroscience*, *15*, 47-56.
30. Fias, W., Reynvoet, B., & Brysbaert, M. (2001). Are Arabic numerals processed as pictures in a Stroop interference task? *Psychological Research*, *65*, 242-249.

31. Fitousi, D., (2010). Dissociating between cardinal and ordinal and between value and size magnitudes of coins. *Psychonomic Bulletin & Review*, 17, 889-894.
32. Fitousi, D. (2013). On the internal representation of numerical magnitude and physical size. *Experimental Psychology*, in press
33. Frenck-Mestre, C., & Vaid, J. (1993). Activation of number facts in bilinguals. *Memory and Cognition*, 21, 809–818.
34. Hayek, M., Karni, A., & Eviatar, Z., (2019) Transcoding number words by bilingual speakers of Arabic: writing multi-digit numbers in a units-decades inverting language, *Writing Systems Research*, 11:2, 188-202, DOI: 10.1080/17586801.2020.1787298
35. Hitch, G. J. (1978). The role of short-term working memory in mental arithmetic. *Cognitive Psychology*, 10, 302-323.
36. Imbo, I., Vanden Bulcke, C., De Brauwer, J., & Fias, W. (2014). Sixty-four or four-and-sixty? The influence of language and working memory on children's number transcoding. *Frontiers in Psychology*, 5, 1–10. doi:10.3389/fpsyg.2014.00313
37. Ischebeck, A. (2003). Differences between digit naming and number word reading in a flanker task. *Memory & Cognition*, 31, 529-537.
38. Lochy, A. (2003, June 10-11). Influence of language in early acquisition of numbers: a comparison of French and German [Paper Presentation] , the 3rd Aachen-Ghent Brain & Number Workshop, Aachen.
39. Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition*, 6, 97–115.
40. McClain, L., & Shih Huang, J. Y. (1982). Speed of simple arithmetic in bilinguals. *Memory and Cognition*, 10, 591–596.
41. McCloskey, M. (1992). Cognitive mechanisms in numerical processing: Evidence from acquired dyscalculia. *Cognition*, 44, 107-157.
42. McCloskey, M. & Macaruso, P. (1995). Representing and Using Numerical Information. *American Psychologist*, 50(5), 351-363.
43. Mann, A., Moeller, K., Pixner, S., Kaufmann, L., & Nuerk, H.-C. (2012). On the development of Arabic three-digit number processing in primary school children. *Journal of Experimental Child Psychology*, 113, 594-601.
44. Miller, K.F., & Stigler, J.W. (1987). Counting in Chinese: Cultural variation in a basic cognitive skill. *Cognitive Development*, 2, 279-305.
45. Noel, M.P., & Seron, X. (1995). Lexicalization errors in writing Arabic Numerals: a single case study. *Brain and Cognition*, 29, 151-179.
46. Noel M. Pascale & Seron Xavier (1997) . On the existence of intermediate representations in numerical processing. *Journal of Experimental Psychology: Learning, Memory and Cognition*. 23(3) , 697-720 .
47. Noel, M.P., & Turconi, E. (1999). Assessing number transcoding in children. *European Review of Applied Psychology*, 49, 295-302.
48. Nuerk, H.-C., Graf, M., & Willmes, K. (2006) Grundlagen der Zahlenverarbeitung und des Rechnens. *Sprache, Stimme, Gehör: Zeitschrift für Kommunikationsstörungen, Schwerpunktthema Dyskalkulie*, 30, 147-153.
49. Nuerk, H.-C., Olsen, N., & Willmes, K. (2005). Better teach your children Japanese number words: How transparent number structure helps number acquisition. Poster presented at 23rd European Workshop of Cognitive Neuropsychology, Bresanone, Italy, January 2005.
50. Nuerk, H.-C., Weger, U., & Willmes, K. (2001). Decade breaks in the mental number line? Putting the tens and units back in different bins. *Cognition*, 82, 25-33.
51. Nuerk, H.-C., Weger, U., & Willmes, K. (2005). Language effects in magnitude comparison: small, but not irrelevant. *Brain and language*, 92, 262-277.
52. Nuerk, H.-C., & Willmes, K. (2004). Externe und interne Repräsentation von Zahlen und ihre Beeinflussung durch sprachliche Struktur. In E. Linz & L. Jäger (Hrsg.) *Medialität und Mentalität*. München: Fink-Verlag, 251-274.
53. Piazza, M., Pinel, P., Bihan, D. L., & Dehaene, S. (2007). A magnitude code common to numerosities and number symbols in human intraparietal cortex. *Neuron*, 53, 293-305.
54. Pixner, S., Zuber, J., Hermanova, V., Kaufmann, L., Nuerck, H.-C., & Moeller, K. (2011). One language two number-word systems and many problems: Numerical cognition in the Czech language. *Research in Developmental Disabilities*, 32, 2683-2689.
55. Pixner, S., Moeller, K., Hermanova, V., Nuerk, H. C., & Kaufmann, L. (2011). Whorf reloaded: Language effects on non-verbal number processing in 1st grade – A trilingual study. *Journal of Experimental Child Psychology*, 108, 371–382.
56. Power, R.J.D., & Dal Martello, M.F. (1990). The dictation of Italian numerals. *Language and Cognitive processes*, 5, 237-254.
57. Proios, H., Weniger, D., & Willmes, K. (2002). Number representation deficit: a bilingual case of failure to access written verbal numeral representations. *Neuropsychologia*, 40, 2341- 2349.
58. Scheuer, N., Sinclair, A., Merlo de Rivas, S., & Tische-Christinat, C. (2000). Cuando ciento setenta y uno se escribe 10071: niños de 5 a 8 años produciendo numerales [When a hundred and seventy one is written 10071: Five to eight-year-olds' production of written numerals]. *Infancia y Aprendizaje*, 90, 31-50.
59. Seron, X., & Deloche, G. (1984). From 2 to two: An analysis of a transcoding process by means of neuropsychological evidence. *Journal of Psycholinguistic Research*, 13, 215-237.
60. Seron, X., Deloche, G. & Noel, MP (1991). Number transcoding by children: writing Arabic numbers under dictation. In J. Bideaud, C. Meljac & J.P. Fisher (Eds.). *Pathway to number*. Hillsdale, NJ: Erlbaum. 245-264.
61. Seron, X. & Fayol, M. (1994). Number transcoding by children: A functional analysis. *British Journal of Developmental Psychology*, 12, 281-300.
62. Seron, X., & Noel, M.P. (1995). Transcoding numbers from the Arabic code to the verbal one or vice versa: How many routes? *Mathematical Cognition*, 2 215-243. Shaki, S., Fischer, M. H., & Petrusic, W. M. (2009). Reading habits for both words and numbers contribute to the SNARC effect. *Psychonomic Bulletin and Review*, 16 (2), 328-331.

63. Sokol, S.M., Macaruso, P., & Gollan, T.H. (1994). Developmental dyscalculia and cognitive neuropsychology. *Developmental Neuropsychology*, 10, 413-441.
64. Sullivan, K.S., Macaruso, P., & Sokol, S.M. (1996). Remediation of Arabic numeral processing in a case of development dyscalculia. *Neuropsychological Rehabilitation*, 6, 27-53.
65. Temple, C. (1989): Digit dyslexia: A category-specific disorder in developmental dyscalculia. *Cognitive Neuropsychology*, 6, 93-116.
66. Van der Ven, S.H.G.; Klaiber, J.D.; Van der Maas, H.L.J. (2017) Four and twenty blackbirds: how transcoding ability mediates the relationship between visuospatial working memory and math in a language with inversion. *Educational Psychology*, 37, 487-505.
67. Van Rinsveld, A., Schiltz, C. (2016) Sixty-twelve = Seventy-two? A cross-linguistic comparison of children's number transcoding. *British Journal of Developmental Psychology*, 34, 461-468. doi:10.1111/bjdp.12151.
68. Walsh, V. (2003). A theory of magnitude: common cortical metrics of time space and quantity. *Trends in Cognitive Sciences*, 7, 483-488.
69. Whorf, B.L. (1956). *Language, Thought and Reality*. Cambridge, MA: MIT Press.
70. Zhang, N., & Norman, D.A. (1995). A representational analysis of numeration systems. *Cognition*, 57, 271-295.
71. Zhou, X., Wang, Y., Wang, L., & Wang, B. (2006). Kindergarten children's representation and understanding of written number symbols. *Early Childhood Development and Care*, 176(1), 33-45.
72. Zuber, J., Pixner, S., Moeller, K., & Nuerk, H.-C. (2009). On the language-specificity of basic number processing: Transcoding in a language with inversion and its relation to working memory capacity. *Journal of Experimental Child Psychology*, 102, 60-77.