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"70.6 Billion World Citizens": Investigating the difficulty of interpreting numbers

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Abstract: Among all the difficulties inherent in interpreting, numbers stand out as a common and complex problem trigger. This experimental study contributes to research on the causes of errors in the passive simultaneous interpretation (SI) of numbers. Two groups of Italian Master's degree students (one for English and one for German) were asked to interpret simultaneously a number-dense speech from their respective B language into their mother tongue, Italian. Note-taking was allowed during the test and both the study participants and their lecturers completed a questionnaire afterwards. Data analysis was conducted with statistical and qualitative methods, combining the cognitivist and contextualist approach. The objective was to ascertain whether one main variable may be held responsible for the high error rate related to interpreting numbers and the difficulty perceived by students in the task. The analysis quantifies the relative impact of different causes of difficulties on participants' delivery of numbers. It stresses the crucial role of the subjective variable represented by interpreters' skills. Didactic implications and directions for future research are discussed in the conclusion.

Keywords: Simultaneous interpreting, numbers, experimental study, cognition, skill automaticity, interpreter training

1. Introduction

Simultaneous interpretation (SI) requires complex cognitive processing. Individual characteristics such as personal experiences, skills, knowledge and thematic preferences unavoidably play a role in the degree of accuracy achieved and contribute to the interpreter's perception of the difficulty of the source speech or of the element to be interpreted. However, there are some elements that seem to represent a stumbling block for virtually all interpreters. The difficulty in interpreting these elements seems to be objective rather than subjective in nature. Such elements are defined as *problem triggers* and are usually associated with a significantly higher error rate than subjective difficulties (Gile, 2015). Among such triggers, researchers have identified numbers as the interpreting problem trigger *par excellence* (Mead, 2015).

A handful of studies have explored the interpretation of numbers by Master's level interpreting students (Braun & Clarici, 1996; Mazza, 2001; Pellatt, 2006; Pinochi, 2009). Even though the study participants had nearly completed their training, the error rate in their delivery of numbers was bafflingly high in all these studies. Braun and Clarici (1996), for instance, registered an error rate of over 60% in the interpretation of a speech dense in numbers. Intersubjective differences in delivery accuracy seemed to disappear when the students were required to interpret numbers (Mazza, 2001). Korpal and Stachowiak's (2017, 2018a) use of eye tracking during interpreting showed that, even with the help of visual input, numbers created difficulties for interpreters. Because numbers represent such a significant challenge for accurate interpreting, researchers have started a dedicated line of research to define the cognitive processes involved in in the SI of numbers (Korpal & Stachowiak, 2018b). However, research on the topic remains scarce, and the prospects of a solution to the problem from the interpreter's and the trainer's side have appeared dim: "*there does not seem to be any real solution to this problem.* […] Perhaps the problem should be *solved at the origin* and, as Pearl suggests: *speakers would be well advised before using figures* to reflect on whether *their point could just as well be made by giving an order of magnitude*, such as: 'much', 'little', 'few', 'a tremendous amount', 'sufficient' etc. (1999, p. 21) [italics added]" (Pinochi, 2009, pp. 55-56).

It may be that specific gaps in research have contributed to the field's inability to find a solution to this vexing problem. The previous studies analysed only a few variables impacting the simultaneous interpretation of numbers and identified various causes for the high error rate. These included the need to switch from 'intelligent translation' of the semantic content of the speech to 'literal translation' of the number (Braun & Clarici, 1996), issues related to working memory and note-taking (Mazza, 2001), the students' background knowledge and adaptability (Pellatt, 2006) and the interpreter's source language (Pinochi, 2009). However, the studies did not systematically correlate these potential causes of difficulty with any specific error pattern, nor did they quantify the contribution of each cause to the overall error rate, so that the extent of the impact of each cause on the delivery of numbers remains unclear. Furthermore, students' skills, training methods and students' metacognitive awareness of the task were not systematically addressed as a distinct variable influencing performance in the interpretation of numbers. As a consequence, crucial phenomena associated with intersubjective differences in skills, such as delivery contradictions and plausibility errors, were not explored. These errors include different interpretations of the same number repeated in the speech, for example "we are in the year 2018 […] in this year, in 2016", and implausible information such as "there are 70.6 Billion world citizens".

This study aims to close some of the afore-described gaps in the field's understanding of why interpreting numbers is so challenging. After collecting samples of simultaneously interpreted number-dense speech, the subsequent analysis focused on determining which cause of difficulty was principally responsible for the overall distribution of errors in the deliveries and for specific error patterns. The study also aimed to investigate systematically the impact of trainee interpreters' competence on the delivery of numbers. The approach to the analysis is both cognitivist, focusing on the cognitive load of specific mental processes, and "contextualist" (Pym, 2008), analysing the numerical information[1] in the source speech and the delivery at semantic, cognitive and pragmatic level. The present article starts by briefly outlining the author's theoretical analysis of the issue. This first stage of the research process served to identify the root causes of the problem, which are here presented in five categories, and to derive a model for the analysis of the deliveries (see processing ladder model in 2.5). The article then describes the experiment and details the methodology used to reach the research objectives. Finally, it summarises and then discusses the key results of the analysis.

2. Theoretical analysis

There are several reasons why numbers represent a common and complex

[1] The term 'numerical information' is used in this article to refer to the semantic and pragmatic meaning of numbers. 'Numerical information unit' (abbreviated as NIU) refers to the number plus the other elements of information such as referent, relative value etc. 'Number' is used generically, while 'number word' denotes the verbal expression of a written numeral.

problem trigger for interpreters. The cognitive operations involved in processing and understanding numbers increase the difficulty of the already complex task of simultaneous interpreting. This very complexity makes it difficult to locate the origin of the difficulty experienced by the interpreter. The present interdisciplinary analysis of relevant theory in numerical cognition, cognitive psychology and the SI of numbers proposes to group the variables, or causes of difficulty in the SI of numbers, into five categories. The categories are identified according to the mental processes that increase cognitive load especially in passive interpretation of numbers and are associated with specific types of processing errors.

2.1 Comprehension

A first type of difficulty leading to interpreting errors may occur in the initial processing of the numbers. The interpreter hears the source-language (SL) number word, processes it (*decoding*), and then transforms it either into a graphic representation (such as into an Arabic number), a process known as *numerical transcoding*, or processes it semantically before it can be rendered into the target language. In these initial processes, specific errors may occur. These errors are designated here as belonging to "Category A."

2.1.1 Decoding and transcoding

Decoding and transcoding a number requires mental processing both of its constituent units by means of lexical operations, and of the inner relations between them through syntactic operations. Different types of errors may arise in these processes, depending on where the failure in mental processing occurs (McCloskey, Caramazza, & Basili, 1985).

Syntactic operations identify the order of magnitude of the number and of its elements (thousand, hundred, etc.) and create a corresponding representation of its syntactic macrostructure. Syntactic errors can be identified in the delivery when the order of magnitude of the number is not correctly recoded into the target language by the interpreter:

1a	*syntactic error*	example: 240,000 → 240

Lexical operations complete the representation of the number's macrostructure with the corresponding digits. If an error occurs in this process, some erroneous lexical items will be found within correct syntactic categories:

2a	*lexical error*	example: 240,000 → 140,000

Large numbers have been found to increase processing latency and effort and have been associated with a particularly high error rate in every-day cognitive operations (Brysbaert, 1995) as well as in SI (Mazza, 2001):

3a	*incorrect interpretation of large numbers*	example: 240,000,000,000 → 240,000,000

2.1.2 Semantic processing

Numerical transcoding is not necessarily semantically mediated, which implies that it is possible to write down a number and/or read it aloud without thinking about its meaning (Dehaene, 2001). Further cognitive processing is required to actually comprehend the number that was heard (Ekuni, Vaz, & Bueno, 2011).

Understanding the meaning of a number requires, first of all, a mental representation of its magnitude. If this level of processing does not take place, the number will not be linked to the corresponding quantity and some of the following errors may be identified in the interpreter's delivery:

4a	*incorrect generalisation/ substitution*	example: 32% → the majority
5a	*syntactically incorrect approximation*	example: 243,546 → about 500

Further processing is required to identify the links between numbers in the text. If this level of processing does not take place, the interpreter may create within-text contradictions:

6a	*within-text contradiction*	example: over *1,000* people participated in the event, *84%* of whom came from the region. *In turn, 160 participants came from abroad* → over *1,000* people participated in the event, *84%* of whom came from the region. *In turn, 600 visitors came from abroad*

Extra-linguistic understanding of the numeral requires relating it to a property of the referent and linking it to prior relevant knowledge to gain information. If this does not happen, the interpreter may incur plausibility errors:

7a	*extra-linguistic plausibility error*	example: the current global population amounts to 7.6 Bn people → the current global population amounts to 70.6 Bn people

2.2 Memory

A memory difficulty (designated here as "Category B") may occur in the retention of the phonological trace of the SL number word in short-term acoustic memory. The interpreter may encounter this difficulty if no immediate transcoding or semantic processing of the number occurs and its phonological trace must be retained. Phonological retention has quantitative and temporal limits; that is, no more than 3 to 5 unrelated items can be retained (Cowan, 2000) for no longer than 2 seconds (Baddeley & Hitch, 1974). To overcome these limits the phonological trace must be refreshed by mental rote repetition, a process known as *sub-vocal rehearsal* (Chincotta & Underwood, 1997). Because in simultaneous interpreting sub-vocal rehearsal is inhibited by concurrent speech production, phonological retention is subject to the strict quantitative and temporal limitations of short-term memory capacity. When these limits are exceeded, memory errors can be expected to occur (Cowan, 2010). Digits disappear from memory following patterns like the *primacy/recency effect* (Morrison, Conway, & Chein, 2014) and the *word-length effect* (Chincotta & Underwood, 1997):

9b	*failure to retain lexical item(s)*	example: 18,765 → 18,005

Additional error classes of memory failure show that transcoding or semantic processing has taken place but that not all the items could be retained:

10b	*correct generalisation*	example: we would like to thank our 600 employees → we would like to thank all our employees
11b	*correct approximation*	example: 18,765 → more than 18,700
12b	*correct substitution*	example: 2017 → that year/this year

The final error in this category is the articulation error. This is considered a memory error because a) target language (TL) production is assumed to be automatic in one's mother tongue; b) robust evidence links errors in speech production to memory overload (Christodoulides, 2016):

13b	*articulation error*	example: 7→ / saven/

2.3 Source language

Source language difficulty (Category C) occurs when the characteristics of the SL number word put extra strain on the processing of the number by the interpreter. Studies have found that similar-sounding number words are often confused, especially in conditions of high memory requirements (Aleuna, 2014, p.15):

17c	*error of phonological perception*	example: eighteen → eighty

The morphosyntactic characteristics of the number word have also been found to influence its processing, increasing latency and cognitive load. In general, the more the SL number word differs structurally from the Arabic numeral, the greater the cognitive load involved in the transcoding process. For example, number words with inverted unit-decimal order, such as the German reading of the number 53 as 'three-and-fifty,' have been found to have a significant influence on decoding latency and transcoding performance (Moeller, Zuber, Olsen, Nuerk, & Willmes, 2015):

18c	*error of inversion/ syntactic position*	example: 18,765 → 18,756

2.4 Information density/objective redundancy

Two additional challenges for interpreters are the high information density and low objective redundancy of numbers (Category D). This difficulty is represented, at the syntactic level, by a high *propositional density* of the numerical information unit (NIU). Propositional density is an objective psycholinguistic parameter that defines the 'ease of comprehension' of an information unit based on a) its number of elements, b) the number of propositional relations that link them, and c) the linearity of these propositional relations (Alexieva, 1999). The number may be accompanied by several elements such as *referent*, *unit of measure*, *relative value* as well as location in time and place. Previous experimental studies on the topic reported a significantly higher error rate in dense parts of text and so concluded that propositional density may be the main variable determining task difficulty (Mazza, 2001). In the present study, the concept of density was combined with the concept of *objective redundancy*. The notion of objective redundancy is derived from Ghelly Chernov's definition in his 'probability prediction model' (1994, 2004; see section 2.5). Through this concept, the cognitive load implied in processing the NIU is analysed not just at morphological and syntactic level but also taking into account the text, the extra-linguistic and the communicative context. For example, at the text level, a number repeated four times is more redundant at its fourth occurrence than at the first. For this reason, the redundancy of a number should be considered when operationalising its difficulty for interpreters.

2.5 Subjective competence

Interpreters' competence in interpreting numbers (Category E) depends on the automaticity of the processes and on the skills that are needed to process the number and elaborate the numerical information. The model presented in this article, called the 'processing ladder model', represents a first attempt to analyse systematically the errors that may occur during the interpretation of numbers because of interpreters' competence in processing the input.

Similarly to Ghelly Chernov's probability prediction model (1994, 2004), which served as the starting point for its development, the processing ladder model uses the concepts of *objective* and *subjective redundancy* to explain the difference between the intrinsic difficulty of processing numerical information and the perceived difficulty as determined by the interpreter's analysis of the input on different levels. Furthermore, anticipatory understanding, automaticity of processing and inference are assumed to be crucial mechanisms in comprehension during SI. Processing of the numerical information during interpretation is assumed to occur on different Levels (I to V). Each level corresponds to a unit of meaning and to a certain depth of processing, as represented in the graphic below:

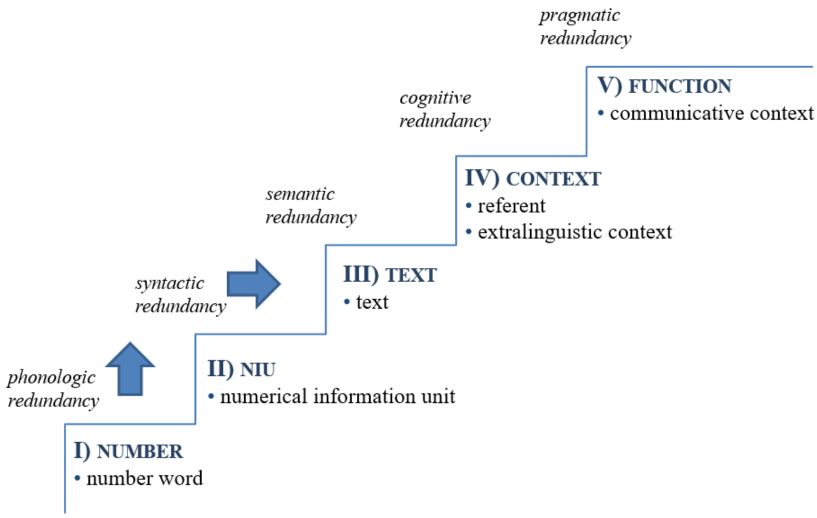


Figure 1. The general architecture of the processing ladder model for the interpretation of numbers.

The objective redundancy in each level is assumed to be determined by the factors that make processing or inferential understanding possible. The subjective redundancy is determined by interpreters' skills and in turn determines their perception of the task's difficulty and the possible error patterns in their delivery (see section 4.2). On each level, processing can be expected to be successful if the necessary skills are available and automatic. The absence of relevant skills or low automaticity can be expected to hinder processing as a result of increased latency and higher processing requirements. Therefore, the delivery of numbers can be expected to reflect the level of cognitive processing accomplished by the interpreter. Production errors can be used as clues to identify precisely which cognitive process is not yet automatic or which skill is still lacking.

This assumption is grounded in cognitive studies. The *automaticity* of cognitive processes is known to determine the subjective cognitive effort in a given task (Shiffrin & Dumais, 1981). In the specific case of numbers, studies in numerical cognition (Olsthoorn, Andringa, & Hulstijn, 2014) have revealed that the subject's competence in the SL number system determines the automaticity of decoding and transcoding operations. Low competence in the number system both increases latency (processing time) and processing requirements (cognitive load) and reduces accuracy in the execution of mental operations with numbers, such as decoding, transcoding and even memory retention. Not only will individual interpreters have different levels of proficiency in the number system of a language, they will also have different levels of proficiency in the learned skills of decoding and transcoding, leading to individual differences in performance (Power & Dal Martello, 1997). Little automaticity of such transcoding operations corresponds, in the processing ladder model, to a decrease in subjective redundancy at Level I, which can be expected to trigger corresponding errors and to prevent processing at higher levels if the interpreter does not use coping strategies. In this case, for instance, no attention might be left to simultaneously process the other units of the numerical information and to elaborate the textual, extra-linguistic and pragmatic meaning of the number.

Other skills relevant to this discussion are inferential skills and background knowledge. The latter is particularly important at Level IV ('context'). At this level, interpreters are required to associate a number with its referent to understand its extra-linguistic meaning and check their interpretation for plausibility. However, this is only possible if they have relevant *encyclopaedic numerical knowledge* (Cappelletti, Jansari, Kopelman, & Butterworth, 2008). Interpreters' encyclopaedic numerical knowledge is constituted of the numbers stored in their long-term memory, which have the same function as general knowledge of the world in text and discourse comprehension. When a new number is to be processed, relevant numbers in the interpreter's memory are linked to the input to transform it into meaningful information. Plausibility errors in the interpretation of numbers can, therefore, be interpreted as a lack in relevant encyclopaedic numerical knowledge.

3. Methodology

The goals of the experiment described in this article were to:

1. Determine which cause of difficulty triggered the most interpreting errors in the renditions of a group of test subjects presented with a number-heavy simultaneous interpreting task;
2. Determine whether the error pattern in the interpretation of numbers could be attributed to a lack of skills, based on the processing ladder model.

The experiment involved two groups of MA students of conference interpreting. The participants were required to interpret simultaneously a speech dense in numbers into their mother tongue (Italian) from their respective active second language, either English or German. At the time of the experiment (March/April 2015), the participants were Master's degree students of Conference Interpreting attending 4th-semester courses at UNINT[2] University in Rome, one group with English ('Pe', 7 participants) and the other with German ('Pd', 8 participants) as their B language. All but one of the participants were native speakers of Italian; the exception was a native speaker of German. The researcher analysed the deliveries of the participants, the numbers they wrote down during interpretation and a questionnaire filled out by the study participants and their instructors.

Two speeches, one in English (Te) and one in German (Td) were selected for the experiment with the objective of assessing the impact of the source-language difficulty (Category C). Both speeches were dense in numbers and took place in similar communicative contexts, i.e. the CEO of a company presenting its performance at the end of the financial year. Both were shortened and adapted, for instance by leaving out specific details about the company's products or specific terminology, to prevent the disturbing influence of elements other than numbers. The texts were then proofread by two native speakers, who checked them for coherence and finally recorded

[2] Università degli Studi Internazionali, Interpreting and Translation Faculty, Master's Degree in Conference Interpreting (LM-94)

them using high-quality equipment. The two speeches are characterised by different levels of information density/objective redundancy, to observe the repercussions of modulating this variable (Category D).

The two groups were examined on two different dates. To create a level playing field, both groups were informed one week before the test of the research objectives. They were also informed of the speech topic to observe whether the participants would use strategies to prepare for the task of interpreting a speech dense in numbers, for instance, by acquiring the necessary encyclopaedic numerical knowledge. On the day of the experiment, carried out by the author in UNINT university's facilities, the participants were provided with more detailed information about the communicative event and with a glossary of terms on a double-sided briefing sheet, to make sure that terminology would not represent an obstacle and that the deliveries would reflect solely the difficulty in the interpretation of the numbers themselves. The participants were allowed 10 minutes to familiarise themselves with the material provided, to prepare for the task and to ask questions. Each participant interpreted the recorded speech simultaneously while alone in a booth. The participants were permitted to bring the briefing sheet into the booth with them and to write down the numbers to support interpretation, on the condition that they hand in the notes after the experiment. Their performance was recorded and analysed at a later date.

After the interpreting test, both the participants and their trainers filled out a questionnaire. The questionnaires served to evaluate students' and trainers' perceptions of the challenge represented by interpreting numbers and of the need for targeted teaching methods to improve performance, as well as to determine whether the students had been provided in their coursework with specific instructions or exercises related to interpreting numbers. The participants' questionnaire also included retrospective questions on their preparation technique, the difficulties encountered during the test and the strategies used to surmount them. Participants' responses were used to characterize their task awareness and their metacognitive skills (see section 4.2.6).

3.1 Analysis procedures

Data analysis consisted of two stages: a statistical analysis that addressed the first research objective and a qualitative analysis to address the second.

3.1.1 Statistical analysis

The statistical analysis was conducted to describe the impact on the accuracy of the interpreting of the categories of difficulties previously identified as objective variables increasing the cognitive load in processing the numerical information: a) comprehension, b) memory and c) source language and d) information density/objective redundancy.

The classification of interpreting errors used to code delivery data is based on the discussion in sections 2.1 to 2.3. Each error class is assigned to one category of difficulty among A: *comprehension*, B: *memory* and C: *source language*, according to the one that is identified as the triggering cause. Where this correlation between error and cause could not be established reliably, because of a lack of theoretical support and/or empirical evidence from previous studies, the error/strategy was assigned to a neutral category (* 'other'). This classification was used to code the deliveries in the following way. The unit of analysis considered was the numerical information unit (NIU). Each NIU was identified with a code. The delivery of each participant was transcribed using phonetic transcription for conversation analysis (Atkinson & Heritage, 1984) and aligned with the ST. Finally, the delivery of the NIU was evaluated using the classification below (see results in 4.1).

A	Comprehension difficulty	
1a	*syntactic error*	incorrect syntactic structure example: 240,000 → 240
2a	*lexical error*	wrong lexical units within correct syntactic categories example: 240,000 → 140,000
3a	*incorrect interpretation of large numbers*	syntactic or lexical mistake triggered by the magnitude effect in the cognitive processing of numbers example: 240,000,000,000 → 240,000,000
4a	*incorrect generalisation/ substitution*	the TL substituent does not correspond to the meaning the SL number example: 32% → the majority
5a	*syntactically incorrect approximation*	approximation fails to convey the order of magnitude of the numeral example: 243,546 → about 500
6a	*within-text contradiction*	the TL numerals are inconsistent example: over *1,000* people participated in the event, *84%* of whom came from the region. *In turn, 160 participants came from abroad* → […] *In turn, 600 visitors came from abroad*
7a	*extra-linguistic plausibility error*	the TL numeral is not consistent with real-world plausibility hypotheses example: the current global population amounts to 7.6 Bn people → the current global population amounts to 70.6 Bn people
B	**Memory difficulty**	
9b	*failure to retain lexical item(s)*	the TL number is correct, except for the omission of one or more lexical items example: 18,765 → 18,005
10b	*correct generalisation*	the TL number is replaced with a generic expression to convey the core message example: we would like to thank our 600 employees → we would like to thank all our employees
11b	*correct approximation*	the number is correctly rounded up or down example: 18,765 → more than 18,700
12b	*correct substitution*	the number is replaced with an equivalent substitute in the text or with its referent example: 2017 → that year/this year
13b	*articulation error*	errors in the verbal production of the SL numeral or of another component of the numerical information (in the interpreter's mother tongue) example: 7 → / saven/
C	**SL difficulty**	
17c	*error of phonological perception*	confusion of similar-sounding numerals example: eighteen → eighty
18c	*error of inversion/ syntactic position*	errors that may occur decoding German numbers with a unit-ten order example: 18,765 → 18,756
*****	**Other, non-classified**	
*8	*Omission*	the whole numerical information is omitted in the TT example: 18% rise in 2013 → Ø
*14	*omission of numerical information component(s)*	one or more elements of the numerical information unit are omitted example: 160% → 160
*15	*incorrect or imprecise numerical information component(s)*	one or more elements of the numerical information are delivered imprecisely example: 88% in 2010 → 88% in 2015
*16	*disfluencies*	fillers, lengthenings, pauses etc. accompany the TL numeral example: 16 → 'si::xteen'

The Category D: *information density/objective redundancy* was quantified for each NIU, following the principles discussed in section 2.4, to determine the extent to which this problem category influenced participants' delivery of numbers. Each NIU was attributed a value corresponding to its information density/objective redundancy. The grading scale was 1–4 for Te, and 1–3 for the more redundant Td. The level of information density/objective redundancy of the numerical information was set as an independent variable in Pearson's Chi-Square Test ($\chi 2$) to test the following hypothesis (see results in 4.1):

HY Information density/objective redundancy is a predictor of the error distribution in the delivery of numbers.

If no significance is found, the null hypothesis is supported:

HY0 Information density/objective redundancy is not a predictor of the error distribution in the delivery of numbers.

3.1.2 Qualitative analysis

The qualitative analysis addressed the second research objective: to determine whether interpreters' competence in interpreting numbers (Category E, discussed in section 2.5) can be considered as a significant variable. The analysis was conducted applying the processing ladder model, which supported the identification of significant patterns of error in the deliveries corresponding to specific processing errors.

Since the first level of processing depends on the automaticity of the decoding and transcoding of the number word, delivery data was triangulated with the participants' notes. In fact, these can be considered an open window on the participant's transcoding process and reveal whether a difficulty occurred in this phase. The following coding method was used:

RI correct and complete numbers leading to correct interpretation
RII incorrect or incomplete numbers leading to correct interpretation
FIII correct and complete numbers leading to incorrect interpretation
FIV incorrect or incomplete numbers leading to incorrect interpretation

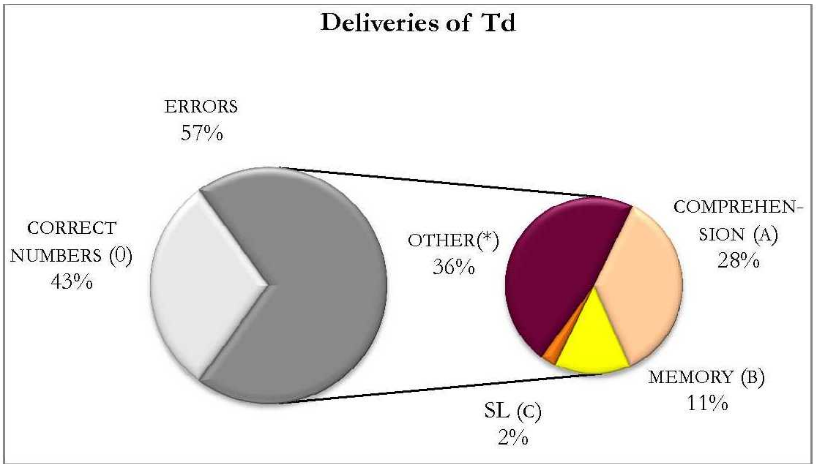
Investigation of the subjective variable also addressed the relationship between performance, participants' strategic behaviour, task awareness and teaching methods. The underlying hypothesis was that student's awareness of the problem and metacognitive skills (Doğan, Arumi, & Mora-Rubio, 2009) and the training received have repercussions on performance. These links were identified through the analysis of the questionnaires administered to the study participants and their trainers.

4. Results

4.1 Statistical analysis

4.1.1 Memory, comprehension, source language.

The first stage of analysis focused on determining the amount of interpreting errors triggered by the problem categories: A: Comprehension, B: Memory and/or C: Source language. The objective was to discover which of these categories of difficulties is the main source of error in the interpretation of numbers. The graphs below show the amount of error triggered by each category in the tests:



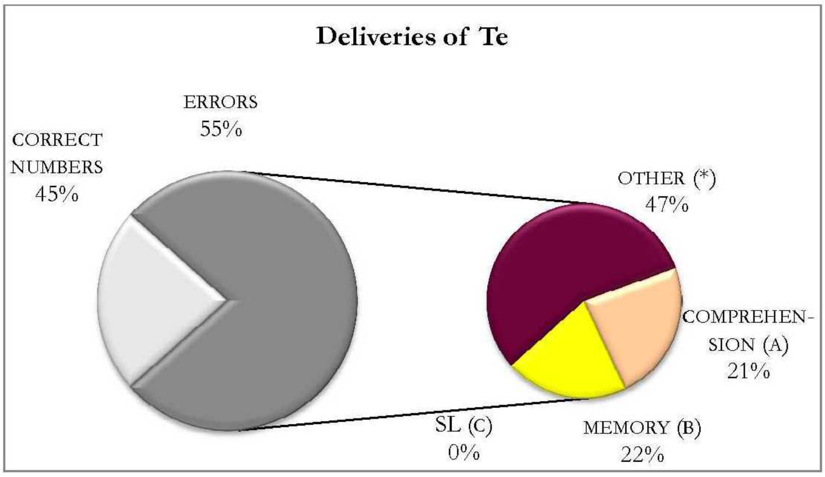


Figure 2. The proportion of correct and incorrect interpretation of numbers in Td and Te and the proportion of each problem category within the total of incorrect numbers.

Of immediate interest is the different impact of each problem category for the different language groups. The prevailing source of error for the German group was comprehension (28%), while memory (22%) and comprehension (21%) triggered nearly the same number of errors for the English group. It is also striking that there is no significant difference in the error rate between the two groups, considering that Te contained a higher density of numbers than Td; in fact, the German group even registered a slightly lower percentage of correct numbers. Furthermore, the arguably more complex German number system cannot be held responsible for the results, as it accounts for only 2% errors.

4.1.2 Information density/objective redundancy

The second stage of analysis addressed the influence of the information density/objective redundancy (Category D) on the delivery of the numerical information. To determine whether a dependency relationship could be established between this problem category and the overall error distribution or the occurrence of one specific phenomenon, Pearson's chi-squared test ($\chi 2$) was performed both on the whole data set and individually on each class of interpreting errors and strategies. A level of confidence in common use in the social sciences was chosen (α= 0.05). The hypotheses were:

HY information density/objective redundancy is a predictor of the error distribution in the delivery of numbers

If the hypothesis is valid, the density of interpreting errors would be greatest where the degree of information density/objective redundancy is highest and would decrease significantly where the degree is lowest. If, on the contrary, the overall distribution of errors does not vary consistently with variation in information density/objective redundancy, the hypothesis would be rejected in favour of the null hypothesis:

HY0 information density/objective redundancy is not a predictor of the error distribution in the delivery of numbers

The results of the experiment overall reveal a non-random distribution of the variables:

TEST $\chi2$ (TE)	3.37529E-05
TEST $\chi2$ (TD)	1.54612E-08

However, a test of homogeneity using contingency tables shows contradictory results. As shown in Figure 1, the relative frequency of correct answers does not decrease linearly as the information density increases, as the hypothesis would predict:

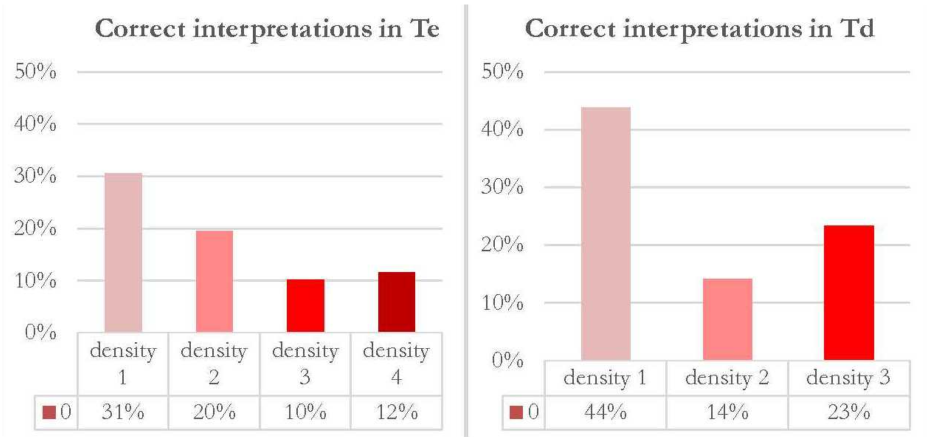


Figure 3. Distribution of the percentage of correct interpretations as a function of information density/objective redundancy of the NIU.

After discovering this discrepancy, the test was performed again on five random re-samplings for both Te and Td, to obtain a higher degree of reliability and to reduce the risk of biases. Again, the percentage of correct interpretations did not decrease based on the level of information density, and great variability can be detected within and across samples. It appears that the null hypothesis is correct; information density is not a predictor of the frequency of error in participants' delivery of numbers.

4.2 Qualitative analysis

In the third stage of analysis, the processing ladder model (section 2.5) was applied to explain systematically how participants' competence in interpreting numbers determined error patterns in their delivery.

4.2.1 Level I: number decoding and transcoding

According to the processing ladder model, processing of the number at Level I requires automatic decoding of the SL number word and transcoding into a graphic number. This process can be reconstructed from the numbers written down by the participant during SI. Errors in participants' notes are evidence of the difficulties encountered in the transcoding process, as a consequence of low automaticity of the underlying cognitive processes.

Error patterns identified as a consequence of non-automatic processing at this level are:

a) inaccuracy of the notes taken, increased latency and effort in the note-taking phase
b) non-strategic (inconsistent and ineffective) use of note-taking

The inaccuracy in note-taking can be seen in the graphs below:

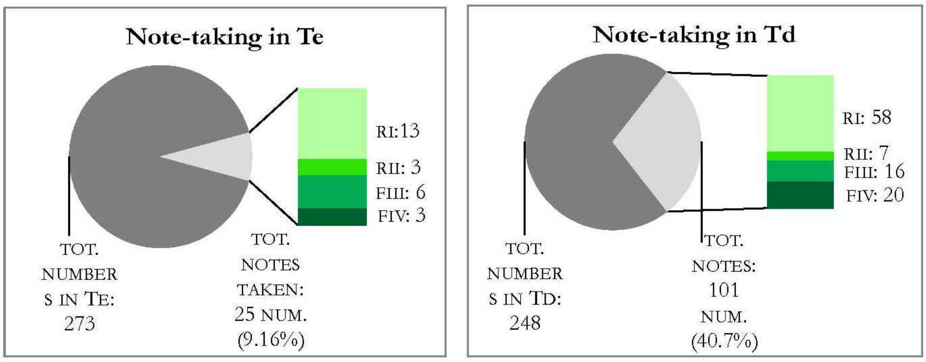
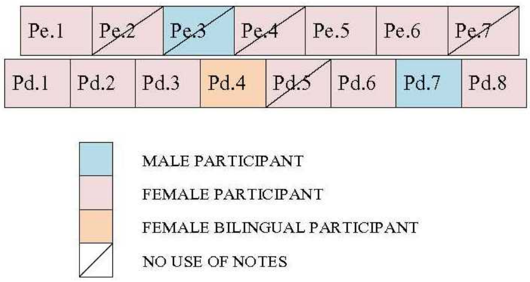


Figure 4. Proportion of numbers in the source speech for which notes were taken by the interpreter and a breakdown of the errors by category

Figure 4 shows that the Italian-German study participants made much more extensive use of note-taking than their Italian-English counterparts. This is true even though only four of the seven participants in the German group used note-taking to aid in interpreting the numbers, while seven of the eight in the English group did so:



The prevailing error patterns differ across the two groups as well. In the German test, 36/101 numbers noted led to an error in the delivery (36%), the most frequent cause being a wrong number leading to wrong interpretation (FIV). In the English test, 9/25 numbers led to an error (also 36%), however the most frequent cause was a correct number leading to wrong interpretation (FIII). This can be explained as an effect of the increased latency, effort and inaccuracy in the decoding and transcoding of the SL number word because of low automaticity.

Low automaticity of number processing had repercussions also on the quality and usefulness of the note-taking for both the German and the English group. The participants wrote predominantly:

- small numbers and dates
- the redundant number in the NIU
- repeatedly the same redundant number

4.2.2 Level II: numerical information unit
Processing the information at Level II requires that the interpreter be able to readily identify the components of the NIU and reconstruct its linear propositional order. When interpreters lack these skills, the result is an interpretation that is missing crucial components of the NIU or that has incorrect links between them. An example can be found in the interpretation of the passage below produced by study participant Pd.3:

SOURCE TEXT	TARGET TEXT
Sie sehen, das internationale Wachstum ist mit +6% stärker ausgefallen, als das inländische. *As you can see, international growth, at +6%, was stronger than national growth	Potete notare che la crescita internazionale è più forte del 6%. *As you can see, international growth is stronger by 6%.

This segment of Td represented a problem for all study participants. It triggered in three of eight cases omissions of components (*14) and incorrect/imprecise numerical information (*15), one of which even resulted in a sense contradiction (6a). It was translated correctly by only 2 study participants, and even these had hesitations and disfluencies (*16). The high error rate in the interpretation of this simple one-digit number can be explained, using the model, as an effect of the non-linear propositional structure of the NIU and of a skill deficiency preventing the interpreters from dealing with the difficulty.

4.2.3 Level III: text
Interpretation of numbers at Level III requires the interpreter to perform semantic inferences to link different NIUs in the text. The following example shows the impact of failure in processing the input at text level:

SOURCE TEXT	TARGET TEXT (Pd.3)
The domestic turnover was 52%	this result was reached so (0.2) considering these results
the foreign was 48%	((information omitted))
The WMF-Group generated over €530,000,000 in sales on the domestic market	the Group (.)
and over half-a-billion abroad	contributed therefore to the national GDP

In this example, it can be seen that the participant Pd.3 struggled to interpret a passage containing several numbers, although these numbers were highly redundant at the text level. In fact, the value of the company's sales revenue, here divided by region, had already been repeated three times before in the speech. The interpreter's difficulty can be explained using the model as follows. Difficulty in processing the input at a lower level prevented the interpreter from analysing the numbers and performing semantic inferences to link them to previous numbers in the speech. In fact, Pd.3 is the study participant for whom the highest error rate in note-taking was recorded: 90% of numbers written down led to wrong interpretation. This can be interpreted as a symptom of very low automaticity in decoding and transcoding the number word, which may be assumed to have increased substantially latency and processing requirements at Level I. Lacking analysis at Level III initiated a downward spiral and a further increase in cognitive requirements, ultimately triggering a 'snowball effect' characterised by a sequence of within-text contradictions.

4.2.4 Level IV: extra-linguistic context
Processing on Level IV occurs when interpreters' background knowledge, especially their encyclopaedic numerical knowledge, interacts with the message to produce sense. Gaps in encyclopaedic numerical knowledge or failure to match the incoming information against these known numerical facts about the world can be identified by plausibility errors in the interpreted speech. Such errors were frequent in both tests and could be detected in four of seven interpretations of Te and five of eight interpretations of Td. An example can be observed in the delivery by Pd.7. In the original speech, the value of the company's sales revenue is repeated 6 times in total. The first time, when it is presented as a rounded-up number, Pd.7 translated it correctly:

SOURCE TEXT	TARGET TEXT
€1 billion	€1 billion

When the speaker specifies a more precise amount, the participant has a decoding difficulty, which blocks processing at Level I and prevents her from performing a plausibility check of her delivery of the number:

SOURCE TEXT	TARGET TEXT
€1.0273 billion	€27.3 billion

She commits another plausibility error when she interprets this same value later on in the speech:

SOURCE TEXT	TARGET TEXT
€1 billion	€1,000

These errors can be reliably linked to an absence of both encyclopaedic number knowledge and cognitive inferences. If the interpreter had activated relevant concepts stored in her long-term memory, such as the average sales revenue of a small-sized enterprise, she could have judged the plausibility of her interpretation.

4.2.5 Level V: pragmatic function
Information processing at Level V relies on pragmatic inferences to identify the communicative function of the numbers. Successful evaluation of the pragmatic redundancy in the numerical information enables the interpreter to select adequate strategies to guarantee as accurate a rendition as possible, as shown by participants' deliveries of the following passage in Te:

> First, let me thank our more than 66,500 employees for making our success in 2013 possible.

Several participants had difficulty at Level I and II in decoding and reporting both numbers. Some of them adopted generalisation or approximation strategies for the number in order to focus instead on conveying the speech act of thanking:

Pe.2	First of all, I would like to thank all our employees for making our success possible.
Pe.3	I would like to (.) thank all (.) our employees for making our success possible in 2013.

Pe.6	We have over 66,000 employees, who made our success in 2013 possible.
Pe.7	Thanks to all our employees (.) for their work and commitment.

On the contrary, some participants were unable to weigh the arithmetic value of the number against its pragmatic function:

Pe.4	*Sap has over 66,000 (.) employees.
Pe.5	*We have many:: employees.

4.3 Insights from questionnaires

Both teachers and most of the students (13/15) stated in the questionnaires that numbers pose a major interpreting challenge. When asked to describe the difficulties experienced during the test, all the participants provided rather vague answers and were unable to identify a specific cause. They described numbers as a source of "distraction", as pitfalls and hindrances to comprehension of the text, even reporting a certain "stress" associated with the task (Pd.1). None of them showed any awareness of the necessity of analysing numbers as a source of meaningful information with a specific communicative function and of prioritising the information in case of unavoidable omissions:

> "I interpreted the numbers if I had time, otherwise I skipped them so as not to also mess up the following sentence." (Pe.5)
> "I selected the ones that I could remember." (Pe.4)
> "I interpreted the ones that I could hear and managed to write down." (Pd.2)

Despite the common agreement regarding the difficulty of interpreting numbers, neither group reported being given specific exercises on this topic in any of their coursework. This was confirmed by both of their instructors, who stated that they provide no specific exercises on interpreting numbers in their courses. Only one of them expressed a belief that targeted exercises might be useful in helping students acquire the skills and techniques that are necessary to improve their performance in this area.

The students reported knowing of no effective techniques or strategies to deal with the challenge. At the same time, students' behaviour during the test appears to have been influenced largely by their trainer's advice. In the English group, for instance, only three of seven participants took notes because:

> "In class, we always go into the booth in pairs. Therefore, when we are interpreting and a number comes up in the text, we simply read aloud the digits that our colleague writes down for us" (Pe.3)

The German group made much more extensive use of notes; seven of eight participants took notes since they were advised to do so by their instructor.

On the whole, students' answers on the questionnaires support the hypothesis that their inability to reflect on the difficulty experienced during the interpreting process (their metacognitive skills), as well as on the different layers of meaning of numbers, limited their capacity to manage the interpreting task effectively. Furthermore, the instructions received from their trainers and the training methods used in class seem to have influenced significantly their selection of strategy to interpret numbers during the test.

5. Discussion of the results

The findings of the present study contribute to defining the causes of the difficulty perceived by trainees when interpreting numbers simultaneously into their mother tongue. The first key finding of the data analysis is the comparison of the impact of each problem category within and across groups. Previous studies had highlighted individual causes of difficulties in the SI of numbers. The results of the present study suggest that the distribution of errors in the delivery samples analysed cannot be predicted by just one *objective* cause of difficulty. On the contrary, the *subjective* variable determined by trainees' skills in the interpretation of numbers emerges as a key predictor of error patterns in the delivery. Considering different levels of meaning of the number (phonological, syntactic, semantic, cognitive, pragmatic), the 'processing ladder model' identified error patterns in response to deficiencies in the skills required on each level of processing. Some key skills were competence in the SL number system, the automaticity of number processing, the acquisition of encyclopaedic numerical knowledge as well as analysis and inference skills. Furthermore, by triangulating delivery data with participants' notes and questionnaires, it was possible to identify a correlation between pedagogical factors, trainees' skills, and their performance during the test.

The most striking example of such interdependency between training, skills and performance can be identified in the participants' use of note-taking during the test. The English-Italian group used note-taking significantly less than the German-Italian group. What could account for this significant difference? In the questionnaires, participants indicated that they selected a technique for interpreting numbers based on instructions received from their trainers and exercises they had previously undertaken in class. While the German students were sometimes sent into the booth alone with a recommendation that they write down the numbers while interpreting, the English students reported that they were accustomed to relying on the assistance of a booth mate in rendering numbers correctly. For this reason, more participants in the German group chose to take notes during the experiment than their English counterparts. The high inaccuracy of participants' notes and their non-strategic use of the note-taking technique suggest low automaticity of the decoding and transcoding processes for both groups. A non-strategic use of note-taking was reported also by previous studies: "*Performance for numbers does not seem to improve when they occur more than once in the speech*. Subjects sometimes even repeat the same numbers in their notes. Repeated numbers are thus treated like all the other numbers [italics added]" (Mazza, 2001, p.101). The fact that participants avoided writing large numbers in favour of one-digit numbers shows, on the one hand, that low automaticity reduced the usefulness of note-taking, preventing participants from using it to fulfil its principal purpose of reducing memory effort. On the other hand, the fact that participants sacrificed new information to repeatedly write down the same highly redundant number shows that they were not processing the semantic relations between numbers in the text (Level III of the model). These observations lead to the conclusion that note-taking is not ineffective per se, as hypothesised by previous studies (Mazza, 2001), but rather that targeted training is needed to maximise its benefits. The fact that neither group was given specific exercises on the topic in any of their coursework certainly contributed to their ineffective use of note-taking.

The application of the processing ladder model to the analysis of participants' deliveries shows that the consequence of skill deficiencies can be disruptive and far-reaching. The breadth and depth of such impact suggests that the subjective variable may be the major cause of failure in the participants' interpretation of numbers and that it may have contributed to the overall error rate more than any other objective cause of difficulties. An example is the lack of automaticity of processing and inference skills at the text level (III), which caused even highly redundant items to become pitfalls and trigger severe errors. Skill deficiencies prevented the participants from performing semantic inferences to link the numbers to previous ones in the speech and recognise internal repetitions. As a consequence, even highly redundant numerical information was experienced as new, requiring more cognitive resources to process than would otherwise be objectively necessary. The corresponding error pattern exemplified a 'snowball effect': a chain of contradictions in the delivery. Another example is represented by plausibility errors, caused, above all, by a lack of both encyclopaedic numerical knowledge and cognitive inferences (Level IV of the model). Interestingly, the participants seemed not to be aware of the need to know relevant concepts in order to be able to perform a plausibility check of the incoming numbers. In the questionnaires no participants reported having searched for relevant data on the internet during preparation for the test, supporting the hypothesis that task awareness and teaching methods are correlated with performance in the interpretation of numbers. A final example that is worthy of notice is the elaboration of the function of numbers within the communicative context (Level V), mediated by pragmatic inference skills. The analysis of this level of meaning of numbers determined participants' selection of appropriate strategies, such as generalisation or lexical substitution, to reduce the cognitive load whilst keeping "communication risks" (Pym, 2008) under control. In this case as well, it is interesting to notice that none of the participants showed any awareness in their questionnaires of the necessity of analysing numbers as a source of meaningful information, contextualising them and prioritising the crucial component of the message in case of unavoidable omissions.

6. Conclusion

The present study contributes to the research on number processing by interpreting trainees during passive SI, and the root causes of the observed high error rate. The study moved from the observation that some knowledge gaps were limiting the field's ability to identify effective coping techniques and teaching methods for the difficulty of interpreting numbers. A first assumption was that the analysis should not only focus on the cognitive mechanisms involved in number processing but also include the textual and pragmatic function of numbers. A further assumption was that students' competence in interpreting numbers should be addressed as a separate variable leading to error. Therefore, the study combined statistical and qualitative analysis together with cognitivist and contextualist approaches to obtain a fully rounded view of the interpretation of numbers. The theoretical analysis was conducted with an interdisciplinary approach, combining the results of previous empirical studies on the SI of numbers with studies in cognitive psychology and numerical cognition. It identified five causes of difficulty in the interpretation of numbers and established a cause-effect relationship with specific types of error. It also presented the 'processing ladder model' that comprises different levels of numeric meaning (phonological, syntactic, semantic, cognitive, pragmatic), defines the skills that are responsible for input processing, and links them to expected error patterns that may occur in response to a skill deficiency on each level. The statistical analysis quantified the relative impact of the causes of difficulties on the accuracy of the interpretation. The qualitative analysis focused on participants' deliveries, while their notes and questionnaires were used as a source of triangulation to investigate the hypotheses made regarding the skills and pedagogical factors influencing performance. On the whole, the analysis showed that each of the objective variables considered had an impact on the delivery, but none of them is correlated with the error distribution. However, the subjective variable represented by trainees' skills does appear to be an accurate predictor of error patterns. The analyses of the notes taken by the participants and of the questionnaires supports the hypothesis that specific skills, task awareness, and teaching methods are correlated with performance in the interpretation of numbers.

Like all research, this study has certain limitations. A broader theoretical base and more data are needed to define more precisely the factors involved in numbers processing in SI, their impact on the delivery and their correlation with skills. The classification developed for the statistical analysis of the deliveries relies on the link established by the researcher between cause and error. If further studies were to adopt a similar classification of errors, the author recommends reviewing the classification and updating it according to new empirical evidence. It is also recommendable to adapt it to the research objectives. For example, the category 'comprehension' could be further subdivided into the cognitive processes of 'transcoding' and 'semantic processing'. A class should be added for errors in pragmatic equivalence since these were analysed qualitatively rather than quantitatively in the present study. While a relationship between cause and effect cannot be established with 100% certainty, improving the understanding of the link between errors and underlying causes may be key to improving the accuracy of simultaneous interpretation of numbers. Even if the sample size of the present experiment is rather limited, the results and the observations made by previous studies seem to fit within the framework proposed here, suggesting that the conclusions drawn about the crucial role of interpreters' competence may be extended beyond this particular study. In fact, previous studies reported similar error patterns, such as the non-strategic use of notes and their ineffectiveness in the interpretation of large numbers (Mazza, 2001), which the present study explained as a cause of participants' low automaticity of numerical transcoding processes.

The results of the present analysis have pedagogical implications that could not be addressed in the present article in the detail they deserve. The discussion has been necessarily limited to first presenting a model linking skills to performance and then demonstrating how this can be applied to the qualitative analysis of the deliveries. Considering the pivotal role of subjective competence, targeted training may compensate for the objective difficulty experienced by interpreting trainees. While numbers are only one of many stumbling blocks that student interpreters encounter in their training, the potential for serious communicative errors inherent in misinterpreting numbers should make them a priority in interpreter training programmes. Furthermore, the use of dedicated teaching strategies for the interpretation of numbers could turn this common stumbling block into a powerful didactic tool, which may be beneficial to interpreters' training in many ways. In the first place, training with numbers may not only improve performance in the SI of numbers, but also support students' acquisition of general interpreting skills and strategies. A gradual skill-based training programme building on the results of the present study should not only focus on the automaticity of number and NIU processing but also improve the student's ability to recognise and leverage on the text cohesion of numbers, their extralinguistic meaning and their pragmatic function. Since these levels of processing are inherent in the interpretation of not only numbers but all messages, it is possible that the skills and strategies trained through the work with numbers may be transferred to other interpreting tasks. Moreover, a training programme that guides students through the root-cause analysis of an interpreting challenge to its subsequent solution in targeted training may strengthen learning autonomy, awareness of the interpreting task and metacognitive skills. The author of the present article is currently working on developing a more detailed skill model as well as a corresponding training plan with dedicated materials. In a further step, the effectiveness of such training programme will be tested in regards to skill acquisition and transferability.

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