Numbers during simultaneous interpreting: an account, from a cognitive science perspective, of the sources of difficulty when interpreting numbers, and an appraisal of advice given to interpreters to address this difficulty

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Numbers during simultaneous interpreting: an account, from a cognitive science perspective, of the sources of difficulty when interpreting numbers, and an appraisal of advice given to interpreters to address this difficulty.

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For the ones who count.

♥

Abstract

Numbers may seem “easy” to interpret, for having fixed correspondences between source and target language. However they are also less predictable, less informationally redundant, and less amenable to terse expression, than other types of information and so are more taxing on working memory, a key cognitive constraint during simultaneous interpreting. The appearance of unpredictable numerical information in a speech causes an increase in cognitive load for the interpreter, which can cause rendering problems. Misalignments between source and target language number systems can add another layer of difficulty. I argue that advice such as note-taking, segmentation, and reformulating the order of information can help mitigate these difficulties to some extent. But numerical information will always be one of the more difficult types of information to interpret, for student and expert interpreters alike. Expert interpreters may be “better at numbers” because of general language proficiency advantages, and because they have acquired long term memory schemas for handling formulaic, non-numerical, parts of speeches, which should also inform advice given to students.

Key words:

numbers ; simultaneous interpreting ; chunking ; working memory ; long term memory ; cognitive load ; numerical cognition ; information processing ; redundancy ; formulaic language ; interpreter training ; expertise

1. Introduction

1.1 Objectives

In this thesis I will first offer an explanatory account of the sources of difficulty in interpreting numbers during simultaneous interpreting (SI). I will then appraise, in light of this account, the suitability of specific examples of advice that may help interpreters to mitigate this difficulty. Throughout the thesis, I will refer to empirical and theoretical research from within the field of interpreting studies, and also from the broader cognitive science literature.

1.2 Rationale

The ability to simultaneously perceive speech in one language, and produce a real-time oral translation of that input, is an intellectual feat that has fascinated cognitive scientists outside of the field of interpreting studies.[1] These researchers have studied the complex specialised behaviour that is the performance of SI in the hope of gaining insights into more general principles of human cognition.[2]

The inverse, of course, is also true. Those who have the most direct stake in there being an improved understanding of this specific and complex skill – interpreting students, practitioners and trainers – can hope to benefit from looking at what the scientific literature has to say about the workings of the very object underpinning this skill, the human mind.

Authors who write on the practice of interpreting identify the presence of numbers in speeches as a particular source of difficulty during SI. [3] By describing this problem in cognitive terms, it is hoped this thesis will provide a better understanding of this notorious difficulty.

At interpreter training programmes and in interpreter course books, advice is given by teachers to student interpreters to help address this specific problem. Importantly, this thesis will appraise the suitability of specific examples of such advice, by considering to what degree it is compatible with what is known from

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1 – For example, consider Adelman, Moser-Mercer, Michel & Golestani (2015), or Becker, Schubert, Strobach, Gallinat & Kuhn (2016)

2 – Such interest is not much different from that seen with other cognitive "extremes"; such as researchers hoping to gain generalisable insights on the training/learning related changes in the human brain by studying the effects of musical training on brain structure - see Herholz & Zatorre (2012).

3 – see section 1.3.3.1 for examples

cognitive science about the capabilities and limitations of the human mind in processing information. By framing the problem in a theoretically organised way, another desired outcome of this work is the generation of specific research questions that merit empirical investigation to shed more light on how to deal with the challenge of interpreting numbers during SI.

1.3 Basic concepts

1.3.1 "Simultaneous Interpreting (SI)"

SI is "the mode of interpreting in which the interpreter renders the speech as it is being delivered by a speaker into another language with a minimal time lag of a few seconds" – Diriker (2015, p382). For the purposes of this thesis, SI is seen as a task practiced in conference settings (i.e. at meetings coordinated by organisations such as the European Union and the United Nations). Aspects of this context in which a practitioner of SI works, such as the presence of a boothmate (with whom the work is shared in alternating turns), the possible availability to the interpreter of a written text of the speech she is working from, of documents discussed at the meeting, or of slides to accompany the speech, are recognised in this discussion. [4]

An important perspective assumed in this thesis is that the perceptual component of the SI task (understanding the source language) can be seen more abstractly as one of signal processing under adverse conditions, or "noise", with the signal being the source-language information. This noise is an obstacle to her ability to robustly perceive the incoming signal (i.e. source speech) – a burden that would not be relevant or present in the context of simple passive listening under optimal conditions. I assume that, while interpreting, signal-degrading noise can result from various factors such as the physical sound of the interpreter's own vocalisations, but also cognitive processes engaged by the interpreter's brain specifically in the context of the interpreting task. Neither the interpreter's own vocalisations, nor cognitive processes such as mental translation (reformulating into the target language) and control of speech production (producing the interpreting output) occur during simple passive listening. These extra, concurrent, tasks make listening to the source speech harder.

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4 – One might think of such contextual details as of secondary importance, when the SI task is being viewed as a complex human skill to be described in terms of cognitive processes operating in the mind of the interpreter. But the use of written aids during interpreting clearly implies the recruitment of additional/different cognitive processes. And factors external to the interpreter's mind, such as the availability of help from a boothmate, clearly affect the cognitive load of said task for the individual who is interpreting.

1.3.2 "Chunking" – two meanings not to be confused

A potential source of confusion that warrants clarification is the difference in meaning between the word "chunking" as used in the field of interpreting studies, and the same word's meaning in psychology with regard to working memory.

1.3.2.1 "Chunking" or "segmentation" in interpreting studies

In his summary of "strategies" discussed in the interpreting literature (that is, techniques employed by interpreters to deal with challenging aspects of the SI task), Pöchhacker (2016, p126-130) describes "chunking" as a "widely taught strategy". A definition of this technique is provided by Seeber (2011), stating that "as a strategy in SI, chunking refers to the process whereby interpreters segment the input into smaller fragments that can be encoded without having to wait for the entire sentence to unfold".

This strategy has also been referred to as the "salami technique" by Jones (2002), and French-speaking interpreting trainers have been known to refer to this same technique as "saucissonnage" [5] – in both cases the metaphor of slicing up a sausage into manageable chunks, rather than attempting to eat it whole is linked to how the interpreter can tackle a complex incoming message. Setton & Dawrant (2016) refer to this same strategy as "chunking and joining" [6]. The relevant entry for this same concept in the Routledge Encyclopedia of Interpreting studies is given the title of "Segmentation" (Pöchhacker, 2015 p367), and this is the term I will use in this thesis when referring to the concept itself, or when qualifying the ambiguous term "chunking".

1.3.2.2 "Chunking" in working memory research

Beyond interpreting studies, in the cognitive science literature on memory, "chunking" is a term used to refer to what is known to be an effective conscious strategy individuals can employ when performing a task designed to tax working memory, or WM, (such as recalling a list of items, e.g. digits, presented aurally or visually), boosting their performance on the task. When the metacognitive strategy of "chunking" is

5 – Author's personal experience at the University of Geneva's MA in Conference Interpreting. This term is also mentioned in Pöchhacker (2015, p368).

6 – The word "joining" is a useful reminder that when "chunking" or "chopping up" the input into "salami slices", things will eventually need to be connected together. As Seeber (2011) notes when commenting upon this technique (which he calls "text chunking"), "Although the [source language] input can be integrated and encoded immediately, the absence of a main verb relating the arguments to each other means that the chunks need to be strung together downstream in order to establish (or recover) the original meaning, causing a temporally deferred increase in cognitive load. A non-negligible drawback of this strategy is that the resulting constructions are sometimes convoluted."

employed by an individual for such a task, units of information are assembled in a meaningful way that can be linked to information that is already stored in long-term memory, with Bor & Seth (2012, p1) describing chunking as a process that "exploits logical or mnemonic redundancies in a dataset so that it can be recoded and a given task optimized". By using this 'trick', individuals can improve their performance as measured by the number of items that can be held in, and retrieved from, working memory. [7] As Bor, Wiseman, Duncan & Owen (2003) have pointed out, working memory item chunking has been employed successfully in contexts as different as exchanging information in Morse code [8], and playing chess[9]. I will call this second type of chunking "WM-item chunking".

1.3.2.3 The relevance of this second type of "chunking"? – three factors

WM item-chunking, as a consciously deployed memory strategy, may seem like something of a party trick and not directly relevant to the problem we are discussing. The use of WM-item chunking in the form of conscious, on-the-fly, mnemonic encoding of items, is unlikely to be a viable, efficient or directly applicable technique for an interpreter who is in the midst of a simultaneous interpretation. The reason I believe chunking is relevant to this discussion, however, is that the (post-encoding) information-retrieval part of the phenomenon of WM item-chunking reveals a more general principle about how the mind operates. It shows that there is a dynamic and functional relationship between three factors – (1) an individual's capacity to process information in working memory at a particular moment; (2) properties inherent to the items[10] needing to be held in working memory at that particular moment, and (3) the availability (or not) to the

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7 – To provide an example of chunking deployed as a metacognitive strategy to improve working memory performance, If someone was trying to hold in working memory a dataset of 7 items corresponding to the 7 active languages the University of Geneva's Masters in Conference interpreting (Arabic, English, French, German, Italian, Russian, and Spanish), they could use a chunking technique to make this easier.

If they already know the UN's official languages (Arabic, Chinese, English, French, Russian, Spanish), the FTI languages can be encoded in this way: "UN except Chinese, pus Italian and German", or simply "Chinese Italian German" (since having encountered the full list of FTI languages once, it may be easy to remember that Chinese is not one of the languages). Now much fewer need to be held in working memory to retain information relating to 7 items, greatly reducing working memory load. Further semantic redundancies can be exploited through linguistic encoding – the Initials of Chinese, Italian and German can be formed into the word "cig" (cigarette), a concrete noun that is easy to remember.

At its extreme, then, long term memory and knowledge can be used to exploit semantic redundancies in the list of 7 FTI languages to greatly facilitate retention of this information in working memory, chunking the original 7 items into just one single item.

8 – Bryan & Harter (1899)

9 – Chase & Simon (1973)

10 – properties such as their intrinsic "informational redundancy" or "linguistic entropy", or their "amenability to chunking" – see sections 2.2 and 2.4

individual of previously stored ‘templates’ in long-term memory that can help group or organise these particular items into chunks – and all of this can be linked to the problem of interpreting numbers.

The first of those three factors is affected by the the second and third. We can draw parallels between the cognitive operations involved when an individual performs a chunking task in a psychology experiment (in which they are handling items in a task designed to tax working memory, and during the later phase of the experiment they are making use of relationships between the items that they had encoded in an earlier phase), and the cognitive operations involved in SI (which can be seen as the handling of units of linguistic information in a complex task that taxes working memory). In this thesis, I consider that working memory capacity is a key (and limited) resource in SI, and whenever there is a higher burden on WM capacity during an interpretation, interpreting becomes more difficult.

With regard to the second factor, In a later section 2.4.3.2 I will discuss a neuroimaging experiment on chunking where the amenability to chunking of the items being processed by participants differed (this difference was deliberately manipulated by the researchers). In relation to this, I will also argue that among the different units of linguistic information in a speech that are encountered by an interpreter during SI we can note a naturally-occurring variability in “linguistic entropy” – a property that is comparable to the factor of “amenability to chunking” that was artificially manipulated in the previously mentioned experiment. During SI, we can say that different elements of the source-speech will be inherently more or less amenable to “chunking”, or in other words will have more or less semantic “glue” binding items together – with information such as numbers (or series of names, or lists) being harder (or impossible) to “chunk” and therefore causing a higher burden on WM, whilst some phrases or sentences have interconnected elements that are easier to “chunk”, which helps to explain why numbers cause difficulty during SI.

Regarding the third factor – the availability to the interpreter of “templates” in long-term memory – the importance of such templates in expert skills (among which I assume SI can be included) will be discussed with reference to the broader cognitive science literature in section 2.4, but it is worth pointing out at this stage that this argument has not been neglected within the field of interpreting studies itself. Seeber (2011, p179) notes, for example, when presenting his Cognitive Load Model of SI, Chase & Simon’s (1973) “chunking theory” of the high-level performance of chess masters and other experts, according to which these experts acquire, through extensive practice and study, a large mental repertoire of chunks that can be accessed and deployed on task. And he asserts that the notion of chunks is essential to the discussion of language processing, relating this work on chunking theory to his own model of SI – which draws theoretical foundations from Cowan’s (2005) theory of “focused attention” in working memory, which is a general cognitive theory not specific to SI – explaining that “Working memory may […] shift between the different hierarchical levels in order to reduce load: chunks can be retrieved and merged into a larger chunk, thereby freeing up capacity" (Seeber 2011, p180). We can also note that in Setton and Dawrant's (2016) interpreting course book, a similar argument (which I discuss in more detail in a later section 2.2.2) is made in less formal terms, with an emphasis on what they see as the experience-dependent acquisition of a "mental phrasebook" among interpreters as being key to the development of expertise in SI. In a later section 2.4, I also consider neuroimaging evidence on chunking and expert skills from beyond the field of interpreting studies, to further develop this argument that attempts to explain some of the difficulty numbers pose during SI in a way that relates to the three factors I have mentioned at the beginning of this section (section 1.3.2.3).

To summarise, the rationale behind discussing WM-item chunking in this thesis is to make the broader point that when processing incoming information, our brains can and do exploit semantic redundancies that may be inherent to that information, and they can also deploy pre-existing schemas (or "templates") from long term memory. The deployment of such pre-existing schemas frees up processing capacity and thus facilitates the task of processing the incoming information. During a task that stresses working memory, of which SI is an example, there can be naturally occurring opportunities to use such pre-existing schemas on-the-fly. Numbers, I will argue, are a type of information that is inherently less likely to either contain semantic redundancies or be linked to pre-existing schemas, both of those being factors that facilitate interpreting by freeing up processing capacity, which helps to explain why numbers cause difficulty for the interpreter that is hard to mitigate.

1.3.3 Is the processing of numbers actually worth special consideration?

1.3.3.1 Insights from the field of interpreting studies

This thesis assumes that numbers are particularly difficult to interpret, that this difficulty stands out enough that it deserves to be understood in its own right, and that ways of mitigating this difficulty ought to be evaluated. It would seem that such a view does find support in both the academic and the pedagogical literature on SI.

For example, the Routledge Encyclopedia of Interpreting Studies contains an entry dedicated to the question of numbers, in which Mead (2015, p286) points to one-to-one correspondences of numbers between languages, and the fact that (beyond their numerical value) number words are "neither intrinsically associated with other extralinguistic referents nor predictable from context", and he goes on to argue that this unpredictability "precludes any opportunity for 'top-down' comprehension or anticipation, except when the figures concerned can be readily associated with a familiar schema (e.g. billions and not millions as the correct order of magnitude for estimates of world population)" (ibid, p 287) – which helps explain why they are difficult to interpret. Lamenting "that there has been relatively little systematic investigation" on the interpretation of numbers (ibid, p286), he nevertheless briefly mentions some pertinent experimental and theoretical research before positing that when interpreting speeches with numerical information the interpreter needs to continually be ready to switch between two listening modes: an "intelligent" top-down approach (for the non-numerical information that provides the context to the numbers) and a "literal" bottom-up approach (for the numerical information that needs to be accurately rendered and causes significant demands on working memory processes). He concludes that:

> "As so much hinges on the ability to switch attention between the bottom-up processing of numbers and the very different demands of interpreting the context they are part of, completeness and accuracy in rendering speech segments which contain numerical data are difficult to achieve and ultimately depend on the combined effect of the many other input variables which affect the interpreter's performance."
>
> Mead (2015, p287)

This thesis' arguments will align with those put forward in Mead (2015), and my discussion of possible mitigating strategies for the difficulty of interpreting numbers during SI will speak to an understanding of the fluctuating top-down versus bottom-up demands of interpreting speeches containing numbers.

With regard to empirical studies, there have been a experiments on interpreting numbers during SI – three are mentioned later in this thesis (see section 2.5.5), and despite their significant limitations in methodology and scope, they demonstrate at least that in the field of interpreting studies this issue is considered worthy of investigation.

Finally, in the pedagogical literature both Jones (2002) and Nolan (2012) dedicate sections of their training books to the question of numbers during SI – the former warns of some of the pitfalls posed by numbers and recommends possible in-booth solutions that can be readily deployed; the latter provides targeted training exercises to be followed by the diligent student, with the desired outcome of eventually seeing improved number processing during SI.

1.3.3.2 Insights from beyond the field of interpreting studies

Looking beyond the interpreting literature, there are reasons to consider that numerical information in a speech is somehow special and different from the rest of language. For example, in the introduction to their paper on numbers during SI, Braun & Clarici (1996, p85) refer to the linguistics literature in characterising spoken number words as being "organized in structured systems and are formed by matching verbal expressions with numerical operations. Linguistically, they are characterised by an extremely reiterative syntax".

In other words, we can say that the mechanism for expressing numbers in spoken language operates like an separate, discrete, embedded grammar system, within the wider linguistic apparatus used to organised words in sentences – this system has its own lexicon (number words) and syntactic rules (a string of number words means different things depending on the position of each word). There are rules of addition (twenty-two = 20 + 2), multiplication (seven hundred = 7 x 100) and different orders of magnitude, that are combined to express any conceivable number. These rules can be aligned or can differ between languages (and as will be addressed in section 2.5.1, this is an important factor influencing the difficulty of interpreting numbers during SI).

Sella, Hartwright & Cohen Kadosh (2018) provide an overview of the neurocognitive bases of numerical cognition – a field of study that addresses the processing of numerical information, whether symbolic (eg via Arabic numerals and number words) or non-symbolic (eg sensitivity to magnitudes, eg by discriminating differing amounts of dots presented to a participant, or even a non-human animal), acquired and developmental disorders of numerical processing, counting, arithmetic, as well as other topics. Methodological approaches range from patient studies to behavioural and neuroimaging experiments. This is a vast field, and in section 2.5 this thesis will limit its discussion of numerical cognition to a handful of research findings that I consider particularly relevant to the interpretation of numbers during SI (that is, topics such as bilingual numerical processing, unit-decade decomposition in numerical perception, number discrimination, and modality effects between number-words and Arabic numerals) .

On the question of whether numbers are special when compared to other parts of language, neuropsychological[11] research has provided insights on how multiple systems that are functionally separable may be involved in processing numbers. Sella, Hartwright & Cohen Kadosh (2018) mention reports of the following impairments: a patient unable to read out loud Arabic numerals, whilst still being about to read out number-words and other words; a former accountant who could not read out loud visually presented Arabic numerals or number words, however this patient could read out other words that weren't numbers, and was able to produce Arabic numerals or number-words in writing ; another patient who had no impairment in reading out loud number words, but had difficulty doing the same for other words. The conclusion from these and other cases is that:

11 – Neuropsychology is a field of study that adopts the information processing view of cognition, and where patients who happen to have acquired or developmental neurological disorders or injuries are studied for the cognitive effects they exhibit. From the patterns of functional disturbance, inferences are then made about how the function is organised in the healthy brain. Neuropsychological evidence has been a key source of insights to how the brain works – for example the study of "split brain" patients by Gazzaniga (1967) has revealed much about how cognitive functions are organised between the two hemispheres of the brain (these patients had their hemispheres separated by surgery to their corpus callosum, as a treatment of last resort for severe epilepsy).

> numerical information in its 'simplest' form – a single Arabic digit or number word, for example – is not equivalent in all modes of presentation. Furthermore, Arabic numbers are not supported by the same cognitive systems that represent alphabetised language. Numerical information is compartmentalised, and distinct domains exist at the neurocognitive level.
>
> Sella, Hartwright & Cohen Kadosh (2018),
> paragraph 4 of section "Exploring Numerical Cognition
> through Cognitive Neuropsychology".

1.3.4 What is meant by "difficulty"?

A common trope in the world of conference interpreting is the image of a swan gliding with seeming effortlessness across a lake, while below the water's surface its feet may be paddling furiously. By comparison, the interpreter may produce a sustained and coherent output but knows herself the variability in demands her work presents over time. To think of moments of "difficulty" during SI only as those occasions where mistakes are observable in the interpreter's performance, would fail to characterise the nature of the task, where different moments during a speech may vary considerably in how difficult they feel to the interpreter, and a moment of great difficulty may not provoke any mistakes (or may do so in a delayed manner, with the difficulty momentarily resolved with a strategy that causes further problems down the line – errors may appear in a section of the output that corresponds to a section in the original speech that in other circumstances might be easily rendered, and that is downstream of the speech element that triggered the initial difficulty). This thesis takes the concept of "difficulty" to mean "cognitive load" during SI, a concept described in the Cognitive Load Model (Seeber, 2011), and which allows for a dynamic view of task demands during SI (see sections 2.3 and 2.4).

1.3.5 Advice on interpreting numbers during SI

As Pöchhacker (2004, p133) explains, the literature on interpreting has long considered "strategies" that are employed by interpreters during the SI task in order to cope with focal points of difficulty. Those discussed include what he describes as "lagging" strategies - when the meaning of the source-speech is not yet clear, the interpreter can either wait silently, or stall (provide "neutral padding expressions or fillers") until "further disambiguating input" arrives. He also mentions the segmentation strategy (the salami slicing technique), which he observes is a more pre-emptive strategy than the lagging ones, avoiding the problem of the "higher storage load" that results from the lagging strategies, which limits their usefulness. Further, he explains that much attention has been given in the literature to anticipation as a strategy — both on the linguistic level, of "word prediction based on familiar lexico-grammatical patterns", and anticipation on the conceptual level, referred to as "sense anticipation". Finally, he also mentions "the strategy of compression, or 'abstracting', in response to high input speed and/or information density in the simultaneous mode" - that is, providing a more concise, and perhaps less detailed, synthesis of the information to be interpreted.

Seeber (2011), when presenting his Cognitive Load Model, considers strategies established by others previously in the interpreting literature – namely the strategies of waiting, stalling, segmentation[12], and anticipation – and he theorises on how they fare for a hypothetical interpreter dealing with syntactic complexity as a factor of difficulty in a source speech.

Of these aforementioned strategies, compression and anticipation will receive further mention in this thesis, with the argument that one of the reasons numbers cause difficulty during SI is their relative lack of amenability to these two strategies. The lagging strategies of stalling and waiting will be characterised as inappropriate for dealing with numbers, and instead their "opposite" strategy of tailing – following the source speech closely in time – will be considered as a possible mitigating strategy for the difficulty of interpreting numbers.

Beyond these "strategies", this thesis will refer to more specific practical advice that might be given by a trainer (such as "always write down numbers during SI") to help a student cope with interpreting numbers during SI. After providing an account of the sources of difficulty in section 2, examples of advice will be re-examined and appraised in section 3. Here I will first describe these pieces of advice:

1.3.5.1 Do targeted training on numbers

In their course book, Setton & Dawrant (2016, p167, p289) have asserted that numbers may require targeted training and are particularly useful in the case of misaligned numbering systems among an interpreter's working languages. They write that this is a case where an "incremental realism" approach to training (where amassing lots of practice interpreting speeches of the type likely to be encountered in real working life is enough to, over time, bring with it improvements in all aspects of SI) will not help improve this sub-skill in a time-efficient manner.

Nolan (2012, p272-277) suggests several exercises aimed at addressing difficulties of interpreting numbers, although he does not provide much in the way of justification for his recommendations. His first exercise presents a passage of text containing various numbers, with the student asked to consider for each number whether it is a "technical measurement" or "order of magnitude" – see section 1.3.5.6 for more on this

12 – Rather than "segmentation", Seeber (2011) instead uses the term "chunking", and in the same paper also mentions the other kind of "chunking" relating to the holding items in working memory. For reasons of clarity, as explained in section 1.3.2, I have referred to the concept as "segmentation" here.

distinction that Nolan (2012, p272) makes. In his second exercise he presents a list of various isolated numbers (eg 80; 92; 270; 80 000; 167,767; 359.98) and instructs the student to record these numbers read out loud at moderate speed in her source languages, and then practice interpreting them into her target language without falling behind, and checking a recording of the interpretation for accuracy. The student should repeat until a perfect performance is achieved, then re-record the numbers being read out in the source languages at a faster speed, and repeat the exercise. To introduce variation, he suggests writing those numbers on index cards, shuffling them after a successful exercise, and re-record the numbers being read out in the newly randomized order. Another exercise involves shuffling the index cards and simply reading them out at speed. And the final exercise he suggests for training on isolated numbers is to listen to recordings of the list of numbers and practice writing them down as quickly as possible.

In a second set of exercises, Nolan (2012, p273-274) suggests training numbers in context, rather than isolation – stressing the importance of interpreters accurately rendering the units or "referents" of the numbers (without which the number can be of little or no use to the audience, or actively misleading). He provides specially chosen number heavy passages of text (dense in numbers and their units, and also packed with many proper nouns and lists of facts) instructing students to first internalise the speeches in memory by listening to them and practicing repeating from memory, then asking them to practice interpreting the speeches until rendered perfectly.

1.3.5.2 Use your boothmate as a number-scribe (or use a real-time transcript)

For challenging speeches, it is common practice within the conference interpreting profession for a simultaneous interpreter to avail herself of her boothmate's help, with the latter writing down source speech numbers if able to understand the language of the source-speech. It is a reflection of the recognised difficulty of handling numbers during SI, and the amenability to assistance via note-taking of these difficult aspects of SI (numbers, unlike a complicated argument or a subtle joke, can be readily noted down), that helping one's boothmate with numbers is advice seen in conference interpreting course books (eg, see p 334 & p415, Setton & Dawrant, 2016). Jones (2002, p119) says a boothmate who understands the language being interpreted should write down numbers, adding that "they should write down solely the relevant numbers, possibly with the units", and that noting down other non-numerical information from the speech surrounding the number is "likely just to confuse their colleague".

The number-scribe that an interpreter can use, however, may not necessarily be limited to her boothmate. In some meetings, particularly in some legal courts, or in educational settings a real-time transcription of the meeting may be provided (typically in one language, usually English, based on the input from the floor when delegates speak in English, and the English booth when they speak a different language) by a 'court reporter' or ‘stenographer’ (Stinson, 2015) . This can be for protocol reasons, it can be a courtesy provided to delegates, or an accessibility service for deaf or hearing-impaired attendees. As Setton & Dawrant (p367-8, 2016) advise, real time transcription can be a boon for interpreters, especially for handling “transcodable”[13] elements of a source speech, and should be used when available:

> the interpreter should request a display screen in order to be able to see the real-time English transcript being produced by the court reporter: this can greatly facilitate accurate rendition (from English into the other language), in particular of complex questions containing numbers, names and dates.
>
> Setton & Dawrant (p367, 2016)

1.3.5.3 Optimise your preparation before interpreting

As Mead (2015, p287) observes, numbers that appear in a speech are difficult or impossible to fully predict or anticipate with prior knowledge, but in some cases they can at least “be readily associated with a familiar schema (e.g. billions and not millions as the correct order of magnitude for estimates of world population)”. One piece of advice, while there are limits to how useful this can be, might therefore be to say that during preparation an interpreter would do well to superficially familiarise herself with relevant figures, their orders of magnitude, and the units typically used to describe them, as well as trends or relations between the numbers (eg, understanding that the company’s results being reported are much better than last year, but still not at pre-crisis levels). And if there are specific figures from meeting documents she suspects are likely to come up, she should ensure that she has a copy of them to hand.

In the case of SI with text, where the interpreter has access to the speech in written form beforehand (or notes of the speech, or presentation slides), the question of how numerical information is considered under the aim of optimal preparation is worthy of mention. Cammoun-Claveira, Davies, Ivanov and Naimushin (2009) conducted a survey of trainers at various interpreter training institutions asking about how SI with text is taught, with several of the interviewees mentioning among the advice given to students that numbers should be marked up. An appendix in the same paper includes in-house training documents from the interpreting service of the European Commission, showing that in the answers from a brainstorming session, and in a “Do’s and Don’ts” list of pieces of advice, numbers feature prominently – they are seen as a type of information within a speech that is mentioned along with acronyms and proper nouns (a grouping that aligns well with the arguments of this thesis developed in later sections), and that is considered as being worth noting or highlighting in the text being prepared; a recommended behaviour if the interpreter has enough time to prepare, but also, importantly, one of only a few pieces of advice deemed worthy of mentioning for situations in which the interpreter is very short of preparation time.

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13 – see section 2.2.2

In the advice that Setton & Dawrant (p330, 2016) give for preparing a text when available, they mention that, for dense parts of the text, names and numbers should be highlighted. Access to numbers in a text is important enough to them that the they also recommend interpreters providing relay share the text with colleagues taking the relay, even if they do not understand the language of the text:

> If you have received an advance copy of the speaker's text in a language that is understood by colleagues in other booths, make sure that they receive it. If you have a copy in your language only and there is time, brief the colleagues who will be taking relay from you on names, numbers, and terms or key messages of special significance in the text. Even a copy of the original text may help them if it is especially dense in names and numbers or international bibliographic references, in tables and lists, for example.
>
> p 333, Setton & Dawrant (2016)

1.3.5.4 Write down numbers whilst interpreting

Jones (2002) suggests that while a number appearing on its own in the course of a speech can be interpreted without special techniques, when numbers arrive multiply in short succession there is a risk of breakdown, and the interpreter should in these cases apply two strategies, with neither being mutually exclusive. The first is described in section 1.3.5.5 and involves the interpreter adapting her output style. The second is to write down all numbers as soon as they are heard. He asserts that this has the effects of "unburdening your memory immediately so you can concentrate on interpreting the rest of the sentence, fitting the numbers in as appropriate", reducing the risk of misinterpreting "difficult numbers", and making it easer to interpret quickly (as he asserts that going directly from source language to Arabic numerals, and then directly from Arabic numerals to target language is quicker and easier than going through a burdensome "translation process") – ibid, p118-119. On this last point he also points out particular difficulties when there are misalignments between the two language's number systems which mean the "grammar" of the way the numerical value is expressed is different, an issue that I will discuss in section 2.5.1. He gives the example of languages where a number such as 48 is expressed as "eight and forty", and says that going through the intermediate step of writing the number in Arabic numerals and reading that out in the target language makes it less likely to be misinterpreted (for example as "eighty four"). He adds that an interpreter aware of this risk can also resolve to always write these two-digit numbers down in reverse, starting with the unit (the 8) as soon as it is heard, and then write the decade (the 4) to the left of the 8.

A piece of advice Nolan (2012) provides for writing down numbers during SI is for students to devise two efficient symbols that they will settle on and use whenever writing down numbers : one symbol to replace two zeros (to indicate the number is a multiple of 100) and another to replace three zeros (to indicate the number is a multiple of 1000), so that they can efficiently write down numbers like 200 or 4000 or 300,000 with just two or three graphical elements.

1.3.5.5 Drive defensively – adapt your output style pre-emptively

This piece of advice is the one that relates most directly to what are traditionally considered interpreting strategies, as described in opening paragraph of section 1.3.5. An intepreter's "adaptive output style" is a catch-all term I use to describe a type of meta-strategy: that is, the intelligent and deliberately varied deployment of various interpreting strategies in order to maintain a faithful interpretation under the pressure of numbers coming in thick and fast. This adaptive "output style" can include consciously adopting a shorter time-lag between the input and output content, choosing to compress information around the numbers into terse phrases, omit non-essential information, re-order information to ease processing demands, and make heavy use of the segmentation strategy. These various strategies can be employed pre-emptively in anticipation of the challenges that a number-heavy stretch of the source-speech will pose, and abandoned and re-adopted over the course of an interpretation when deemed necessary by the interpreter to ensure an optimal transmission of the speaker's main message given the challenging circumstances.

For example, Setton and Dawrant (2016) describe how the interpreter can adopt a short lag and make heavy use of segmentation, what they call "tight chunking":

> A short lag is safer for getting short-span items like numbers and new names, but the resulting narrow window prevents waiting or stalling while complex embedded structures resolve themselves, leaving skilful 'tight chunking' as the only recourse. is is a difficult skill that also inevitably destroys or defers some logical links between the propositions, shades of relative emphasis, etc., which then have to be restored, either linguistically or by intonation.
>
> p305, Setton & Dawrant (2016)

Jones (2002, p118) advises that once two or more numbers appear in a speech, the interpreter should change their approach and:

> "unload their memory and say numbers as soon as possible after the speaker has said them […] This means modulating the distance they keep from the speaker […] if the interpreter senses that numbers are going to be given, they should accelerate their own speech so as to catch up with the speaker. If a speaker announces numbers with a phrase such as 'Let me provide you with some statistics', the interpreter may do well to skip that sentence altogether, as it will make it easier for them to catch up totally on the speaker. If the interpreter cannot catch up with the speaker, they must finish the sentence preceding the numbers as quickly as possible and then move on to the sentence including the numbers *by saying the numbers first.* […] If the speaker says, 'Imports of jeans from China have increased by 9.3%, from the Philippines by 6.5%…', the interpreter can interpret '9.3% is the increase in jeans imports from China, 6.5% from the Philippines…', so as to say the numbers instantaneously.
>
> p118, Jones (2002)

The same advice on reordering sentences so that the numbers are uttered first is given by Seleskovitch & Lederer (1989, p156). They also stress the importance of interpreters being able to exert an elastic control of their time-lag:

> Le rythme que les étudiants doivent acquérir n'est pas régulier ; il faut leur apprendre à travailler en accordéon, à ouvrir le soufflet pour bien comprendre et exprimer les idées, à le refermer pour mieux transcoder.
>
> p157, Seleskovitch & Lederer (1989)

1.3.5.6 Provide an approximation of the number

Jones (2002) writes that there are occasions where every digit of a number must be accurately interpreted, giving the example of customs tariff codes, where individual digits are crucial to determining a tariff classification. But he says there are also occasions where it is possible to use approximations (eg interpreting "295.6 tonnes" as "290-odd tonnes" when the point being made is that a quota of 300 tonnes has almost been used up), with the message not suffering in its essential meaning. He explains that this approach can be necessary "where there is a sequence of numbers where it is well nigh impossible to interpret them all, or where there are other very difficult elements in a speech that the interpreter needs to be able to concentrate upon" (ibid, p120).

Nolan (2012) similarly makes a distinction between situations where approximations are permissible and others where they are not, saying "Figures given by speakers are generally offered either as an order of magnitude or as a technical measurement" (ibid, 272). In the first case, approximations are acceptable and even recommended, in as much as they do not harm communication and help avoid breakdowns by reducing processing demands for the interpreter. In the second case (he gives the example of the figure 873.5 milligrams to an audience of pharmacologists), providing a wrong measurement is not acceptable and may be worse than not providing the number at all. When approximating numerical information, he goes on to advise that "at the very least, the interpreter should strive to accurately render the quantitative or quantitative concept correctly, that is to use the right unit of measurement or make clear whether the speaker is talking about an increase or decrease, for example." (ibid,272). He also suggests an exercise where the student examines a number-heavy text and determines which numbers can be approximated without harming the meaning and which cannot – which suggests he believes that being able to spot opportunities for permissible approximations of numbers is a useful skill that interpreters can and should develop, and take advantage of in the booth.

2. Why are numbers difficult to interpret?

In this section various explanations for why numbers present difficulty during SI will be discussed. Not all explanations will necessarily be relevant to every situation where an interpreter faces difficulty (for example, when interpreting from one's native language, the effect of language proficiency in comprehension of the source-speech, described in section 2.1, will not be so relevant; or when an interpreter has difficulty accurately rendering "quarante-deux" as "forty-two", number-system misalignments described in section 2.5.1 cannot be the source of this particular moment of difficulty). Considering the provided explanations as a group, however, it is hoped that one or more of them may be able to offer a plausible account for each real-life instance of difficulty interpreting numbers.

2.1 The effect of language proficiency

Within the conference interpreting profession, interpreter's languages are classified as 'A', 'B' or 'C' languages (AIIC, 2012). An 'A' language is an interpreter's mother tongue or language of culture and education, into which she works from her 'B' and 'C' languages, a 'B' language is a foreign language the interpreter uses both passively (interpreting from it into an 'A' language) and actively (interpreting into it from an 'A' language, and sometimes also from any other 'C' languages). 'C' languages are purely passive foreign languages from which the interpreter works into her A language, and sometimes B language[14]. In this part of the thesis, I will consider the issue of insufficient proficiency in a foreign language as a reason for an interpreter having difficulty with numbers during SI. For ease of discussion, I will address this "effect of language proficiency" in terms of interpreting from 'C' into 'A', a not uncommon mode of interpreting, and perhaps the dominant one at major institutions where conference interpreters can work with multiple C languages.[15]

With regard to the expected level of proficiency in comprehension of a 'C' language, the International Association of Conference Interpreters says a 'C' language is one which the interpreter "understands perfectly" (AIIC, 2012), and the European Union (2018, p1) considers a 'C' language to be one which is

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14 – Some interpreters only use their B language actively when interpreting from their A language, not from other B or C languages. At the European Union, interpreters with a B language are only expected to interpret actively into this language from their A language. (European Union, 2018)

15 – Looking at the list of language profiles in demand with the EU interpreting services for the freelance interpreter testing cycles 2018-2019 and 2019-2020, we can observe that 23 of the 24 booths (organised by A language) are willing to test interpreters for accreditation who offer no B languages in their language combination, but who do offer at least 2 (or in some cases at least 3) C languages – European Union (2018). At the United Nations, interpreters working in the English, French, Spanish and Russian booths only ever interpret into their "main language", that is their A language, from their other languages – in other words, from C to A (United Nations Language Careers, n.d.)

"fully understood". It can be argued that such a description, however, is lacking and could be improved through wording such as "comprehension at levels that are similarly accurate, rapid and robust when compared to native-speakers".

I mentioned in section 1.3.1 that the source-language comprehension aspect of SI can be looked upon as an example of speech perception under adverse conditions (such as occurs for speech perception in noise). Here the level of receptive proficiency one has in the source language becomes relevant. In their daily life, experienced second language users may well find understanding multilingual announcements made over a tannoy system harder to follow in their second language than in their native language, and yet once they know the substance of the announcement and hear it in their second language again, they can now understand it and can see that had it originally been made under acoustically optimal conditions they would have "fully understood" the message the first time. Similarly, they may find a persistent difficulty in following conversations over the telephone, or in a noisy room, in their second language compared to their native language, whilst not feeling impaired to a similar degree between the two languages when having in-person conversations under optimal acoustic conditions. Indeed, various studies[16] have looked at the issue of non-native listeners and their poorer ability to cope with speech perception under adverse conditions compared to native-listeners, whose comprehension also suffers but not to the same extent, with this relative robustness of perception among native-listeners perhaps revealing a sensitivity to more of the cues (phonetic, lexical, syntactic, conceptual, formulaic speech elements) that remain in the degraded signal and in the listener's brain and can be exploited in its potential perceptual repair. With regard to interpreting numbers during SI, it seems there are two areas in which proficiency effects may arise: when processing the non-numerical parts of a speech, and when processing the numerical parts.

2.1.1 Proficiency effects in the non-numerical parts of a speech

It is possible to conceive of two interpreters (or interpreting students) both accurately understanding a sentence in a source language, and managing to accurately interpret it into their target languages, whilst differing in the amount of cognitive effort deployed in the first place to understand that sentence – a factor that may have knock-on effects for the interpretation of subsequent parts of the speech even if it doesn't affect the interpretation of the particular sentence in question. For example, for one interpreter, a sentence could contain tricky syntax, or could contain sequences of formulaic speech[17] (such as collocations, proverbs, or any multi-word chunk that is one of the more 'natural' ways of expressing a particular idea in that

16– See, for example, Cooke et al (2008) ; van Wijngaarden et al (2002) ; Garcia Lecumberri et al (2010) ; Tabri et al (2011) language). These features of the sentence may be transparent enough in their meaning (decipherable either directly or through context) that these sequences can be understood accurately without the interpreter needing to be familiar with them or even implicitly sensitive to their statistically “formulaic” nature which makes them idiomatic ways of expressing such ideas. The other interpreter with higher comprehensive proficiency will, however, be understanding that sentence both more rapidly and more robustly – through activation of implicit memory, she may already be anticipating the tail ends of collocations when they begin, understanding them as single chunks of meaning, and may be able to perceptually repair a part of the signal she misses or hears imperfectly because she already has a template in her long-term memory of the multi-word chunk or the syntactic pattern to which that part belongs, all of which means that the sentence can be more readily and robustly processed. Accuracy of comprehension, therefore, is not on its own an adequate measure of proficiency in second language comprehension, just as subjective difficulty during SI cannot only be inferred from observable errors in the interpreter’s output (see section 1.3.4).

Various neuroimaging studies have demonstrated more effortful processing happening “under the hood”, when comparing second language (or L2) comprehension to native language (or L1) comprehension. Typically this more effortful processing is seen through increased activation, and more distributed activation (activation present in more areas of the brain, particularly frontal regions) for L2 compared to L1 comprehension[18], but this seems to be an effect driven more by differences in proficiency rather than the ‘nativeness’[19] of the language or its age of acquisition, and the more proficient one is in understanding their L2 the more their brain response during comprehension tasks appears like that for their L1.[20]

In later sections of this thesis, I will argue that numbers are inherently dense in information, low in

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17 – A strong command of formulaic speech is considered a key feature setting apart the most highly advanced second language speakers from other advanced speakers – see, for example Lundell et al (2014).

In an evidence-based review, Ellis (2012) highlights the importance of formulaic speech in the acquisition, comprehension and use of both first and second languages, arguing that advanced comprehension of a language entails sensitivity to formulaic language and statistical learning of words and their transitional probabilities with other words (seen for example in perceptual repair of ambiguous stimuli, and in faster reaction times revealing priming effects of formulaic sequences). He argues “against a clear distinction between linguistic forms that are stored as formulas and ones that are computed or openly constructed. Grammatical and lexical knowledge are not stored or processed in different mental modules, but rather form a continuum from heavily entrenched and conventionalized formulaic units (unique patterns of high token frequency) to loosely connected but collaborative elements (patterns of high type frequency)” (ibid, p25).

18 – See Centeno et al (2014) ; Roncaglia-Denissen & Kotz (2016)

19 – See Nevat, Khateb & Prior (2014) – the language in which you are most dominant for a particular task domain is the one for which brain activity will be most efficient in that particular task domain.

20 – See Roncaglia-Denissen & Kotz (2016) ; Shimada et al (2015) ; Consonni et al (2013) ; Leonard et al (2011) ; Stein et al (2009); Kotz (2009)

predictability and poor in semantic associations compared to most other parts of a speech – with this being true regardless of how well the interpreter understands the language – factors that mean interpreting numbers is more demanding in terms of cognitive resources (especially when the numbers appear in quick succession) than those other, non-numerical, parts. If the interpreter is already processing the non-numerical parts with great effort due to insufficient proficiency in her comprehension of the C language, then the challenge of numbers appearing in quick succession may represent a challenge too far. In contrast, another interpreter with high receptive proficiency, with ready and robust comprehension of the non-numerical parts, will be better able to apply the interpreting strategies of anticipation and compression on those portions of her interpretation. Applying these strategies would free up resources and have the effect that she is now better able to cope with any momentary peaks in processing demands that may arrive in the course of her work, triggered, for example, by a list of numbers appearing in the speech.

2.1.2 Proficiency effects in the numerical parts of a speech

With regard to the numbers themselves, proficiency effects may also be relevant. In a review of the literature on bilingualism and cognitive arithmetic, Rusconi, Galfano & Job (2007, p169) make the point that:

> According to self reports, bilinguals tend to count and do arithmetic in just one of their languages, which is usually the one in which they were taught arithmetic (this is also true for the participants of Rusconi et al. 2006c). When, after having received formal education in one language, people move to a different linguistic community and remain there for a long time, they tend to lose proficiency in L1. But even when L2 has become dominant, they keep working out numbers and calculations in their original language (Dehaene 1997).
>
> Rusconi, Galfano & Job (2007, p169)

And so an interpreter working from her C into her A language may not be perceiving numbers in the source language as readily as she would if she were hearing them directly in her A language. Furthermore, as her general cognitive experience of numerical processing may be overly reliant on using L1 labels for numerical concepts, wherever there are misalignments in the number system there may be further impairments. For example, the French expression for 93 is 'quatre-vingt treize', literally "eighty thirteen", and if French is her C language, and English her A, an interpreter may hear that number as "80" followed by "13" and then have to do a quick mental conversion to arrive at 93, whereas a native speaker of French, or a non-native speaker of French with adequate proficiency and experience of handling French numbers, would likely have a single mental template for the multi-word phrase "quatre-vingt treize" that is readily matched to the Arabic numeral representation of "93", more or less as easily as "ninety three" is for a native English speaker.[21]

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21 – This is a question worth testing experimentally. And furthermore, for individual interpreters who work from French as a C language it would be of personal professional interest to know if they can identify numbers in the range 71 - 99, going from French number-words to Arabic numerals, as well as they could in their A language, and if not that would perhaps indicate the need for them to do drills to bring such processing up to speed.

2.2 Redundancy and information processing

In this section, I argue that numbers are difficult because they are information dense, low-redundancy elements of a speech that, in order to be successfully interpreted, require the production of a single equivalent term in the target language. In this sense, numbers share their difficulty with other speech elements, such as names and technical terms, and I will point to earlier work in the field of interpreting studies that sees and treats numbers as belonging to a broader class of items sharing the properties of low redundancy and of having an exact equivalent in the target language. I will also consider to what extent these two properties are factors of difficulty, but, somewhat paradoxically, can also be factors of task facilitation.

2.2.1 Numbers as "problem triggers" in Gile's Effort Model of SI

Gile's Effort Model of SI (presented in section 2.3.1) identifies various "problem triggers" that can cause errors, omissions or "infelicities" (sub-optimal translations):

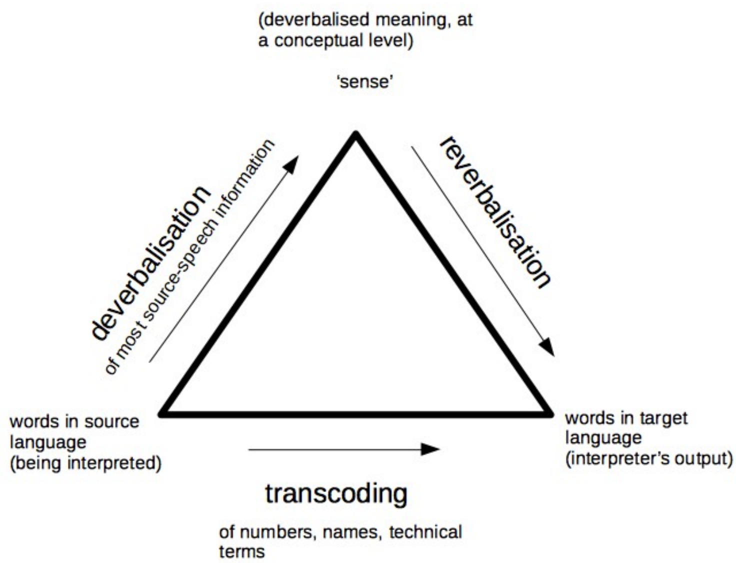
> Problem triggers include speeches with high information density and speech rate, enumerations, compound names, unfamiliar accents, poor voice quality, singular logic, non-standard lexical usage, syntactic complexity, interpreting between syntactically very different languages, lexical gaps and short words with little redundancy such as names and numbers, as their information content can be difficult to recover in the case of any momentary lapse of attention in the ListeningEffort.
>
> Gile (2015, p136)

It is interesting to note that numbers are considered in tandem with names as being difficult for the similar reason of their low-redundancy. "Compound names" and "enumerations" (lists) could also be considered to form a natural grouping with numbers and names – all representing dense portions of a speech where a relatively high amount of information, that must be rendered, appears in a concentrated portion of the speech (packed into single words rather than distributed over several words) that is devoid of interstitial grammatical function words or of content words offering redundant semantic cues.

2.2.2 "Transcodables" in the Paris triangle

Some of the most prominent work during the years in which interpreting studies was emerging as an academic discipline was pioneered by Danica Seleskovitch and Marianne Lederer, and is known as the Paris School, or Interpretive Theory paradigm ("théorie du sens" in French) – Pöchhacker (2016, p69). They proposed a triangular model to describe the interpreting process, and this model seemed to have as much prescriptive value to its proponents as it did explanatory ambition (describing how the ideal interpretation should be carried out, based on the intuitive expert insight of SI practitioners). Indeed it was in response to the IT paradigm that other researchers in the 1980s moved towards a more descriptive, empirical approach to studying interpreting, feeling the "need to move beyond the certainties and 'truths' established by the Paris School" (ibid, 37).

A conceptualisation of the Paris triangle is provided in the figure below. Proponents of this model stressed that interpreting is not (or should not) be an operation of mere "transcoding" of words from one language to another – instead, meaning needs to be extracted from the original language in a process termed "deverbalisation". Once held and understood at a conceptual level, the "sense" or meaning of the original speaker's words are then to be "reverbalised" into the target language output. The Paris School's insistence on the importance of deverbalisation was to ensure that the interpreter avoids linguistic interference, with the output following from a conceptual representation and therefore being more likely to be well styled, internally coherent, and idiomatic target-language output. The model did, however, identify some types of information in the source speech that are supposed to be transcoded, since by their very nature they cannot be "deverbalised" into a conceptual representation that has multiple possible "reverbalised" renderings.



<u>*Figure 1. The Paris Triangle*</u>
based on descriptions in Setton and Dawrant (2016, p104) and Seleskovitch and Lederer (1989, passim)

Referring to these transcodable speech elements, Seleskovitch and Lederer (1989, p140) single out numbers as being a classic case where transcoding is acceptable and required during SI, but also list other types of information that must be transcoded: technical terms, specific fixed translations established by the target-language community (eg for titles of books and films) or forming part of the jargon used at the meeting (references to laws, language of parliamentary procedure etc), and finally deliberate word choices that must be faithfully reproduced (they give the example of Charles de Gaulle preferring to say "la Russie" rather than "l'Union Soviétique" and Reagan speaking of US activities in space as being "defence" initiatives, while Gorbachev would speak of the "militarisation" of space)

Setton and Dawrant (2016, p104) refer to a "famous analogy" made by Seleskovitch, comparing interpreting to the baking of a brioche aux raisins (a currant bun). Much of the material in the original speech, like the ingredients used to make a bun, is unrecognisable after the transformation process of deverbalisation and reverbalisation, but just as the "currants" are still physically intact and discernable in the baked bun, certain types of information (names, numbers etc) are readily identifiable in the end product of an interpretation. The authors also assert that "numbers are the best example of transcodables: they have fixed translations, and are quickly forgotten unless noted down (or converted quickly, in SI)" (ibid, p104).

This Paris School's model was as much an instruction as it was a description of the interpreting process - an interpreter approaching the task by attempting to "transcode" all information from one language to another was doing it wrong. In contrast, Setton and Dawrant (2016, p128) make a case that challenges this dogma. Beyond the natural set of information-types that are, by default, "transcodable" (numbers, names of institutions, chemicals, etc.) they argue that one can expand the original concept of "transcodables" to include "collocations, formulas, sentence openings and framing devices", meaning there is less that needs to be de- and re-verbalised. They argue that the interpreter can, and does, acquire a set of 'ready equivalents' over the course of her professional practice, a "mental phrasebook" comprising "a core of useful, more-or-less-safe, tried-and tested words and phrases" than can be employed, and simply "transcoded", during SI "provided that monitoring (vigilance) for appropriateness in context is not completely switched off", and this, they argue, "might very much reduce the effort of interpreting without any real decline in quality".

If most of the interpreting act involves more than mere transcoding, with more active engagement for the processes of "deverbalising" and "reverbalising", it might seem to follow logically that "transcodables" – a category that includes numbers – are to be seen as the easy part of an interpretation. In the context of a written translation, when appropriate verification sources are available, a fixed correspondence is perhaps more easily rendered in the target language than other parts of the text. But the simultaneous interpreter faces the crucial difference of having to work under severe time constraints, and here is where transcodables become difficult. Other non-transcodable parts of the source-speech are more semantically redundant and thus amenable to compression and concise representation either at a conceptual level or in the target language output itself. Unpredictable transcodable items such as names or numbers, if they are successfully resolved in the interpreter's output, can (in most cases) only be resolved in their full, uncompressed (and incompressible) form. And this requires processing the full-form items, holding them in WM, and incorporating them into the output. As WM is limited in capacity, this means such transcodables increase cognitive load and make the interpretation act as a whole more difficult. Conversely, when capacity is available, and the interpreter has, readily available, a target language equivalent of transcodable item stored in long-term memory (an "entry" in the "mental phrasebook"), the task of rendering it in the interpreter's output is made easier as it means deploying an already existing template from long-term memory.

2.2.3 "Linguistic entropy" – synthesis of sections 2.1 and 2.2

This thesis assumes that the perceptual component of the SI task can be viewed as a problem of signal processing under adverse conditions (such as with noise present), and in section 2.1 I argued that for native-level listeners the more redundant and formulaic a portion of speech is, the easier it is to interpret and that greater, native-like proficiency in a second language is characterised by greater sensitivity to formulaic language. In this section (section 2.2) I have been arguing that numbers and other unpredictable "transcodable" elements of a speech, for which the interpreter does not have templates in long term memory, are inherently much less redundant and more information-dense elements of speech, and therefore harder to interpret regardless of whether the source-language is an L1 or L2.

A study by Van Wijngaarden, Steeneken and Houtgast (2002) speaks to both of these points. It quantified the performance difference in Dutch subjects listening to sentences in their native language and in two foreign languages (German and English), under conditions of noise using the Speech Reception Threshold (SRT) method – "an adaptive method that measures the speech-to-noise ratio at which 50% of the tested sentences are perceived correctly". They found that participants listening to a foreign-language sentences required "1–7 dB better speech-to-noise ratio" than native listeners to reach the 50% sentence intelligibility threshold being measured.[22] More interesting is that subjects also performed a letter guessing task on the sentence sets (at the level of individual subjects the same sentences were not used for the two tasks). In this task the ends of sentences are revealed visually (orthographically) letter by letter, as the participant tries to guess each letter - from performance on this task a measure of linguistic entropy was derived, reflecting how redundant and predictable the sentences are to the participant, which reflects the interplay of properties of the sentence itself

22 – As explained in section 2.1.1 there are various studies looking at this effect of native-language status of listeners and speech perception under adverse conditions.

and the participant's linguistic knowledge[23]. To help construct the measure of linguistic entropy, a manipulation in the previously described experiment involved the use of different sets of sentences varying in their semantic redundancy - "proverbs", "standard sentences", and "semantically unpredictable" sentences. This linguistic entropy measure was compared against performance in the SRT task, with the authors finding that "differences between native and non-native speech intelligibility are largely predicted by linguistic entropy estimates as derived from a letter guessing task. Less effective use of context effects especially semantic redundancy explains the reduced speech intelligibility for non-native listeners." (ibid, 2002).

In other words, increased (or native-level) proficiency in a language brings an increased ability to exploit semantic redundancy in speech signals to aid comprehension – but when the signal itself is an information-type that does not offer much semantic redundancy for the listener to exploit, even more proficient language users will struggle.

We can link this conclusion to SI. Doing so provides another explanation, beyond that given in section 2.1 (asymmetric comprehension proficiency between languages), for why numbers seem to be a persistent point of difficulty during SI, even for experienced interpreters – because numbers are a type of information that increase "linguistic entropy" in a sentence (a property inversely related to semantic redundancy and to predictability). Numbers are highly specific pieces of information with low informational redundancy - most of the relevant information about the number is contained in the number itself. If you miss the number, you cannot normally repair it's identity in the signal through contextual semantic cues (you might be able to tell it's a bigger or smaller number if the speaker is talking about a trend, for example, but you cannot normally reconstruct the number itself in all its detail from semantic contextual cues in the words surrounding the number).

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23 – This is evocative of the Cognitive Load Model's consideration of both source signal properties (external to the interpreter) and mental resources (within the interpreter's brain) when accounting for cognitive load during SI.

2.3 “Difficulty” in SI as high cognitive load given limited capacity

In this section I will mention two models of SI from the interpreting literature that will be used to frame the discussion of the question of numbers during SI.

2.3.1 Gile’s Effort Model of SI (EM)

According to Gile (2015, p135) the EM was designed “to help students and practitioners understand recurring difficulties that could not be explained by lack of linguistic or extralinguistic knowledge alone”, and it was not intended to describe SI, but only to “highlight the theoretical and practical consequences of the limited availability of processing capacity” during SI. There were four “efforts” in the model – Listening and Analysis, Memory, Production, and Coordination, represented by the shorthand of SI = L + M + P + C (Gile 1995). Despite the descriptive power of the model being limited in its intent, it did make broad assumptions about the cognitive underpinnings of the SI process : that “the total required processing capacity for all active Efforts must not exceed the interpreter’s total available capacity” (Gile, 2015 p136). On the basis of frequently observed errors, omissions and sub-optimal translations (what were called “infelicities”) in interpreters’ work, Daniel Gile posited that there are various “problem triggers” (see section 2.2.1) that cause these disruptions to the SI process, and their ability to trigger such disruptions is due to what was named the ‘Tightrope Hypothesis’ – that the interpreter is constantly operating near the limits of what Gile (1999) conceived to be a singular entity of total available processing capacity, itself the sum of the four “Efforts”.

2.3.2 Seeber’s Cognitive Load Model (CLM)

The Cognitive Load Model (Seeber, 2011), was partly inspired by the EM but was conceived with divergent characteristics intended for it to be more plausible with respect to what is understood about cognitive processing. It is a proposed way of looking at the SI task as one occurring in an “inherently capacity-limited system” in which fluctuating levels of cognitive load are generated dynamically over the course of the SI task as a function of both changing properties in the source signal, and changing strategies employed by the interpreter. It is a complex model that Seeber (2011) presents after considering various findings from cognitive research on working memory, psycholinguistics and syntactic theory. In this thesis, only some aspects of the CLM will be remarked upon in so far as they speak to the argument for why handling numbers during SI may at times be difficult, and how it may at times be made easier.

The CLM considers working memory as a set of limited attentional resources, and Seeber (2011) makes reference to the phenomenon of WM item chunking – that WM can hold a fixed number of “items”, but through chunking of information, more items can be held (a chunk being "a set of items of information that are merged into one larger retrievable unit of information", p179). He explains how they have a role to play in expertise development, stating that "chunks recurring regularly during practice or study are thought to evolve into more complex structures (templates), which allow information to be encoded into long-term memory (LTM) more swiftly" (ibid, p179). Seeber (2011) goes on to mention the difference in approach between meaning-based strategies during SI (which we can associate with the de- and re-verbalisation processing of the Paris Triangle), and transcoding, when discussing how synergies can appear, and shortcuts can be exploited, during the SI task – this helps explain how Setton and Dawrant's (2016) assertion that transcoding can sometimes make interpreting easier might work in practice, through a lessening of cognitive load (when it involves the deployment of well rehearsed "ready equivalents" from the expert interpreter's acquired "mental phrasebook").

I believe one of the key points Seeber (2011, p186) makes in the same paper is that "simultaneous performance of several cognitive tasks is likely to reveal new constraints which, rather than being inherent in the component tasks, do not emerge until they are combined, or else, their effect is negligible within one task but is compounded when processes are combined." In a section 2.4 of this thesis, discussion on articulatory suppression effects in digit-span working memory tests will be mentioned to emphasise this point. And so when tasks are performed together, as during SI, there may or may not be situations of interference that arise. Seeber relies on Wickens' Multiple Resource Model to justify the sophistication deliberately included the CLM where different resources are concurrently engaged during multitasking, rather than conceiving of one single composite resource that fills up in a zero-sum way (as is the case for Gile's (2015) Effort Model and its concept of "total available capacity"). He assumes that "tasks interfere with each other more strongly when they have structures in common, i.e., if they demand the same level of a particular processing dimension, than if they rely on different structures" (Seeber, 2011 p187). The CLM, therefore, calls for an understanding of the source of difficulties, at the level of separate cognitive processes that may or may not interact, when attempting to describe the dynamic effort deployed during SI.

Specifically, the CLM is presented with a conflict matrix, to reflect the amount of interference generated between different concurrent cognitive tasks, with their own "demand vectors"[24] – "P" for "perceptual auditory verbal processing of input and output"; "C" for "cognitive-verbal processing of input and output"; "R" for "verbal-response processing of output" and "I" for interference "calcuated (and added as a conflict coefficient) whenever two or more tasks overlap". Another "S" storage component is included "to reflect

24 – That said, just as Gile's shorthand of SI = L + M + P + C was not a computational model, Seeber's (2011) CLM was not something proposed as a way to quantitatively "calculate" load either, but rather to make a theoretical point of there being multiple resources that can interact and interfere and in doing so contribute to an epiphenomenal factor of "cognitive load", a construct that reflects the dynamic effort deployed by an interpreter during her work.

load generated by storage in working memory of constituents prior to their integration and/or production". Using this matrix, Seeber (2011) describes how ongoing fluctuations in cognitive load experienced by an interpreter can be modelled by describing changing task engagement (of multiple, concurrent, sometimes conflicting tasks) that is driven both by properties of the "input" source-speech (he considers how different syntactic structures might defer or front-load cognitive processing temporally), and by strategies deployed by the interpreter during the SI task (comparing how different strategies of stalling, text chunking (i.e. salami slicing), waiting and anticipating might impact upon cognitive load as regards it's distribution over time).

While Seeber (2011) does write about synergies that can be exploited during the SI task, an opportunity is missed to incorporate this observation directly into the CLM. Over the course of an interpretation, when a moment arrives during which two concurrent sub-tasks share the same resource, a conflict is registered in the CLM with an interference coefficient applied to the share of cognitive load produced by that subtask, leading to an increase in overall load. Another scenario is also possible. When two subtasks can proceed concurrently, it is conceivable that they might not only proceed without causing conflict or interference (because they do not share the same resource), but that there is a facilitation that comes with this parallel processing, a reduction in load that would not have occurred had either subtask been executed without the other one also occurring. This could happen if the resources underlying each subtask are separate but interlinked – we might imagine, for example, rapidness and robustness of perception during SI of a difficult to catch number being aided by the priming effect of seeing the number on the speaker's presentation slides (and even consciously anticipating the number) before it is uttered by the speaker. Indeed, in a recent paper on multimodal processing in SI, Seeber (2017) acknowledges the possible existence of both facilitatory and inhibitory effects on processing when identical or complementary information is redundantly present in two modalities (eg with spoken and written text). To operationalise these variable effects in the CLM, therefore, an inverse "facilitation" coefficient could be introduced (or the "interference" conflict coefficient, could be renamed as one of "interaction", allowing inverse values).

An essential (and appealing) property of the CLM is how it views SI from more than one perspective and combines them – in accounting for the dynamic effort required to perform SI, it presents the SI task within a single system, incorporating features both external to the interpreter (properties of the source-speech signal) and internal to the interpreter (cognitive strategies deployed by the interpreter, inherent capacity limits of cognitive resources available to the interpreter). In a theoretical demonstration of the model, Seeber (2011) considers how it responds to the external factor of syntactic complexity in the source-speech under different scenarios where "internal" features are variously present (the deployment by the interpreter of different cognitive strategies of waiting, stalling, text-chunking/salami-slicing, and anticipating). As a result of this theorising, he argues that, unlike the strategy of "anticipation",

> “the “three “safe” strategies (i.e., waiting, stalling and chunking[25]) require considerably more cognitive processing resources than baseline. Consequently, one could argue that the amount of cognitive load experienced by interpreters might be causally related to the amount of restructuring they engage in.”
>
> Seeber (2011, p197)

2.3.3 The CLM as a framework for discussing numbers during SI

This thesis’ account of how handling numbers during SI can present difficulties can also be adapted to the CLM relatively well. I have argued that low semantic redundancy (high linguistic entropy) is a property of the “transcodable” elements of a source-speech, of which numbers are a prime example. Linguistic entropy will vary over the course of the sentence with localised peaks (at the occurrence of numbers and other low-redundancy transcodables) causing localised increases in processing demands (and hence cognitive load). Internal features that are susceptible to changes in linguistic entropy include (1) the robustness of perceptual number processing (which is often foreign-language perceptual number processing in the context of SI), (2) the availability of ‘ready equivalents’ in the interpreter’s ‘mental phrasebook’ to easily discharge the rendering of a transcodable item, and (3) the limits of WM capacity in holding full-form low informational redundancy items. On the last point, this thesis will argue that such ‘internal’ capacity limits can be circumvented, or worked with, using real-life in-booth strategies that affect the system being observed – for example, being able to write down a number and have that ‘stored’ on paper might in effect increase the WM capacity of the interpreter, by reducing storage load in the CLM system.[26]

25– By “chunking”, Seeber (2011) is referring to the strategy of segmentation, as explained in section 1.3.2

26 – And consequently, the cognitive strategies such as waiting or text-chunking, might now be as or more appealing to the interpreter compared to anticipation, given that the load-cost of opting for one of the “safe” strategies is reduced.

2.4 Linking the CLM, working memory (WM), and numbers during SI

We have considered the Cognitive Load Model as presented by Seeber (2011), and discussed how concepts such as dynamically varying linguistic entropy can fit within it. It is useful now to further consider how various findings from empirical research might fit within this theoretical framework.

2.4.1 WM capacity

A prominent model of WM in the scientific literature is the one first proposed by Baddely & Hitch (1974), which has been refined over the years and presented again, for example, in Baddely (2003), where it conceives of the WM system as involving a central executive and two storage systems: the phonological loop and the visuospatial sketchpad - information in these storage systems is held only for a limited amount of time, after which point it will decay rapidly over time unless refreshed through a deliberate encoding strategy. For example, a series of units of information, if they can be coded linguistically, can be maintained in the phonological loop through subvocal rehearsal (repeating the words in one's head over and over). That said, even with time available for refresh kept constant, any increase in delay still worsens recall (Portrat, Barrouillet & Camos, 2008) and so time-related decay remains a characteristic feature of information held in WM. Among classic tests of WM capacity is the digit span test, where participants hold in WM increasingly long chains of single (verbally encoded) digits ("one, six, five …"), to determine how many such discrete and low-redundant units of information they can maximally hold in WM (typically around seven items, when respecting serial order). Other tests include word-span (using a list of real or nonsense words) and sentence recall.

2.4.2 Suppression of WM capacity

As Baddely (2003) explains, one known effect in word-span tasks is the word-length effect, with longer words being harder to recall. Another, which supports the idea of a phonological loop's involvement in WM performance, is the effect of articulatory suppression – when digit sequences are presented to participants (visually, as arabic numerals), they are instructed to repetitively verbalise a sound, for example "la-la", and by doing so, they are engaging the articulatory language processes which are thought to underlie the ability to perform subvocal rehearsal (repeating a word in one's head), and thus prevent or impair use of the phonological loop during encoding of the to-be-recalled digit sequences.

On the word-length effect, the key factor may in fact be articulatory ease rather than the number of syllables a particular word has. Of relevance the the question of SI, particularly when interpreting numbers from C into A languages, is research on digit span among bilinguals. Bilinguals have a longer digit span in the language in which they also have a faster reading speed, typically their native language – da Costa Pinto (1991) has demonstrated this mother tongue advantage even when phonological encoding of digits uses more syllables in the mother tongue than in the second language, and has argued after looking at bilingual participants' reading speeds and their performance on digit span tasks, that what is more important in underlying digit-span performance is articulation speed, arguing that "digits are subject to massive practice in one's native language with a strong tendency to be abbreviated, thus reducing its spoken duration" (ibid, p471).[27] This argument relating specifically to bilinguals aligns with recent work pointing to the importance of speed of subvocal articulatory processing more generally in explaining differences in verbal WM performance (Mattys, Baddely & Trenkic, 2018).

In a study by Chincotta & Underwood (1998), the researchers were interested in the fact that this previously mentioned mother-tongue advantage in digit span is itself susceptible to an articulatory suppression effect (digit span being both smaller and equal between languages under articulatory suppression), and wanted to know whether this still held true for a special group of bilinguals, simultaneous interpreters, who have developed expertise at a task involving concurrent language production and perception processes. They looked at Finnish-English bilinguals (all mother tongue Finnish), in an experiment where the control group comprised Finnish undergraduates majoring in English, and the experimental group comprised simultaneous interpreters fluent in both languages. Both groups showed a mother-tongue effect in the condition without concurrent articulation, with longer digit spans in Finnish than English despite the former language having longer number-words (in terms of syllable count). And a general articulatory suppression effect was seen as digit span performance suffered for both groups under concurrent articulation. However, whereas the control participants showed diminished and equal performance in Finnish and English digit span tests under concurrent articulation (supporting a model of WM in which a phonological loop mediates performance on this task), among the simultaneous interpreters there remained an advantage for Finnish over English. To help make sense of this finding, we can consider Seeber's (2011, p186) warning that the "simultaneous performance of several cognitive tasks is likely to reveal new constraints which, rather than being inherent in the component tasks, do not emerge until they are combined, or else, their effect is negligible within one task but is compounded when processes are combined." In attempting to describe the interpreting act, we can consider that WM capacity (operationalised via "storage" demands in the CLM) is under pressure during a context of concurrent perception and production, but that perhaps this pressure is less severe when the interpreter is experienced versus a novice.

27 – This finding is of relevance to the argument on proficiency effects in section 2.1.2.

In the context of SI, it would therefore make sense to advise interpreters that when there are portions of a speech that cause peaks in cognitive load because WM performance is key to their processing (such as low-redundancy portions, containing, for example, a burst of numbers) speaking during that moment will compromise the amount of information that can be held and processed in WM. This will perhaps be less of an issue when one is an experienced interpreter, but WM capacity is still compromised by concurrent speech production even with experience. It is clearly not possible to avoid speaking during SI, but given this issue, some of the advice that is sometimes heard for mitigating the difficulty of interpreting numbers would seem to make sense. Firstly, to get the numbers out of WM as quickly as possible – Jones (2002, p118) writes of "unburdening your memory" – by writing them down, and/or reorganising the phrase so that the numbers are uttered as soon as possible in the interpretation. Secondly, to be silent and fully attentive when numbers are heard (and write them down):

> Il est plus facile de garder en tête une idée et de la restituer à un moment qui semble opportun, avec parfois une phrase entière de retard sur l'orateur, que d'essayer de se souvenir d'un chiffre, pour le restituer ultérieurement. Cet effort est inutile et souvent vain – certains professionnels et non des moindres, disent parfois avec lassitude qu' « ils ratent toujours les chiffres »
> […]
> L'anticipation du transcodage sur l'expression des idées n'est pas la seule méthode pour le réussir. On peut conseiller aux étudiants de noter les chiffres – ils ont appris en consécutive à dresser l'oreille et à noter les termes qui devront être transcodés ; ils peuvent appliquer en cabine la technique acquise: pour écouter réellement les sonorités des chiffres, il faut une minuscule pause dans l'écoute de la suite des paroles de façon à laisser les sonorités des chiffres résonner un court instant avant d'être notés ; sinon le nombre noté sera aussi faux que s'il avait été transcodé trop tardivement.
>
> Seleskovitch & Lederer (1989, p157)

2.4.3 Expansion of WM capacity through chunking

2.4.3.1 Importance of item-type in WM tasks

A component Baddely (2003) added to the WM model as a result of its refinement over the years is the episodic buffer, to account for apparent evidence of how the three previously described components of a central executive and two storage systems interact with long-term memory (LTM) . Such evidence included the phenomenon of chunking, which he states allows "information in LTM to supplement immediate serial recall. Chunking results in an immediate memory span for sentences of about 15 words, compared to five or six unrelated words" (ibid, p835-836). He defines the episodic buffer as a "limited capacity store that binds together information to form integrated episodes. It is assumed to be attentionally controlled by the executive and to be accessible to conscious awareness. Its multidimensional coding allows different systems to be integrated, and conscious awareness provides a convenient binding and retrieval process.” (ibid, p836)

Here the concept of chunking is not just referring to metacognitive strategies that rely on mnemonics (and that might seem as important to this discussion as party tricks), but to a broader meaning that applies also to the processing of sentences. It is about the brain being able to process more information when this information’s elements are amenable to being grouped into larger chunks. This difference of a shorter WM span for digits or unrelated words versus a longer span for sentences where the words are held together by both syntax and a propositional sense is, I would argue, highly relevant to SI. This difference is comparable to what, I have argued, are the different WM demands of processing numerical (or high linguistic-entropy) parts and non-numerical (or lower linguistic-entropy) parts of sentences during SI.

2.4.3.2 Neural correlates of WM-item chunking

To develop this point on the relevance of chunking to the discussion of SI and link it to the CLM, it is useful to consider a neuroimaging study by Bor, Duncan, Wiseman & Owen (2003), which used fMRI to capture the neural correlates of “chunking” as a WM encoding strategy. Participants’ brains were scanned as they carried out the Spatial Span Task, involving the conscious encoding and recall of the movements of a visually presented sequence of locations on a grid, with these movements being more or less structured and thus more or less amenable to a chunking strategy (e.g. a structured trial might involve movements left to right along all grid positions in the top row, then some movements all the way down to the bottom etc. with each movement spanning several grid locations; whereas a less structured trial would involve movements from location to location that were harder to group and so needed to be encoded individually or in smaller groups of movements). In each trial there were encoding, delay and recall stages – the sequence movement would be presented with participants attempting to encode this into memory, then a randomly varied delay (of 6-10 seconds) occurred during which participants would hold the sequence in their minds, and then in the recall stage they were instructed to recreate the sequence of movements via button presses.

Although in this experiment they used a visual working memory task (whereas SI is a complex language task), the findings are still pertinent – the authors themselves argue that the structuring of information in WM (through the chunking strategy) that they were investigating is “analagous to semantic clustering in verbal episodic memory paradigms”[28], and when discussing the brain activations in their results they considered that this similarity lined up with left frontal-lobe activations seen in other experiments where participants are

28 – Bor, Duncan, Wiseman & Owen (2003, p364)

"instructed to reorganize encoded word sequences into semantic categories."[29]

The neuroimaging results of this experiment can be related to questions raised by Seeber's (2011) presentation of the CLM. Bor et al (2003) argue that they found neural correlates of participants' minds employing WM-item chunking strategies for the structured trials, as reflected in greater activity in the left and right lateral frontal cortex, the inferior parietal lobule and the fusiform gyrus when participants viewed structured sequences compared to unstructured sequences, with this difference being most pronounced at encoding. The frontal and parietal regions, it was argued, were known to be involved in working memory, and the fusiform gyrus known to be a pattern matching region, lending credence to the claim that this activation pattern reflected encoding of the sequences and deployment of an item-chunking strategy.

In the same experiment, another set of brain regions showed a different pattern for a different stage of the Spatial Span task – during the delay stage, left and right parietal and premotor cortex was more active for unstructured versus structured trials, a finding the authors related to the greater storage demands for unstructured trials (which involve information that is less redundant, less amenable to WM-item chunking), pointing out that previous research has linked these brain regions to working memory storage operations, and making the case that this difference "might reflect a decrease in storage and general working memory demands for the structured trials, as a result of more efficient encoding".

The interesting aspect of these results is the "see-saw" nature of the activation patterns and the plausible account given for it as reflecting how the deployment of a cognitive strategy differentially affects components in a cognitive system, increasing load in some resources, decreasing it in others. In contexts where a WM-item chunking strategy is deployed, and where overall task performance and subjective ratings of the easiness of a task go up, "under the hood" we see that brain regions involved in memory storage work less, but brain regions that are involved in encoding work harder. When such an encoding strategy cannot be deployed, task performance is worse, the task is perceived as being more difficult, memory storage regions are more active, and there is lower activity in the encoding network.

This finding speaks to the theoretical work carried out by Seeber (2011) in presenting the CLM, looking at how different interpreting strategies of anticipation, segmentation, waiting, and stalling affect cognitive load. He argued that in his model the latter three strategies could "require considerably more cognitive processing resources than baseline" and that "the amount of cognitive load experienced by interpreters might be causally related to the amount of restructuring they engage in" (Seeber, 2011 p197). In the Bor et al (2003) study, despite a chunking strategy involving increased activity in the brains encoding network, performance in this

29 – Bor, Duncan, Wiseman & Owen (2003, p364)

context was better and trials in the experiment that were amenable to chunking were subjectively experienced as being easier for participants. In other words, viewing the mind as a multiple resource system (as per the CLM), the encoding resource can actually be put under increased load and this can be accommodated and actually lead to task facilitation, and a separate memory storage resource behaves differently, with increases in load in this resource being more harmful to overall performance, making it what we might call a "bottleneck resource". This speaks favourably to Seeber's (2011) insistence on a multiple-resource approach to modelling task difficulty – when Seeber (2011) considers the increased cognitive load predicted by his model for commonly deployed interpreter strategies he argues that his theoretical findings lead us to the assumption that interpreters often work significantly below saturation levels.

On the broader relevance of chunking to cognition, Bor & Seth (2012) argue in another paper that behavioural and neuroimaging work looking at the chunking strategy in action reveals a brain network (the posterior parietal network) that underpins a function much more fundamental to cognition and broader in scope than a simple memory trick – they argue that "it is possible that chunking, as a tool to detect useful patterns within an integrated set of intensely processed (attended) information, has a central role to play in consciousness" (ibid, p1). In the context of the SI task, it can also be argued that the exploitation of semantic redundancies present in the source signal is of central importance to successfully understanding, deverbalising, representing and rendering the information from one language to another.

2.4.4 A two-stage framework for acquiring SI expertise

One paper by Guida, Gobet, Tardieu & Nicolas (2012) is, I would argue, highly relevant to the key arguments I propose to account for the difficulty of interpreting numbers. The authors reviewed 8 neuroimaging studies of working memory related tasks carried out by experts and novice controls – the expertise across the different studies being in the domains of mental calculation, Japanese abacus, mnemonics, and chess. They also looked at 12 neuroimaging studies on novices before and after training on working memory related tasks. In an account that attempts to reconcile apparently divergent activation patterns between these two groups of studies, they propose a two-stage model of expertise acquisition that I believe applies well to the subject of learning to better cope with numbers during SI. In novice training paradigms, improvement in WM-task performance via strategies like chunking is characterised by decreased activation in brain regions that are usually more engaged during WM tasks, but no qualitative functional reorganisation. In contrast, experts show characteristically different activation patterns compared to their control participants, patterns that imply a heavy involvement of LTM templates or schemas that are incorporated into the WM system during task performance in the expert brain – in other words, with the acquisition of expertise there is a "recruitment of new structures activation areas and a shift in the cognitive process underlying task performances […] which in this case means that resources previously […] allocated to WM are later (after expertise acquisition) allocated to LTM" (ibid, p221).

In the Guida et al. (2012) account, at early stages of expertise acquisition, chunking strategies are engaged via the WM system. And with the accumulation of the extensive practice that leads to expertise acquisition, many chunks are laid down in LTM as templates or schemas that, increasingly, can be retrieved and deployed online during task performance. One estimate in the literature of the number of "chunks" (arrangements of chess-piece positions) needing to be internalised to reach a "master" level in chess is 300,000 (Gobet & Simon, 2000). Guida et al. (2012) mention, however, that there are limits to the WM advantages provided by an LTM mental "library" of chunks – their usefulness is limited by the appearance of the very same chunks in the task itself. When random positions of chess pieces on a chess board are generated (ones that do not follow a legally possible sequence of player moves and therefore cannot appear in a game and therefore have not been fully or partially internalised by the expert) then the experts no longer maintain as substantial an advantage over novices in performing a WM task relating to the arrangement of pieces compared to when this arrangement is "legal" – indeed, these random positions have typically been used as the control condition in experiments comparing novices and experts (Gobet & Simon, 1996).

This account of expert performance in WM tasks aligns well, I believe, with the characterisation of the problem of numbers during SI that I first presented in this thesis in section 1.3.2.3 mentioning three key factors. Firstly, the assertion that a WM-task is easier when the items being interpreted can be grouped meaningfully into chunks aligns with what we know about the size of WM capacity; that it can be greater for sentences than for semantically unrelated lists of words which are less "chunkable" – just as a burst of numerical information during SI is an inherently less "chunkable" type of information (see section 2.4). Secondly, as was demonstrated by the random arrangements of chess pieces in the WM experiments comparing expert and non-expert chess players, there is a limit to the possibilities of chunking and it's improvement – some information is inherently resistant to chunking, is unpredictable, low in redundancy and high in informational entropy. Such information will be among the most difficult of information types being processed in a speech regardless of the level of the interpreter's expertise. Thirdly, the ability to facilitate the WM task increases over time, as there is an increase in the sophistication of the brain's network of chunking processes engaged, as LTM templates relevant to the task are acquired and used through many hours of practice – this relates to the arguments about the expert interpreter inevitably and necessarily acquiring a "mental phrasebook" (see sections 2.1 and 2.2) of useful equivalents for certain speech elements and their translations that can be readily retrieved and deployed during an interpretation.

To summarise, although *overall* doing SI may become easier with acquired experience, with a bank of ready equivalents in one's "mental phrasebook" and an increased skill at exploiting semantic redundancies, speech items such as unknown or unexpected[30] numbers will nevertheless always remain one of the more tricky aspects of an interpretation because of the high level of cognitive load they provoke due to their inherently high level of linguistic entropy.

30 – I make this qualification of "unknown or unexpected", because a number appearing in the phrase "George Orwell's 1984" should, even if acoustically degraded, be easily rendered as the interpreter should already know the number through general knowledge. Similarly, numbers of a small set of laws likely to be discussed at a meeting for which the interpreter has prepared adequately should be easily interpreted as readily available known entities (from long term memory, and/or with the help of a "cheat-sheet" glossary at hand). Perhaps a type of transcodable element that is even harder to interpret and has even more linguistic entropy than an unpredictable number is an unfamiliar and unique or foreign name – here the interpreter relies on phonological working memory to reproduce it and has no known pre-existing lexical units in her mental lexicon against which the name can be matched (unlike the component number-words in a complex number).

2.5 Research on numbers within and beyond interpreting studies

So far in this thesis, in accounting for their difficulty during SI, I have treated numbers as belonging to a broader category of speech elements that are “transcodable” and have high levels of “linguistic entropy”, a category that also includes, for example, names (of institutions, laws, people, chemicals and so on). When low informational redundancy items are uttered in a speech being interpreted, this increases the density of information needing to be interpreted in that given window of time, which in turn results in an increased cognitive load. The points of difficulty I have considered so far could conceivably be triggered by different types of low-redundancy “transcodable” speech elements, and not just numbers, because they share common properties that cause such difficulty. It is important, however, to also examine questions that are specific to the processing of numerical information, and that provide additional insights into the difficulty of interpreting numbers.

2.5.1 Misalignments between languages’ number systems

Even if numerical perception and production is at near-native levels for both languages in a language pair (and certainly if it is not at near-native levels for one or both of the languages), difficulties may arise from the extra processing requirements during the interpreting task when the “grammars” or expressive logic of the two languages’ number systems are not perfectly aligned, and an extra conversion operation is required. This is a problem uniquely arising from the interpreting task, where numbers by definition need to rendered from one language to another. This issue was considered in Pinochi’s (2009) study, with respect to German unit-decade inversion for numbers between 21 and 99 (not seen in Italian or English). Further examples of number-system misalignments are the remnants in French of a vigesimal system for expressing numbers between 70 and 99 (soixante-douze = “sixty-twelve” = 72 ; quatre-vingt seize = “four twenty sixteen” = 96).

On unit-decade inversion, we know at least that, developmentally, children have difficulty transcoding (writing down) from spoken two-digit numbers to Arabic digit representations when they two systems are misaligned due to unit-decade inversion of number words. They show the same inversion-specific errors – e.g. writing down “vier und zwanzig” (24), literally “four and twenty”, incorrectly as 42. Zuber, Pixner, Moeller & Nuerk (2009) showed that for almost half of the errors committed by 6-7 year olds are attributable to the inversion problem. In a different study, Pixner et al (2011) examined transcoding of two-digit numbers in the Czech language by 7 year olds – Czech has two coexisting systems for expressing two-digit numbers, one is unit-decade (eg "patadvadset", literally “five-and-twenty” for "25") the other is decade-unit ("dvadsetpat", literally “twenty-five” for “25”). They found that for unit-decade trials, about half of all errors were related to inversion, whereas hardly any such errors occurred for the decade-unit trials.

Another kind of misalignment is apparent in the case of how large numbers are organised and labelled according to different orders of magnitude. For example, this difference is seen between Chinese, Japanese and Korean on the one hand, and languages such as English, French, Spanish, or German on the other.[31] It is also seen in Indian English[32] where numbers are often expressed in units of “lakhs” (1 lakh = 100 thousand) and “crore” (1 crore = 100 lakhs = 10 million). Finally, among major european languages, there are similar differences that may cause problems during interpreting – whether or not the two languages are aligned in using “long scale” or “short scale” for large numbers, a distinction first named by the mathematician Geneviève Guitel as between “échelle longue” and “échelle courte” (Guitel, 1975). Examples from English, French and Spanish are given in Appendix 1, where a world map indicating usage of long and short scale, or other number systems, is also shown. An example of these differences is that in August 2018 British[33] and American headlines reported on Apple Inc. becoming the first public US company to achieve a valuation of “one trillion” dollars, similar to how Brazilian headlines reported the figure as “um trilhão”, while in Portugal it was reported as “um bilião”, in Spanish-speaking countries as “un billón”, in German as “eine Billion” and in French as “mille milliards”. During SI, there are potential processing costs here to inhibiting activation of false cognates (through phonological priming) and converting/calculating between multi-word and single-word expressions operating under different logical syntax.

We can consider possible consequences of all the aforementioned misalignments on the difficulty of interpreting numbers, as well as possible mitigations for this issue, in the framework of the CLM. If numbers already cause an increase in cognitive load due to their status as low-redundancy and high-entropy speech elements, this load will be even higher if a conversion process is also required to adjust for number-system misalignments, and that may be too much load for the system to cope with, leading to a breakdown. For the case of a number like “quatre-vingt treize” in French, an interpreter could perhaps train on identifying French numbers in the 70-99 range until she feels fully at ease with them. Now these numbers will have become readily identified templates in her mental phrasebook, and a conversion process is no longer required when they appear during SI, merely an identification and retrieval process. For language pairs that differ in

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31 – For example, as explained by Cheung (2008), while there are direct equivalents between English and Chinese for “ten”, “hundred” and “thousand”, larger numbers are denominated according to multiples of “wan” (1 “wan”= 10,000), including hundreds of “wan” (millions) and thousands of “wan” (tens of million), with another word, “yi”, for one hundred million. Cheung (2008, p62) refers to this interpreting difficulty of misalignments between the number systems in a language-pair as one of “syntactic conversion”.

32 – For example, see BBC News Online (2017).

33 – Since 1973, British and American English have been aligned in their use of short scale over long scale – see Cracknell & Bolton (2009).

whether unit-decade order is reversed for two-digit numbers (eg when working from German into English), writing down the component numbers as heard, from right to left, eases the working memory demands of the identification task, and could conceivably facilitate the interpreting task.[34] Writing numbers down may also help for other misalignments involving different orders of magnitude for large numbers. Closely successive identification and conversion processes may as a combination cause higher peak demand than closely successive identification and note-taking processes which are followed later by a process of naming the written number in the target language. If one is adept at identifying and writing down numbers from one's working languages, and at ease reading out Arabic digits in one's target languages, this removes the problem of an online conversion process needing to be engaged with at a less than opportune moment, when load is already high – the interpreter frees up her working memory, has the number on paper, and can weave it into her interpretation when there is a section of the speech that is not as attentionally demanding as those sections containing content with high linguistic-entropy.

2.5.2 Unit-decade decomposition

A concept from the literature on numerical cognition that may be relevant to this discussion is that of "unit-decade decomposition" for two-digit numbers. This is the idea that, when presented in Arabic digit form, the component numbers in two digit numbers can be, and are, processed by the brain separately and in parallel rather than just sequentially and holistically. Evidence for this comes from so called "compatibility effects" – when judging which of a pair of two-digit numbers is mathematically larger, participant responses are faster when both the unit and the decade of the smaller two-digit number are smaller than their corresponding unit and decade in the larger number: e.g. participants will be quicker to select the number on the right when the pair of numbers is "52 67" than when it is "47 62", implying that for numerical processing there is some amount of separate but parallel processing of the component digits in a two digit number, and not just holistic processing (Nuerk, Weger & Willmes, 2001).

This effect is not universal, but it does remain under various circumstances. It is not just present when the number pairs are presented to participants simultaneously, but also when they are presented sequentially with an intervening mask (Moeller, Klein, Nuerk & Willmes, 2013). Under sequential presentation, the compatibility effect is greater during experimental conditions containing a greater proportion of within-decade "filler" comparison trials, eg a trial with "43 48", which shows the effect is susceptible to modulation (ibid, 2013). Manipulations of the stimulus set can also lead to a reverse compatibility effect,

34 – In contrast, writing 80 and 13 when hearing "quatre-vingt treize" may not be a useful solution, as a potentially burdensome, or confusing, calculation process will inevitably be required when moment arrives to name the number as "ninety-three" in the target language.

however. Macizo & Herrera (2011) manipulated the ratio of within-decade comparison trials to between-decade comparison trials, with conditions of 20%, 50% and 70%, and were able to elicit a shift in compatibility effects from reverse to regular. They explain these results in terms of cognitive control, with the task's relevant emphasis on unit processing within a two digit number affecting the nature and degree of unit-decade decomposition effects.

This seems to be an effect established early on in developmental term and the effect is even seen implicitly, when processing two-digit numbers is irrelevant to the task at hand. For example, when participants are presented with a pair of two-digit numbers that are graphically composed of dots, and where the dots for one of the numbers are larger, and the task is to select the number with the larger dots, the pattern of reaction times suggest that adult brains still process the two-digit numbers automatically and in a decomposed and parallel fashion (Chan, Au & Tang, 2011). Automatic processing of numbers also seems to occur in children, but first takes the form of sequential and holistic effects (seen in children aged 7) and then developmentally shifts to a more adult-like pattern of effects suggesting decomposed and parallel processing of two-digit numbers (seen in children aged 8-11) – ibid, 2011.

For numbers of or more than two digits, Meyerhoff, Moeller, Debus & Nuerk (2012) argue for there being a combination of sequential and parallel processes engaged in the brain – this based on experimental findings testing for compatibility effects in two-, four- and six-digit numbers. They propose a "chunking hypothesis" to account for these results, according to which "multi-digit numbers are separated into chunks of shorter digit strings. While the different chunks are processed sequentially, digits within these chunks are processed in parallel." (ibid, 2012 p81)

This phenomenon of unit-decade decomposition relates to the mental processing of Arabic digits, which are a shared form of numerical representation across languages. This phenomenon has nevertheless been shown to be susceptible, to some degree, to effects driven by the native-language status of participants (Nuerk, Weger & Willmes, 2005) – with the compatibility effect on these tasks involving Arabic digits being larger for native speakers of languages such as German with a unit-decade order for number-word (i.e. spoken) versions of two-digit numbers, opposite to the order of written Arabic digits.[35] But for numbers larger than two digits, language-specific modulations of the compatibility effect seem to be absent. While Bahnmueller, Moeller, Mann & Nuerk (2015) did indeed find larger compatibility effects for two-digit numbers in German

35 – A possible explanation of this language-effect is offered by Bahnmueller et al (2015, p2) who write that "number word inversion influences the comparison process as the unit digit being named first in the respective number words (erroneously) implies a higher importance and activation of the unit digit, although it is actually irrelevant for the decision. The higher activation of unit digits elevates the compatibility effect, because it is actually a unit interference effect, where the automatic activation of irrelevant unit comparisons cannot be completely suppressed thus hindering or prolonging responses in incompatible trials."

L1 participants compared to English L1 participants, they found that other kinds of reliable compatibility effects in larger numbers (hundred-decade and hundred-unit effects) were detectable in both groups of participants with no apparent modulating effect of language.

The links I wish to draw between this phenomenon and the question of interpreting numbers during SI are as follows. If during SI the interpreter uses (via mental imagery or actual pen and paper) Arabic digit representations of numbers, during source-language comprehension, inter-language conversion, or target-language production, the fact that such numerical representations can be processed in a decomposed fashion (separate but parallel processes operating on units and decades, or hundreds and decades, or hundreds and units) could mean that these are natural failure points that follow on from natural perceptual break-points – the interpreter may get the unit right, but not the decade, or vice versa, and the same for hundreds and decades or hundreds and units etc. The interpreter should be alert to this possibility, and this is also an avenue for research worth investigating – perhaps experiments looking at errors for rendering numbers during SI might show patterns that reflect these natural break-points.

2.5.3 Number discrimination

As Sella, Hartwright & Cohen Kadosh (2018) in the section of their chapter entitled "Symbolic number comparison: distance and size effect", an established finding from the numerical cognition literature is that when judging which of two numbers are larger (and this holds for single as well as multi-digit numbers) the greater the numerical distance is between the two numbers, the faster and more accurate participant responses are (this is the "Numerical Distance Effect", which has also been seen in other explicit tasks such as number naming and parity judgment, as well as implicit tasks of numerical priming). In another effect, when comparing pairs of numbers that are are of equal numerical distance within each pair, response times are slower for the pair of numbers that have a higher numerical value (this is the "Numerical Size Effect"). In other words, our brains are slower at judging the relative size of numbers when comparing large numbers, and/or when comparing two numbers that are close in value. Beyond the more trivial observation we can make that larger numbers are "harder" than smaller numbers to process, a possible relevance of these two established effects to the question of approximations during SI is mentioned in section 3.6.

2.5.4 Modality: written and spoken numbers

In the pedagogical literature, Jones (2012) asserts, without explanation, that in the course of SI it is often easier for an interpreter to write down a number heard in the source language into Arabic digits, and then read out those Arabic digits in the target language, than to do a mental conversion and interpret the number without these intervening steps of note-taking and note-reading. This assertion may seem counter-intuitive as it implies more work, and writing down or naming the numbers may interfere with the main task of SI.

As mentioned in section 1.3.3.2, the patient literature suggests number word and Arabic-digit representations are linked but functionally separable. This thesis has adopted the framework of the CLM in considering SI, and its multi-resource model, where cognitive processes may or may not be in conflict depending on whether they rely on shared resources. It follows, then, that during SI the acts of writing down numbers, and reading them out, whilst being extra behaviours, may not necessarily come with a cost to overall, or peak, cognitive load at any given moment, and may be comfortably accommodated by the system.[36]

A justification for Jone's (2012) assertion can also be provided if we consider that, in the context of interpreting numbers during SI, and at the interface of number words and Arabic digits, number naming might be possible via both lexico-semantic pathways and non-semantic routes. Duyck, Depestel, Fias & Reynvoet (2008) demonstrated cross-lingual priming in a numerical distance task in trilinguals (L1 Dutch, L2 English, L3 French). The task was to verbally translate visually presented number words from L1 to L3, and masked number word primes in L2 were presented during the trials. When the masked prime was the same magnitude as the L3 target (that is, a translation equivalent), number naming was facilitated. The same effect was found translating from L3 to L1. As the primes were masked, it was assumed they were being processed automatically rather than consciously and deliberately. The authors argue that this finding "confirms the existence of strong L2 lexicosemantic mappings for number words and generalizes previous semantic effects in L1-L2 translation to translation processes between L1 and L3" (ibid, 2008 p1281). In a different study, using just Arabic digits as the stimuli, Ratinckx, Brysbaert & Fias (2005) investigated the naming of two-digit Arabic numerals, manipulating masked primes to see their effect on naming speed. They found that naming of target numbers was facilitated compared to baseline when a digit was shared between the prime and the target in the same position (eg the target 28 could be primed with a facilitatory effect by 18 and 21), whereas naming was slowed down compared to baseline when the prime contained a digit also in the target but in a non-corresponding place (eg the target 28 could be primed with an inhibitory effect by 82, 86 or 72). On this basis they argue that "The data point to a nonsemantically mediated route from visual input to verbal output in the naming of 2-digit Arabic numeral" (Ratinckx, Brysbaert & Fias, 2005 p1150).

In the context of SI, therefore, attempting to do the conversion of a number from source-to-target language entirely in one's head, may involved lexico-semantic processing already under strain from interpreting the rest of the message. In contrast once a number has been written down in Arabic digits (or if it is already available in that form in a transcript), when the time comes to read it out, perhaps non-semantic pathways

36 – A related point is made in the final paragraph of section 2.5.1

can be engaged reducing load and conflicts with semantic-pathways already engaged in interpreting the rest of the message. In this sense, we can see how the "extra" work of noting down heard number-words into Arabic digits, and then reading them out again, may in effect produce fewer resource conflicts and be easier for the interpreter to do. This, added to the previously suggested (see section 2.5.1) WM advantage of having the number in written format and so being able to incorporate the naming of the number at a more opportune moment (in terms of cognitive load), can help to explain why the assertion made by Jones (2012) could be valid.

Future research to directly confirm the helpfulness (or not) of noting down numbers would be welcome. Participants could in one condition be instructed to write down all numbers while interpreting, and in another condition be instructed to do all translations mentally, and in both conditions aim to be as accurate and complete as possible. The experiment could be repeated to see if, over time and with training and practice, the systematic writing down of numbers during SI does indeed show itself to be a readily actionable piece of advice that improves interpreting performance both for numbers and as a whole.

2.5.5 Experiments on numbers during SI

In this section, I will discuss two experiments from the field of interpreting studies that addressed the specific topic of interpretation of numbers during SI, and from which we can draw some insights.

2.5.5.1 Cheung (2008)

This study is unfortunately of limited inferential usefulness, but raises some questions worth further empirical investigation. Three groups of students were tested on a passage containing numbers that they had to interpret from English to Chinese. One of the groups underwent half-an-hour of "training" identifying numbers presented in isolation, another group similar training but with numbers with referents (eg 200mg, 4 million people), and a third, "control", group received a lecture on balancing the need to correctly translate numbers and produce a fluent delivery. The results are of limited value, as this was not a real training study where performance and improvement could be tracked over time (or at least compared between a group receiving substantial training over time, and another receiving no or different training). The classification of number translations was unusual, with many considered types of acceptable approximation. The control group showed the greatest number of ommissions but it was "unclear whether participants omit the numbers from their renditions because they feel incapable of translating them or because they feel it is permissible to do so and they make the deliberate choice" (Cheung 2008, p79).

There are some aspects of the experiment that could be picked up again in more useful further research. It would be interesting to know if training on numbers in isolation is helpful in improving translation of numbers during SI. And also if there is a benefit to training on numbers with referents compared to numbers in isolation, or numbers appearing in more authentic contexts, such as in number heavy speeches. This should be done in a context where participants are encouraged to strive to achieve maximum accuracy and completeness for numerical information.

2.5.5.3 Pinochi (2009)

This was an experiment that, although limited in scope (with 8 participants in each group interpreting a single text including a total of 61 numbers belonging to as many as 5 different number categories that were separately analysed), nevertheless introduced innovations in design and its approach to investigating the research problem, providing both an useful framework for developing further empirical research and a notable set of theoretical contributions.

The study compared the performance of two groups of interpreting students (who had all passed their exams for the language combination being tested) in interpreting a semantically identical text that was heavy in numerical content — one group worked from German into Italian, the other from English into Italian. The aim was to investigate language-independent and language-specific factors in the difficulty of rendering numbers during SI.

Overall, there were high error rates in rendering the numbers for the two groups of around 40% for both the German and English speeches – this overall error rate was not significantly different between the two source languages, but when results were broken down by error types, a significant language-effect was discovered, with significantly more “transposition” errors for the German speech. The author attributed this difference to “inversion” errors (there being opposite unit-decade and decade-unite order for German and Italian numbers, compared to aligned decade-unit order for Italian and English). An additional conversion/inversion process is required when rendering numbers from German to Italian, which may be the source of errors of this nature.

By breaking down results according to categories of numbers and categories of number-handling errors further insights were gained that applied cross-linguistically. Not all numbers are equally difficult, and an innovation of Pinochi's (2009) study was precisely the way that different numbers were treated in the analysis of results – after pointing out that previous research had shown that big numbers were particularly difficult during SI, Pinochi states that it was important to specify what exactly “big” should mean in this context. Merely considering numerical value is not a satisfactory approach as the [37]divergences between efficiencies in Arabic digit and number-word representations was, for Pinochi, something that "could not be neglected when setting up the number categorization".

Table 1 in Appendix 2 shows the categories used by Pinochi (2009). It is worth noting that although the numbers are broadly categorised by numerical value (and so described in terms of Arabic digits), the distinction between categories A and B relate to the surface phonological form of the numbers (how many blocks of number-words are required for them to be "read" out). Of the five categories, category B was indeed the one with the highest error score among participants, with Pinochi (2009) suggesting this could be due to word-length effects – these longer numbers (in terms of phonological form) being more challenging to retain in WM (see section 2.4).

Just as not all numbers are equally difficult to interpret, not all errors are of the same seriousness or qualitative type. Table 2 in Appendix 2 below shows the categories of error-types Pinochi (2009) used in her experiment. The most common errors in both languages were omissions (around 50% of errors in both languages) and approximations (18.9% in English, 14.1% in German), which the author points out are often deliberate strategies. It can be argued that these are preferable to other types of errors as it is better to lose detail from the original speech than to introduce incorrect detail. The distribution of error types was generally similar for the two source languages – but a significant between-language difference was found for one category of errors, transpositions, where they were much higher for German (7.1%) than for English (1.5%). For the German speech, Pinochi (2009) reported that the prevalence of transposition errors in German could mainly be attributed to the incidence of classical inversion errors in that category.

Participants in the study were allowed to take notes during their interpretation, and all except one chose to do so, allowing for an analysis of the notes and how they related to task performance. Category B numbers (those representable by 4 or more Arabic digits, and which are read out in two blocks) were only written down 31% of the times they were encountered by participants in German, 33.4% in English, with the author suggesting that they these numbers were perhaps perceived as structurally too complicated even to write down. In contrast, numbers from from categories A and D were both written down over 50% of the time they were encountered in either German or English, with Pinochi (2009) suggesting that this was because they are

37 – This point relates to the relative efficiency of the numerical code based on Arabic digits, versus the spoken and written codes based on number-words. Pinochi (2009) points out that despite the numbers 39,000 and 39,754 being large numbers of the same order of magnitude, and requiring the same number of digits to be represented in the Arabic digit-code, the second number requires many more number words than the first number when both are expressed verbally.

difficult to hold in memory but quite easy to represent with Arabic digits (requiring just a few digits). Category E numbers (dates) were noted down the least, with Pinochi suggesting by way of explanation that they were perhaps the easiest to interpret, and engaged a different processing modality (13.1% errors in GT and just 4.3% in ET). She argued that the dates category was the only one that could be "visualized" and associated to a semantic meaning, which makes retention simpler than in the others, where interpreters have to rely only on phonological clues.

Some inferences and suggestions for future research that we can draw from the Pinochi (2009) study are as follows. Firstly the study found evidence that number-system misalignments increase related errors (finding that unit-decade misalignments elicited a greater number of inversion errors), confirming that this is a legitimate source of difficulty for interpreting numbers during SI.

Secondly, on the question of note taking, the author of the study considers it surprising that the very numbers that perhaps would benefit most from note-taking were the ones least likely to be taken down. As for the Cheung (2009) study, a problem in experimental design is with the instructions given to participants. While on the one hand, allowing and observing the use of notes leads to and understanding of what student-interpreters do when tackling number heavy speeches, more useful insights would be gained from instructing participants to write down all numbers to help them with interpreting, and from the results learning whether for different types of numbers (or for all numbers) note-taking helps, does not help, or hinders the achievement of accurate target-language renditions.

Thirdly, the distinction made my Pinochi (2009) between numerical size and phonological length of large numbers is an interesting one that warrants further investigation. It would indeed seem plausible in light of the arguments in section 2.4 of this thesis, that it is a pertinent distinction to be made. Whether the fundamentally relevant measure of "length" is number of syllables or simply number of component number-words is not clear (it may well be the latter since number words are lexical items that are highly familiar, and well rehearsed in articulatory terms, and so the relevant factor may be at a broader resolution of how many units of information there are in a number). It seems plausible that in terms of difficulty, "twenty three" and "two thousand" will be closer to each other than either of them is to "two hundred and sevent-nine" or "two thousand and forty-six" respectively.

Ideally a future study would take on this perspective of attempting to describe a natural typology of numbers and of number errors that is relevant to the difficulty of interpreting numbers during SI. It would systematically investigate numbers for specific language pairs and thereby be able to confirm, or fail to confirm, suspected points of difficulty (such as the numbers 71-99 in French, short-scale/long-scale misalignments, the phonologically/morphologically longer numbers in ranges of numbers of similar numerical value etc.) From these insights, interpreters would be equipped with the knowledge of which numbers to practice, and which to pay special attention to and be wary of during an interpretation.

3. An appraisal of advice on interpreting numbers

Having considered reasons for how and why the handling of numbers during SI proves difficult, we can now appraise the different pieces of advice for mitigating this problem that were first presented and described in section 1.3.5.

3.1 Do targeted training on numbers

The exercises described in section 1.3.5.1 seem to have both a novel items and repeated practice approach to training numbers. For example, the training on isolated numbers with the shuffling of cards is a pseudo-novel items approach – a more sophisticated version of this might be a computer program that can randomly generate numbers. The idea is to be able to train on rapid identification, translation, and note-taking of unexpected numbers. This would seem to be a plausible strategy for bringing non-native numerical perception in general up to near-native levels (see section 2.1.2) and for automatising note-taking or translation of particular subclasses of numbers within a language pair that tend to cause difficulty because of number system misalignments (see section 2.5.1 mentioning how processing could be sped up via LTM template formation) or other numbers that may cause difficulty across all languages (e.g. morphologically/phonologically long numbers with multiple component number words). With regard to future research, it would be of great value to have experiments that identify for particular language pairs which, if any, subclasses of numbers cause exceptional difficulty. Also welcome would be experiments to confirm or deny the generalisability of training on isolated numbers (or numbers with units) to improved performance in the translation of numbers during SI of number-heavy speeches.

One of the exercises involves repeated practice on the same number-heavy speech until the student is able to interpret it with complete accuracy. This may seem less useful at first, given that with repeated practice the numbers are no longer novel and unexpected, but this exercise does seem to be useful in training another skill. For all the acquired years of experience an interpreter has, unexpected numbers will always be among the more information dense and therefore more difficult parts of a speech to interpret (see argument in section 2.4.4). For this reason it is perhaps important for students to develop a familiarity with what it feels like when the "output style" of the interpretation is modulated (e.g. by adopting a very short time-lag around information dense portions of a speech, and tersely expressing any parts of the speech that are amenable to compression) in order to achieve a successful interpretation of a number-heavy speech. This could be the useful skill that such a "repeated practice" exercise trains – to teach the student that it is possible to interpret information dense speeches, and how to control one's output strategies to do so.

3.2 Use your boothmate as a number-scribe (or use a real-time transcript)

I have argued that numbers, like other low-redundancy "transcodables", cause a higher load on WM storage than other speech elements, so having the numbers readily available in written format would relieve cognitive load in the interpreting "system" (as presented in the CLM) by reducing WM storage demands, thus avoiding a processing bottleneck, and freeing up resources to allow for improved performance during SI. SI requires WM processes for maintaining representations of information to enable subsequent interpretation of said information, but with this piece of advice some of that representational maintenance has been "outsourced" to a representational format outside of the interpreter's brain (i.e. writing on paper, or on screen). Another process inherent to the SI act, that has been "outsourced" with this strategy, is the identification of the source-speech number and its representation in a deverbalised format (arabic numerals) that is more amenable to direct rendering in the target language than the audio of the source speech would be. Further, as mentioned in section 2.5.4, Arabic digit-naming may be able to exploit non-semantic pathways and doing so may relieve load on semantic pathways simultaneously engaged for processing non-numerical parts of the speech.

One of the CLM's strength is that it views the SI act in the context of a system, where there is an interface of internal and external load factors (differently limited capacities of different cognitive resources within the interpreter's brain, which experience different levels of load over time driven by properties of the source speech, which is external to the interpreter). In a sense, this piece of advice adds another processing module to this interface system, increasing resource capacity via "extended cognition".

3.3 Optimise your preparation before interpreting

The advice in section 1.3.5.3 on the interpreter familiarising herself with broad trends in the numbers being discussed, and having an idea of the order of magnitude of the numbers likely to come up would seem to make sense in that it would to a limited extent increase the predictability of the speeches, reduce the linguistic entropy, improving anticipation of information and also aid the ability to repair information that is misheard or poorly heard. It would also ensure that, should numbers be missed, the sense of an argument is less likely to be lost.

Highlighting numbers in a text during preparation, including when there is little time to thoroughly prepare the text, also seems to be sound advice when we consider that numbers are amongs to most difficult items to interpret, even for experienced interpreters, because of their low redundancy and high linguistic entropy. Making them salient and readily available, so that they do not need to be held in WM but can simply be checked against the source speech and read out (with naming of Arabic digits perhaps relieving semantic processes engaged during SI, see section 2.5.4) will ease the processing demands of SI.

Another aspect of optimal preparation for a meeting, when there is enough time to do so, is for the interpreter to thoroughly familiarise herself with numbers that are likely to be cited in the meeting repeatedly (eg the names and numbers of laws). This advice works because of the formation of LTM templates (see section 2.4.4). If she has the items internalised in memory or has at least a ready visuo-spatial recollection of where the items sit on a "cheat-sheet" glossary, then whenever one of them appears in a speech this highly information-dense transcodable item can simply be retrieved and discharged by the interpreter from memory (or by reading it out). An item that would otherwise be of high-linguistic entropy and difficult-to-interpret is now easily rendered and amenable to anticipation and even repair during a period of degraded signal. For example, an interpreter adequately prepared for the Universal Periodic Review of a country at the United Nations Human Rights Council will have familiarised herself with the names of any international instruments likely to be cited by delegates, after studying recordings and documents relating to meetings of the same body. As a result, when instruments such as "ILO Convention 189" are mentioned, the interpreter will have already been primed to hear this number, rather than encountering it as simply a number like any other, devoid of any meaning beyond its numerical reference, that has to be identified and rendered on the fly. Further, she may even anticipate it before it is mentioned – the speaker may be talking about economic empowerment of vulnerable women and protecting their rights, and then go on to say their country "wishes to see the urgent ratification of ….", with the interpreter able to perceptually anticipate mention of ILO 189 (since it concerns domestic work, a sector whose workforce is overwhelmingly female). So if and when the speaker does say the number, it is readily identified and rendered by the interpreter without the same degree of increased cognitive load that would be experienced at the point of encountering a number not amenable to perceptual anticipation.

3.4 Write down numbers whilst interpreting

This advice provides similar advantages to the "extended cognition" nature of having a boothmate's transcription of the numbers – by writing a number down, it does not have to be consciously maintained in WM lest it be lost, instead only a placeholder needs to be remembered ("the number is written down there on the page"), thus a limiting processing bottleneck is bypassed.

Unlike the use of a boothmate scribe, however, here the interpreter herself has to do the work of identifying and converting the number from its source language phonological form into a conceptual form (i.e. in Arabic digits) that can be rendered into the target language. Forming a visuospatial representation (in Arabic digits) and writing this down implies extra cognitive resources in the SI act that will imply extra processing.

However, as explained in sections 2.5.1 and 2.5.4 this may not come with a cost to overall task performance (which may even be facilitated by certain kinds of extra processing that simultaneously, or in a deferred manner, tax non-bottleneck resources whilst relieving load on bottleneck resources).

For unit-decade order misalignments in a language pair, eg when working from German into English, writing down two-digit numbers from right to left, and anticipating the need to do so, may well ease processing demands of SI in those moments. Another “trick” mentioned in section 1.3.5.4, is of the interpreter developing efficient symbols (perhaps of only one graphical stroke) to combine with Arabic digits to represent multiples of one-hundred and one-thousand (replacing two or three zeros). Like for writing German numbers backwards, this symbol trick would also make the note taking process more efficient, and resolve the few circumstances where the number-word modality seems to be more efficient than the Arabic digit modality (eg “two thousand” is made of two rapidly pronounced words, but “2000” comprises four symbols; if the interpreter is to be temporarily silent while noting down number, as suggested in the advice cited at the end of section 2.4.2, then writing down the numbers should not take much longer than the duration of its utterance in the source-speech).

By writing numbers down, the constraints of WM for holding information – both the amount of information, and the fact that representations in WM decay without active conscious maintenance – can be escaped to some extent, allowing for the more intelligently processed and idiomatic rendering that a longer lag can allow whilst also containing the risk of information loss it normally carries. For all interpreters, regardless of what we might call their “default output style”, lag needs to be elastic and adapt to the demands of the incoming speech (which can fluctuate over the course of time in informational density, and therefore WM load) – and so the precautionary systematic writing down of numbers by the interpreter can be an effective strategy to help mitigate against sudden increases in WM load that risk causing breakdowns. And systematically writing down numbers during SI, even when they seem easy, will also bring with it the benefit of training numerical identification and conversion into written form.

3.5 Drive defensively – adapt your output style pre-emptively

This soundness of this advice is apparent when we consider the benefits it provides to the interpreter during SI – at dense, high-linguistic entropy portions or a speech, such as with bursts of numbers, having a short time lag allows for the discharge of this information that would otherwise be held in WM for longer. With WM capacity being more limited for less redundant information (see section 2.4), quick discharge of information ensures that breakdowns and errors are less likely to occur. For non-numerical parts of a speech, adopting a longer lag to allow for compression helps minimise acoustic disturbance (and articulatory suppression effects on WM – see section 2.4) from the interpreter’s own vocalisations, ensuring that when numbers do appear downstream they are more likely to be accurately perceived by the interpreter and therefore more likely to be accurately and completely rendered.

As evidence that experienced interpreters can and do modulate their "output style" during SI, we can consider an experiment by Meuleman and Besien (2009) which tested interpreters working from French into Dutch on two passages presenting different kinds of difficulty – the first had complex sentence structure and the second had a high delivery speed. They found that most interpreters produced acceptable interpretations and opted for a segmentation strategy for the first text, with only a few adopting a tailing strategy (having a short time lag), but this was reversed for the second text with most adopting a tailing strategy.

Some interpreter trainers may advise students that tend to adopt a longer lag that this is dangerous at early stages of their training, and that for this reason they are missing too much information. Whilst this may be true, the trainers may go on to advise them that for the moment they should stick close to the speaker and adopt a shorter time lag and only at later stages of the student's training start to experiment with taking the risk of occasionally adopting a longer lag to improve reformulation. In the light of this thesis' discussion, I believe this to be unhelpful and possibly counterproductive advice. It seems to me that neither a consistently long or short time lag is optimal for addressing the challenges of SI and, instead, students should be encouraged from the very outset to intelligently modulate their time lag. Having a short time lag when not necessary, when information could instead be compressed, deprives the student of the much needed opportunity to ease processing demands, minimise acoustic disturbance, and mitigate WM articulatory-suppression effects, such that she is in the best position possible to cope with a momentary increase in linguistic-entropy that comes with a burst of numbers or a list of names. Consistently adopting a short time lag could therefore only make the problem of interpreting numbers harder for the student. If the student is not yet adept at the kind of modulation required of expert interpreters, then rather than adopting a consistently-short time lag for all new speeches she encounters, she can instead repeatedly practice the same speeches (that contain number-heavy portions and number-free portions) so that she learns to be familiar with how it feels to optimally modulate one's time-lag to provide a good interpretation, an important skill to develop.

3.6 Provide an approximation of the number

This advice seems appropriate for the reality that there will be some situations, as Jones (2012) explains, where it is nearly impossible for any interpreter to fully and accurately render all numerical information (eg fast, delivery of a burst of complex numbers with different referents and no supporting text available to the interpreter). And in section 2.4.4 I consider that unpredictable numbers will always be one of the more difficult aspects of a speech being interpreted, regardless of the level of one's expertise at SI. So as a mitigating strategy of last resort, it seems appropriate.

Beyond that, however, it can be an intelligently deployed strategy, one used in anticipation of upcoming difficulty. In light of the numerical distance and numerical size effects (described in section 2.5.3) rounding and approximating numbers may help the interpreter get a better handle of the relationships between the numbers being interpreted (whether an increase or decrease, an improvement or deterioration, is being discussed) and therefore avoid making a misleading error regarding the fundamental message being communicated.

Also, if one is able to discern that full accuracy for a number is not essential to the meaning being transmitted, then by providing an approximation of a complex number (which may, for example, drastically reduce the number of component number words), WM demands can be eased and accuracy of the overall interpretation improved. As numbers often come with referents or units of measurement, without which they are not of much use during the interpretation, these referents (if not obvious in advance) also represent low-redundancy information that needs to be processed and will bring their own WM demands. It is therefore perhaps safer to approximate whenever acceptable, and thereby improve the chances that useful piece of information is transmitted in the target language rather than a less useful piece of information containing a complex number without a referent.

4. Concluding remarks

I have argued in this thesis that it is helpful to see numbers as part of a broader category of “transcodable” elements, including names of people, institutions, technical terms etc. In a sense transcodables are easy – they have one-to-one correspondences between source and target languages, and the interpreter can easily deploy the target language versions as rehearsed chunks, or “ready equivalents” available either in their ‘mental phrasebook’ or in a supporting transcript (e.g. when the text of a speech is available, and the numbers are printed in Arabic digits).

But because of their one-to-one correspondences, which are all or nothing forms, these transcodable items when not already predictable or known to the interpreter are low in semantic redundancy and so when they appear in the source speech they cause increases in cognitive load as they need to be held in working memory, which is a limited resource among the multiple resources that together work in a system for carrying out SI.

Load in this system is the product of interfacing internal and external factors – cognitive resource capacities in the interpreter’s mind, and properties of the source-speech signal. Sources of support that the interpreter uses can also be incorporated into this model (e.g. the written notes an interpreter uses can be seen as a storage format module that expands storage capacity and prolongs information representation in the system).

Working memory constraints can be seen as the most important processing bottleneck in the SI act, and many of the strategies considered in this thesis seem to target this weakness in the SI system to enable successful handling of numbers during SI.

Whilst numbers in general may be difficult, some subcategories may cause heightened difficulty (complex numbers comprising many component number words, cases where there is a misalignment in the source-language and target language number-systems).

One piece of “non-advice” a student interpreter may be accustomed to hearing is that numbers are difficult even for the experienced interpreter, but not-to-worry, it does get a somewhat easier over time. In the light of this discussion, this seemingly empty advice does seem to have merit. The more long-term memory templates an interpreter acquires for perceiving and translating formulaic speech (that is either idiomatic to her working languages, or specific and commonly encountered jargon and procedural language in particular employment contexts) the easier SI will become overall, and the more ready she will be to cope with those momentary peaks in cognitive load triggered by, for example, a burst in numbers for which no template will be available. So if a student is having difficulty with interpreting numbers, she should be mindful of the need not only to focus on this problem, but also enhance her language skills and interpreting experience more generally.

Further research on the topic of discussion that would be welcome includes confirming whether and under which circumstances note-taking is helpful during SI, and systematically identifying, for different language pairs, types of numbers that cause difficulty for the interpreter, and types of number-rendering errors that are produced by the interpreter during SI.

All of the pieces of advice considered in this thesis do seem to have merit in light of the discussion of sources of difficulty. Of these pieces of advice, it seems that some are more ‘ready to use’ than others, and therefore worth encouraging students to deploy – being ready to adapt output style, or approximate a number is a useful skill to develop. Committing oneself to the habit of always writing down numbers is also a strategy that is readily implemented (and this conscious processing of numbers is itself a naturalistic way of training number identification, as in strategy 3.1, without sacrificing training time on actual speeches). While there are no magic solutions to the problem of interpreting numbers during SI, it does seem that there are usable mitigations, and in a limited capacity system they are welcome.

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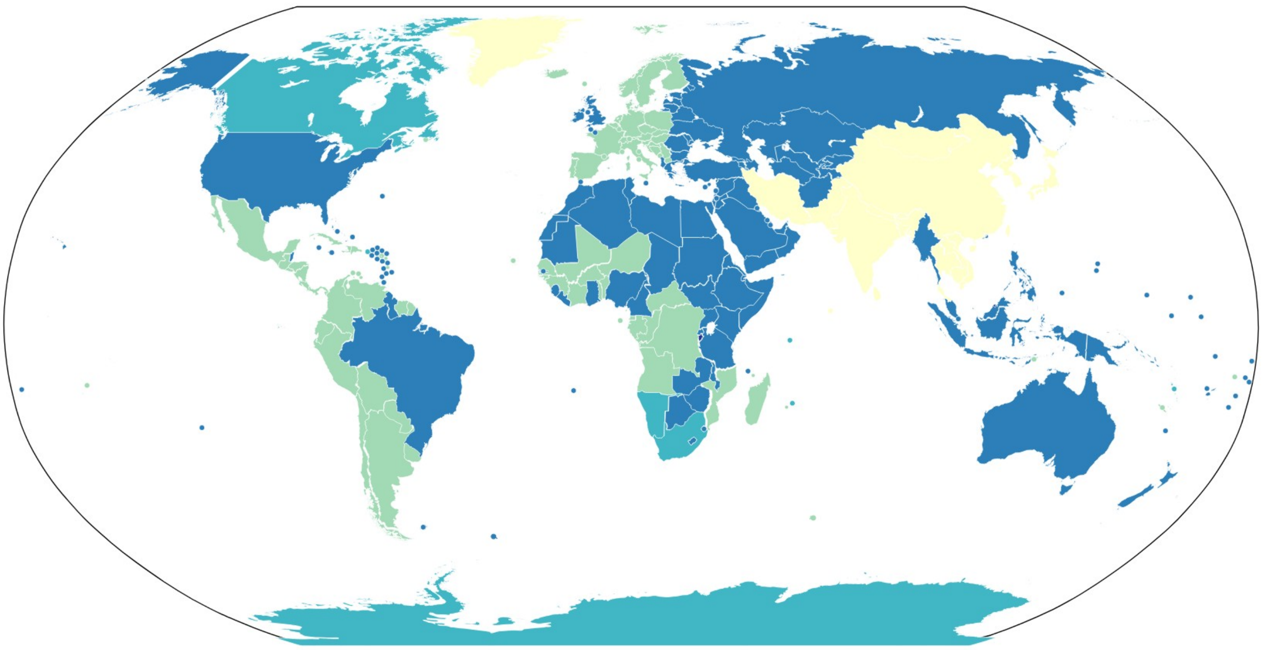
Appendix 1

World map of number systems



Key:

Green – long scale ; Blue – short scale ; Turquoise – both short scale and long scale ; Yellow – other

Author: Citynoise

Date: 15 June 2012.

Retrieved on Aug 10 2018 from https://commons.wikimedia.org/w/index.php?%20title=File:World_map_of_long_and_short_scales.svg&oldid=179392903

Large numbers in English, Spanish and French

Numerical value	English	Spanish	French
10^6	one million (1×10^6)	un millón (1×10^6)	un million (1×10^6)
10^9	one billion (1×10^9)	mil millones ($10^3 \times 10^6$)	un milliard (1×10^9)
10^{12}	one trillion (1×10^{12})	un billón (1×10^{12})	mille milliards ($10^3 \times 10^9$)

Appendix 2

(Content adapted from the text of the corresponding article.)

Table 1. Number categories used in Pinochi (2009)

Categories of numbers used by Pinochi (2009)	
A	Numbers with 4 or more digits read at once (e.g. 920,000)
B	Numbers with 4 or more digits read in two blocks (e.g. 928,346)
C	Numbers with less than 4 digits
D	Decimals
E	Dates

Table 2. Number-handling errors categorised in Pinochi (2009)

	Categories of errors used by Pinochi (2009)
Omissions	number left out altogether, or replaced with a generic expression (eg many, few)
Approximations	the order of magnitude is respected, but the number is rounded up or down, often a deliberate strategy as indicated by accompaning qualifiers not present in the original such as "about", "more than"
Lexical errors	"the order of magnitude of the stimulus is maintained, but one or more number-words within the numeral have been misinterpreted (e.g. 277,000 translated to 276,000, or 2004 translated to 2005)."
Syntactical errors	"the number is of a wrong order of magnitude even if possibly containing the right figures in their correct sequential order (e.g. 300 being translated as 300,000, 150,000 translated to 1,500 or 47,000 to 47%)"
Phonemic misperception	"the error can be related to a phonemically wrong perception of the stimulus in cases of similar sounding linguistic features (e.g. 17, "seventeen", perceived as 70, "seventy")."
Errors of transposition or position errors	"the wrong assembly of the figures composing the number, which are correctly selected but misplaced. This includes on the one hand the classical inversion errors typical of the German-Italian language pair with its different numerical structures, but on the other hand it also includes all position errors, possible in English as well, which are not directly attributable to the numerical system structure [... e.g.] 7.6% → 6.7% 8.1% → 1.8% 528,015 → 285,000."
Other mistakes	"all other mistakes not belonging to any of the previous types and whose causes are often not apparent. These errors are kept apart and form a rather miscellaneous group (e.g. 528,015 translated with 270,000 or 22.4% with 3.5%)."