On linguistic properties of verbal number systems: A cross-linguistic study of number transcoding errors observed in a Basque-French bilingual patient with aphasia

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Abstract

The present study aims to assess the assumption that number transcoding processing is driven by the linguistic properties of verbal number systems, through the analysis of errors produced by a Basque-French bilingual adult with aphasia, in a number dictation task. In particular, it was predicted that errors would not be the same in Basque and French given their respective differences in the formation of numbers (Basque has a vigecimal regular system whereas French has a decimal irregular system). A 44 year-old Basque-French bilingual patient with aphasia, and a control subject, were assessed on a dictation task. The task consisted in hearing Basque or French numbers, and writing them in Arabic numerals. Results show that the patient produced different errors in each language. The errors can be explained in terms of the different linguistic properties of the Basque and French numeral systems. That this could be observed in one and the same bilingual individual, whose two languages use different numerical systems, suggests the involvement of distinct transcoding processes respective to the particular language in which numbers are being processed. This highlights an interaction between language and number representation and processing, a new and active field of inquiry in contemporary cognition research.

Highlights

· Number transcoding errors are influenced by the linguistic properties of verbal number systems

· Interaction between language and number representation and processing

· Dissociation in number transcoding can emerge from the assessment of bilingual individuals

· Necessity to include number transcoding tasks in language assessment batteries

· Necessity to assess bilingual patients in both languages

Keywords

Number transcoding; bilingualism ; aphasia ; Basque ; French ; numerical cognition.

1. Introduction

1.1 Lexical and syntactic processes inherent to number transcoding

Number transcoding consists in transcoding a number from a verbal input to an Arabic digit output (‘thirteen’ à ‘13’) or vice versa, from an Arabic digit input to a verbal output (‘6’ à ‘six’). This is an activity we practice on a regular basis. For instance, when asking somebody’s phone number, usually, numbers are given orally and transcoded by the listener from a verbal input to its corresponding Arabic digit output by writing this number down on paper or directly into a phone. (Note that it would be surprising to write these numbers in word-form instead of in Arabic digits.) Therefore, numbers are manipulated either verbally or as Arabic digits, and generally, the transcoding activity is not problematic for adults that have received a standard education. However, this is not the case regarding typically developing children or brain-damaged patients showing acalculia. Acalculia refers to numerical processing and calculation impairment that may result from a brain injury such as strokes, cerebral traumas, but also dementias and degenerative diseases (De Luccia, G. and Ortiz, K.Z., 2016).

Deloche and Seron (1987), Deloche, Seron and Ferrand (1989) analysed errors produced by aphasic patients in oral and written number transcoding tasks (reading and repetition; dictation and copy, respectively). The authors observed various error types, which led them to suggest that the transcoding activity involves at least two different levels and that a disruption to one or other would result in different error types.

The first level is ‘lexical’. At this level, numbers are characterized by two pieces of information: 1) class (e.g. units, teens, tens, hundreds, and so on) and 2) position in the class. For instance, ‘thirty’, ‘thirteen’ and ‘three’ belong to different classes (respectively tens, teens and units) but they share the characteristic of being each at the third position of their respective class. A disruption occurring at this level would

result in lexical errors. Among them, class and position errors are distinguished: e.g. class error: ‘fifteen’ transcoded as ‘50’; e.g. position errors: ‘fifteen’ transcoded as ‘13’.The authors also reported other error types, which belong to lexical errors such as for instance inversion errors: ‘five hundred’ transcoded as ‘105’, and partial encoding error : ‘eight thousand and three’ transcoded as ‘1003’.

The second level is the transcoding itself. The most frequent errors resulting from a disruption of this level are referred to as ‘lexicalisation errors’ : the subject trancodes the elements ‘term by term’ without integrating them into the right syntactic structure : e.g. ‘thirty-seven’ transcoded ad ‘307’. According to Deloche and Seron, it is clear that, in this kind of error, the lexical processes are preserved since the participant transcodes every number into its corresponding Arabic digit; therefore, these errors are syntactic by nature and manifest a pure transcoding deficit. Other error types are also related to a disruption of the second level ; for instance, when the multiples 100 or 1000 have been transcoded like 1 or 0 : e.g. ‘eight hundred and fifty-seven’ transcoded as 8057.

Therefore, Deloche and Seron’s model established a distinction between lexical and syntactic errors. Lexical errors result from a disruption of the first level of the transcoding processing. During this so-called ‘lexical level’, numbers are characterized by two information types: class and position. Syntactic errors result from a disruption of the second level: the transcoding process itself. Such errors show that the first level is not affected as participants transcode every verbal number accurately; however, they do not succeed in ordering these numbers into the right syntactic template.

1.2 Numeral system acquisition across languages

Syntactic transcoding errors have not only been observed in brain-damaged patients and in children with dyscalculia, but also in typically developing children. Seron and Fayol (1994) reported number transcoding errors produced by French speaking

children from the second grade. Interestingly, this study did not only reveal that children made syntactic errors but also that errors varied with the verbal number system in use. The study involved two groups of children: one group from France and one group from Wallonia (a region of Belgium). Although both countries use the French language, the French and Walloon verbal number systems differ in forming two ten-words: 70 and 90. While the French system uses the terms *soixante-dix* and *quatre-vingt-dix* (literally, 'sixty-ten' and 'four 79 twenty-ten'), the Walloon system uses the words *septante* and *nonante* (literally, 'seventy' and 'ninety'), respectively. Thus, the Walloon verbal number system is slightly different from the French verbal number system in keeping the regularity by suffixing the morpheme -***ante*** t/ to particulars in order to form tens: *sept**ante*** 'seven-**ty**'*and non**ante*** 'nine-**ty**'. Children from France produced more errors than the children from Belgium and the difference observed between the two groups involved the numbers 70 and 90: only French children showed difficulties for transcoding these ten-complex forms. Through this study, Seron and Fayol showed that the linguistic characteristics of French and Walloon number systems had an impact on children's errors in number transcoding tasks.

Moreover, different error types were found depending on the children age, which seemed to reflect **a** lexicalization process of French complex number acquisition. Some French children transcoded the number 'ninety' ('four-twenty-ten') as '42010', showing that they did not lexicalise this number while others transcoded it as '8010', showing that they partially lexicalised it. In the latter case, a part of the number was transcoded correctly since within the verbal form *quatre-vingt-dix,* 'ninety', (literally 'four-twenty-ten'), *quatre-vingt* 'eighty' (literally 'four-twenty') was transcoded accurately as '80' and not as '420'. Finally, this number (90) is fully lexicalised by French adults who end up forgetting that this number verbal form expresses the product of (4x20) +10.

In summary, these studies have shown that number transcoding tasks involve lexical and syntactic processes, which are variable across languages. This affects the way children acquire numeral systems and the type of errors produced by both typical and atypical populations.

1.3 The present study

1.3.1 Basque and French verbal number systems

The term ‘verbal number system’ refers to how languages express numbers. Basque and French verbal number systems display different linguistic properties (Cf. Appendix A). While the French verbal number system is decimal (base ten), the Basque verbal number system is vigesimal (base twenty) Also, French has irregularities in the formation of tens whereas Basque is very regular. Until the number 20, French and Basque are alike: both use a specific term to name the numbers 10 (*French : dix [dis] ; Basque : hamar [amaʀ])* and 20 (*French : vingt [v] ; Basque : hogei [ogeɪ]).* Contrary to English ‘twenty’ in which we recognize the number stem ‘two’ and the suffix -ty /tɪ/that expresses tens (2x10), neither French nor Basque uses a term like ‘deuxante’ or ‘berramar ‘ (‘two-ten’) to create the verbal form of the number 20.

Basque and French differ in the formation of tens. In Basque, all ten verbal forms are based on the number 20. Exactly like in French regarding the terms that express the numbers 80 and 90, which can be translated as: *quatre-vingt* ‘four (times) twenty’ (4x20) and *quatre-vingt-dix* ‘four (times) twenty (and) ten’ (4x20+10), Basque ten numbers can literally be translated as:

Table 1. Basque verbal formation of tens

20	*hogei* ‘twenty’	*20*
30	*hogei ta hamar* ‘twenty and ten’	*(20+10)*
40	*berrogei* ‘two twenty’	*(2 x 20)*
50	*berrogei ta hamar* ‘two twenty and ten*’*	*((2 x 20) + 10)*

60	*hirurogei* 'three twenty'	*(3 x 20)*
70	*hirurogei ta hamar* 'three twenty and ten'	*((3 x 20) + 10)*
80	*laurogei* 'four-twenty'	*(4 x 20)*
90	*laurogei ta hamar* 'four twenty and ten'	*((4 x 20) + 10)*

On the other hand, instead of having a vigecimal base, French verbal number system has a decimal base : French uses the suffix *–ante* / t/ to form ten names. Fo instance, *tr**ente*** **(30)**, *quar**ante*** **(40)**, *cinqu**ante*** **(50)**, *soix**ante*** (60) are ten multiples of the respective units: *trois* (3), *quatre* (4), *cinq* (5) *six* (6).

Considering that French verbal number system is decimal, the verbal form of the numbers 70, 80, and 90 can be seen as irregular since they are formed on a base 20: *quatre-**vingts*** (80) 'four-twenty' and *quatre-**vingt**-dix* (90) 'four-twenty-ten'. And the verbal form of the number 70 (*soixante-dix* 'sixty-ten' *[swas tdis]*) is formed by adding ten (*dix [dis]* 'ten') to the verbal form of the preceding number 60 (*soixante [swas t]* 'sixty'*).*

In summary, Basque verbal formation of tens reflects the computation made to form these numbers on a common base (= 20). In French, ten names are formed by suffixing the morpheme–ante / t/ to the verbal form of particulars. However, the verbal forms corresponding to the numbers 70, 80 et 90 are irregular in French, while Basque uses a regular vigecimal system.

1.3.2 Hypotheses and predictions

The present study aims to test the assumption that number transcoding errors are driven by the linguistic properties of number systems, through the assessment of a Basque-French bilingual individual with aphasia. As Basque and French verbal number systems display different linguistic properties, it was assumed that the verbal properties of Basque and French numerical systems would have an impact on number transcoding skills in this patient. This study follows the same line of research initiated by Seron and Fayol (1994), and parallel works (Miura, Okamoto, Kim,

Steere, and Fayol, 1993, 1994), which showed an impact or verbal structure "transparency" on number transcoding skills. For instance, Walloon *nonante,* literally 'ninety', is considered to be more transparent than French *quatre-vingt-dix,* literally 'four-twenty-ten', for transcoding 90; Korean and Japanese literally ´three-ten-seven´ are more transparent than English *thirty-seven* for transcoding 37.

Therefore, we assumed that number transcoding errors would not be the same in Basque and French, and that the main difference would concern tens, due to distinct properties of ten verbal formation in these languages. In particular, ten number transcoding would be vulnerable in Basque, but not in French (until 60), assuming a distinct lexicalization level. In Basque, we assumed lexicalised numbers to be the following ones: units and numbers until 20; hundreds until 1000 (100, 200, and so on); thousands until 10,000 (1000, 2000, and so on), but not tens. In addition, non-lexicalised numbers other than tens would be the same than French ones, i.e. those composed of different lexical primitives, e.g. 287.

In French, we assumed that lexicalised numbers would be the following ones: units (from 1 to 9); numbers lower than 100 (except 70 and compound, 80 and compound, 90 and compound); hundreds until 1000 (100, 200, and so on); thousands until 10000 (1000, 2000, and so on). Numbers that are not integrated as such in the subject's lexicon are numbers with a complex structure, that is a combination of several lexicalised numbers ; for example, in 'eight thousand and fifty six', we assumed that 'eight thousand' would be lexicalized, and `fifty-six' as well, but not this number as a whole. In summary, we assumed numbers containing tens would be more prone to errors in Basque than in French because they would not be lexicalised (or partially lexicalised) in Basque, while they would be lexicalised in French.

2. Method

2.1. Participant

Two subjects were assessed in this study: a patient with aphasia and a control subject. The patient was a Basque native 44 year-old man, who received education in French only, until secondary school. When he was 39 he suffered a stroke resulting in non-fluent aphasia. The patient's and control subject' characteristics are summarized in the table below:

Table 2: Participants' characteristics

	Patient	Control
Gender	Male	Female
Year of birth	1961	1940
Age	44	66
Date of CVA	13/09/00	-
Years post onset	5	-
Profession	Town employee	Retired book seller
Highest educational level	Secondary school (in French)	High school
Mother tongue Dialect	Basque (age of acquisition: 0) Navarro-Lapurdian	Basque (age of acquisition: 0) Navarro-Lapurdian
Other languages: learned used on a daily basis	French (age of acquisition: 6); Spanish Basque; French	French (age of acquisition: 6); Spanish Basque; French
Parents´ languages	Father: Basque only Mother: Basque and French (passed away when the patient was 8)	Father: Basque Mother: Basque
Handedness subject	Right 100%	Right 100%
Clinical information	13/09/00 Scanner: Left sylvian superficial Motor: hypodensity Brachio-facial right Speech: Mixed aphasia	- -

	27/12/00 Motor: Complete recovery Speech: Good comprehension, but significant lack of words	-
	October 2005 Motor: Complete recovery Speech: Good comprehension with mild agrammatism	-

2.2. Materials

The patient was first assessed with the French language assessment battery MT-86 (Nespoulous et al. 1992), which includes a series of linguistic tasks, among them a number reading and copy task, involving ten numbers. This list was used in dictation. In addition and in order to further assess the patient´s number transcoding skills, we added a list of thirty-three numeral stimuli that was used by Seron and Fayol to assess participants with aphasia in different tasks (repetition, reading, copy and dictation). Only the results collected from the number dictation task are discussed in this paper.

2.3. Procedures

The same list of numbers was dictated in Basque or French, in two separate sessions. In the Basque version, numbers were dictated in Basque and the patient wrote them down in Arabic digits (e.g. *zortzi* 'eight' → '8'). In the French version, the same numbers were dictated in French and the patient wrote them down in Arabic digits (e.g. *huit* 'eight' → '8').

3. Results

In the linguistic transposition tasks included in the MT-86 (reading, repetition, dictation, copy), the patient was not able to read a full text but he was able to read words in isolation. He could repeat words ; however, words longer than three

syllables (e.g. *surpeuplement*, /syʀpœpləmɑ̃/, 'overcrowding') provoked hesitations (/sssss….syʀ…syʀpœpləmɑ̃/). He could repeat simple sentences (e.g. *Le ciel est couvert.*, 'The sky is overcast.') but he tended to simplify complex sentences (e.g. *Le grand chien noir du voisin a mange la poule → Le grand chien a mangé la poule.* 'The neighbor's big dog has eaten the chicken. → The big dog has eaten the chicken.) He could not perform the dictation task but had no difficulty in copy.

Table 3 : Results from the MT-86 number transcoding task (dictation)

Total	Stimulus under dictation	French transcoding	Basque transcoding
1	8	8	8
2	12	12	12
3	70	70	*310
4	606	*6006	*6006
5	4003	*40003	*43000
6	578	578	*57800
7	6021	*600021	*6001
8	96	96	*806
9	7200	7200	7200
10	232	*20032	*200032

Table 4 : Results from Seron and Fayol number list (dictation)

	Stimulus	Patient		Control	
		FRENCH	BASQUE	FRENCH	BASQUE
1	40	40	*200	40	40
2	53	53	*213	53	53
3	80	80	*60	80	80
4	79	79	*790	79	79
5	600	600	600	600	600
6	402	*4002	*4002	402	402
7	815	*80015	*80015	815	815
8	730	*70030	*70030	730	730
9	950	*90050	*90050	950	950
10	142	*10042	*10042	142	142
11	365	*30065	*3005	365	365

12	480	*40080	*40060	480	480
13	679	*60079	*60019	679	679
14	2000	2000	2000	2000	2000
15	5008	*50008	*50008	5008	5008
16	9013	*900013	*900013	9013	9013
17	6020	*600020	*600020	6020	6020
18	8040	*800040	*80004	8040	8040
19	4032	*400032	*400012	4032	4032
20	8056	*800056	*800016	8056	*8096
21	5070	*500070	*500050	5070	5070
22	1093	*100093	*100013	1093	1093
23	6074	*600074	*600014	6074	6074
24	2900	*2000900	*2000900	2900	2900
25	5807	*50008007	*500087	5807	5807
26	3416	*300040016	*3000416	3416	3416
27	9720	*9000720	*900020	9720	9720
28	8650	*800050050	*800050	8650	8650
29	7235	*700020013	*700020015	7235	7235
30	6948	*600090048	*60009008	6948	6948
31	1490	*100040090	*100040010	1490	1490
32	2179	*200060079	*20001009	2179	2179
33	4385	*400030085	*400030015	4385	4385
TOTAL ERROR		27/33	31/33	0/33	01/33

4. Discussion

4.1. Error typology

Two main observations emerge from the results: first, transcoding errors appear in both languages (see table 3, stimulus 4: ‘six hundred and six ‘ transcoded as ‘6006’). Second, some responses vary from one language to another (see table 3, stimulus 3: ‘seventy’ transcoded as ‘310’ in Basque and as ‘70’ in French). Deloche and Seron’s transcoding model established a distinction between lexical and syntactic errors. Lexical errors (e.g. class errors such as ‘thirteen’ transcoded as ‘30’ and position errors such as ‘13’ transcoded as ‘15’) are not found in the subject’s production. The errors produced by the subject rather correspond to syntactic errors: numbers are

transcoded term by term without being integrated into the right syntactic template: e.g. ‘six hundred and six’ transcoded as ‘6006’; ‘four thousand and three’ transcoded as ‘40003’; ‘six thousand and twenty one’ transcoded as ‘600021’; ‘two hundred and thirty-two’ transcoded as ‘20032’.

It would be tempting to link the errors found in this patient to his agrammatic verbal behavior, assuming that individuals who have syntactic difficulties in language encoding, also make syntactic errors in Arabic digit encoding. However, another Basque-French patient with typical agrammatic aphasia (described in Pourquié, 2016) did not show any difficulties in number transcoding. On the other hand, dissociation between spared transcoding skills but impaired grammar has also been reported in the literature (Varley, Klessinger, Romanowski and Siegal, 2005), although it does no lead to a consensus (De Luccia, G. and Ortiz, K.Z., 2016). In addition and more importantly, many errors this patient produced concern only a part of the number. For instance, he transcodes ‘two hundred and thirty-two’ as ‘20032’ and not as ‘2100302’. This thus means that the transcoding step is not totally affected and reveals to some extent spared transcoding abilities in this subject (‘two hundred’ and ‘thirty two’ are transcoded accurately in this example). Therefore, the hypothesis that the number syntactic errors produced by the patient are related to his agrammatic aphasia is ruled out.

On the other hand, as this patient’s educational background is low, one can assume that his performance is comparable to children in the process of learning. As noticed above, some numbers are transcoded accurately and errors do not reveal a total deficit of transcoding processing. As mentioned previously, studies have suggested that number lexicalization may depend on both the age of acquisition (e.g. French children may transcode ‘ninety’ as 42010 whereas French healthy adults may not) and the linguistic properties of verbal number systems (e.g. French children may transcode ‘ninety’ as 42010 whereas Walloon children may not). Therefore, the

errors produced by the patient might reflect a lexicalization process deficit assuming that once a number has been lexicalised, transcoding it is no longer problematic.

Finally, as most errors concern long numbers and within them the transcoding of the final part (e.g. stimulus 32), a short term memory deficit can also be postulated in this patient. His results in the digit span did not reach the 2nd level.

4.2. Number transcoding error analysis from a cross-language perspective

Error differences collected from the Basque and French dictation appear to be driven by the linguistic properties of the Basque verbal number system. For instance, in Basque, 40 is literally said 'two twenty' and the subject produced '200' (i.e. two hundred); 53 is literally said 'two twenty thirteen' and he produced '213' (i.e. two hundred thirteen); 80 is literally said 'four twenty' but the patient produced '60' (i.e. 'three twenty'). In line with our predictions, the different errors collected from the Basque and French dictation mostly concern tens. We interpret that the only two numbers that were transcoded correctly in Basque (600 and 2000) are numbers that could have been lexicalized. That is why we find errors such as '800056' for 'eight thousand and fifty-six', which we assumed not to be lexicalised. The correct answers produced by the patient under dictation in French were: '40', '53', '80', '79', '600' and '2000'. We interpret that these numbers are lexicalized and this would explain why the patient did not make transcoding errors on these numbers. Similar production in Basque and French, correspond to stimuli that do not contain tens (see underlined stimuli in Table 4). Therefore, they are also in line with our predictions, since we assumed that the main differences between French and Basque number transcoding errors would involve tens.

However, other results are not in line with our predictions. For instance, (see Table 4, stimuli 8 to 10), numbers were transcoded in a similar way in Basque and French despite the fact they include tens. Then it seems that the numbers 30, 50 and 42

within the numbers 730, 950 and 142 are partially lexicalised in Basque: sometimes the subject is not able to transcode 53 accurately (stimulus 2), but he transcodes 50 correctly within the number 950 (stimulus 9); similarly, he does not transcode 40 accurately (stimulus 1) while he transcodes 42 within the number 142, accurately (stimulus 10).

Finally, various errors are observed, which are not only of the syntactic type, i.e. by transcoding lexical numbers term by term without being integrated into the correct syntactic structure. We also find omission errors or 'partial encoding' in Seron's words (Seron, 2001) : for instance, (cf. the stimulus '11' in Basque), the patient omitted to transcode '60'. We also notice that the patient often omitted the base 'twenty' within a compound number: for instance, instead of transcoding 'ninety' (literally 'four-twenty-ten') as '42010', he transcoded it as '410', i.e. 'four-ten' by omitting twenty. It could be assumed that the Basque morpheme expressing 'twenty' is phonologically non-salient, thus making this number particularly prone to omission errors. This would highlight again the impact of number system linguistic properties on the number transcoding process. Moreover, this error type could also be seen as a piece of evidence supporting a relationship between phonemic awareness and number transcoding as assumed in recent studies (Lopes-Silva, Moura, Júlio-Costa, Haase & Wood, 2014). This hypothesis could also explain why this patient produced many errors in all "oral" transcoding tasks (reading; repetition and dictation; see his results in Appendix B) but not in copying, suggesting that the copy task does not require phonological awareness while the reading, repetition and digit production under dictation tasks do.

4.3. Conflicting cognitive debate on number transcoding: Lexical, syntactic or semantic

Different models have been proposed to account for number transcoding errors observed during development but also after stroke, in patients with aphasia. Interestingly, while the amount and type of overlap between the linguistic and

numerical cognitive systems within the human brain has not been defined yet (Dehaene, 1992 ; Gelman and Butterworth, 2005), the terminology related to the field of linguistics is used in models of numerical cognition. For instance, every model agrees that number transcoding processes involves a lexicon (basic numbers) and syntactic (transcoding) rules (Barrouillet, Camos, Perruchet, & Seron., 2004). However, it is still debated wether the number transcoding process involves a semantic path or not (Power and Dal Martello, 1997; Barrouillet et al., 2004 ; Verguts and Fias, 2006).

Regarding the debate found in numerical cognition research, which seeks to determine whether number transcoding involves the activation of a semantic path or not (Power and Dal Martello, 1997; Verguts and Fias, 2006), we believe that the distinction established between ‘lexicalized’ and ‘non-lexicalized’ numbers is relevant for that purpose. In particular, we assume that transcoding lexicalized numbers (e.g. 20) would activate a semantic path, while transcoding non-lexicalized numbers (e.g. 2563) would not. In addition, assuming that number lexicalization varies across languages as being dependent on their respective linguistic properties, the degree of semantic activation would also vary across languages during development. For instance, ‘nonante’ (‘ninety’) in Walloon would activate a semantic path in most children from second grade school but not ‘quatre-vingt-dix’ (‘four-twenty-ten’) in French. On the other hand and in certain circumstances, non-lexicalized numbers can also be lexicalized and thus, they would also activate a semantic path. For example, this is the case of complex numbers referring to historical dates, postcodes, phone numbers, date of birth, and so on. It turns out that the patient did not make transcoding mistakes on these numbers.

5. Conclusion

The data discussed in the present study revealed a strong influence of the linguistic characteristics of Basque and French verbal number systems on the production of Arabic digits under dictation, which would have never been observed if the patient

had been assessed in one language only. The fact that the patient was Basque-French bilingual and that each of these languages uses a specific verbal number system, distinct errors emerged from the same individual's assessment. Therefore, the assessment of number processing becomes highly relevant from a neurolinguistic perspective too. Basic arithmetic and transcoding tasks should be systematically included in aphasia batteries in order to determine the amount and type of overlap between the linguistic and numerical cognitive systems (De Luccia, G. and Ortiz, K.Z., 2016).

On the other hand and as a follow-up, it would be of particular interest to study the development of Basque-French and Basque-Spanish bilingual children's transcoding skills. Since these languages use different number systems, this would allow us to test the assumption adressed in the present study that number lexicalisation depends on a set of factors, which are mainly: i) the age of acquisition; ii) the language in which number transcoding rules are taught; iii) the linguistic properties of each verbal number system. Such studies will contribute to cross-cultural sociolinguistic and neurocognitive research development into number representation during childhood, which is a modern inquiry in numerical cognition research that speaks directly to our multilingual societies (Imbo, Vanden Bulcke, De Brawer and Fias, 2014; Towse, Muldoon, and Simms, 2014 ; Salillas, Barraza, Carreiras, 2015; VanRinsveld A., Brunner, M., Landerl, K., Schiltz, C., and Ugen S., 2015; Bonifacci, Tobia, Bernabini & Marzocchi, 2016).

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References

Barrouillet, P., Camos V., Perruchet, P., & Seron X. (2004). ADAPT: A Developmental, Asemantic, and Procedural Model for Transcoding From Verbal to Arabic Numerals. Psychological Review, 111(2), 3, 68-394

Bonifacci, P., Tobia, V., Bernabini, L., & Marzocchi, G. 402 M. (2016). Early Literacy and Numeracy Skills in Bilingual Minority Children: Toward a Relative Independence of Linguistic and Numerical Processing. Frontiers in Psychology, 7, 1020

Dehaene, S. (1992). Varieties of numerical abilities. Cognition, 44 (1-2):1-42

Deloche, G., Seron, X. and Ferrand, I. (1989) Reeducation of Number Transcoding Mechanisms: A Procedural Approach. *In X. Seron* and G. Deloche (Eds.), 49-87

De Luccia, G. and Ortiz, K.Z. (2016) Association between Aphasia and Acalculia: Analytical Cross-Sectional Study. International Journal of Clinical Medicine, 7, 1-9

Gelman, R. and B. Butterworth (2005). Number and language: how are they related? Trends in Cognitive Sciences 9(1): 6-10

Imbo, I., Vanden Bulcke, C., De Brauwer, J., and Fias, W. (2014). Sixty-four or four and-sixty? The influence of language and working memory on children's number transcoding. *Frontiers in Psychology*, *5*, 313, 1-10

Lopes-Silva, J. B., Moura, R., Júlio-Costa, A., Haase, V. G., & Wood, G. (2014). Phonemic awareness as a pathway to number transcoding. *Frontiers in Psychology*, *5*, 13

Miura, I. T., Okamoto, Y., Kim, C. C., Steere, M., & Fayol, M. (1993). First graders' cognitive representation of numbers and understanding of place value: Cross-national comparison—France, Japan, Korea, Sweden, and the United States. *Journal of Educational Psychology, 85,* 24–30.

Miura, I. T., Okamoto, Y., Kim, C. C., Steere, M., & Fayol, M. (1994). Comparisons of cognitive representation of number: China, France, Japan, Korea, Sweden, and the United States. *International Journal of Behavioral Development, 17,* 401–411.

Nespoulous, J-L., Lecours, A.R., Lafond, D., Lemay, A., Puel, M., Joanette, Y., Cot, F., A. Rascol., Béland, R. and Giroud, F. (1992) Protocole Montréal-Toulouse d'Examen Linguistique de l'Aphasie - Livret de Passation, 425 Version 1992, in *Les Protocoles Montréal-Toulouse : Neurolinguistique et Neuropsychologie*, Isbergues, L'Ortho-Edition, J-L Nespoulous, Y. Joanette and A.R. Lecours (Eds.)

Pourquié, M., (2016) A cross-linguistic behavioral study of agrammatism in Basque and French. In Faustino Diéguez Vide (Eds.), CS 35- Temas de Lingüística Clínica, 174-188

Power R. and Dal Martello, M., (1997) From 834 to Eighty Thirty Four: The Reading of Arabic Numerals by Seven-year-old Children, *Mathematical Cognition*, 3(1)

Seron, X. (2001). Introduction: Number and language processing. *Aphasiology, 15*, 629-633

Seron, X., Deloche G. (1984). From 2 to two: an analysis of a transcoding process by means of neuropsychological evidence. *Journal of Psycholinguistic Research*, 13, 215-36

Seron, X. and Fayol, M. (1994) Number Transcoding in Children: A functional analysis, *British Journal of Developmental Psychology*, 12, 281-300

Salillas E., Barraza P., and Carreiras M. (2015) Oscillatory Brain Activity Reveals Linguistic Prints in the Quantity Code. PLoS ONE 10(4)

Towse, J., Muldoon, K., and Simms, V. (2014). Figuring Out Children's Number Representations: Lessons from Cross-Cultural Work. *Oxford Handbooks Online,* 402-414

Van Rinsveld, A., Brunner, M., Landerl, K., Schiltz, C. and Ugen, S. (2015) The relation between language and arithmetic in bilinguals: insights from different stages of language acquisition. *Frontiers in Psychology*, 6(265)

Varley, R.A., Klessinger, N.J.C., Romanowski 448 C.A.J., and Siegal, M., (2005) Agrammatic but numerate, *PNAS*, 3519–3524

Verguts, T., and Fias, V. (2006) Lexical and syntactic structures in a connectionist model of reading multi-digit numbers. *Connection Science,* 18**,** 265-283

Appendix A : Basque and French number systems (SB= Standard Basque ; NL= Navarro Lapurdian)

	Basque	Literal translation	**French**	Literal translation
1	bat	*One*	un	*One*
2	bi	*Two*	deux	*Two*
3	hiru	*Three*	trois	*Three*
4	lau	*Four*	quatre	*Four*
5	bost	*Five*	cinq	*Five*
6	sei	*Six*	six	*Six*
7	zazpi	*Seven*	sept	*Seven*
8	zortzi	*Eight*	huit	*Eight*
9	bederatzi	*Nine*	neuf	*Nine*
10	hamar	*Ten*	dix	*Ten*
11	hamaika	*Eleven*	onze	*Eleven*
12	**hamabi**	***Ten-two***	douze	*Twelve*
13	**hamahiru**	***Ten-three***	treize	*Thirteen*
14	**hamalau**	***Ten-four***	quatorze	*Fourteen*
15	**hamabost**	***Ten-five***	quinze	*Fifteen*
16	**hamasei**	***Ten-six***	seize	*Sixteen*
17	**hamazazpi**	***Ten-seven***	**dix-sept**	***Ten-seven***
18	**hamazortzi**	***Ten-eight***	**dix-huit**	***Ten-eight***
19	**hemeretzi**	***Ten-nine***	**dix-neuf**	***Ten-nine***
20	**hogei**	*Twenty*	vingt	*Twenty*
30	**hogei-ta-hamar**	***Twenty-and-ten***	trente	*Thirty*
40	**berrogei**	***Two-twenty***	quarante	*Fourty*
50	**berrogei-ta-hamar**	***Two-twenty-and-ten***	cinquante	*Fifty*
60	**hirurogei**	***Three-twenty***	soixante	*Sixty*
70	**hirurogei-ta-hamar (SB)** **hirutan hogoi ta hamar (NL)**	***Three-twenty-and-ten*** ***Three times twenty and ten***	**soixante-dix**	***Sixty-ten***
80	**laurogei (SB)** **lautan hogoi (NL)**	***Four-twenty***	**quatre-vingts**	***Four-twenty***
90	**laurogei-ta-hamar (SB)** **lautan hogoi ta hamar (NL)**	***Four-twenty-and-ten*** ***Four times twenty and ten***	**quatre-vingt-dix**	***Four-twenty-ten***
100	ehun	*Hundred*	cent	*Hundred*
200	berrehun	*Two hundred*	deux cents	*Two hundred*
300	hirurehun	*Three hundred*	trois cents	*Three hundred*

400	laurehun	*Four hundred*	quatre cents	*Four hundred*
500	bostehun	*Five hundred*	cinq cents	*Five hundred*
600	seirehun	*Six hundred*	six cents	*Six hundred*
700	zazpirehun	*Seven hundred*	sept cents	*Seven hundred*
800	zortzirehun	*Eight hundred*	huit cents	*Eight hundred*
900	bederatzirehun	*Nine hundred*	neuf cents	*Nine hundred*
1000	mila	*A thousand*	mille	*A thousand*
200	bi mila	*Two thousand*	deux mille	*Two thousand*

Appendix B : Patient 1, 2 and control´s results in the four transcoding tasks (Fayol and Seron´s list)

	P1		P2		CONTROL	
COPY	FR	BSQ	FR	BSQ	FR	BSQ
/33	0	1	1	2	0	0
	0,00%	3,03%	3,03%	6,06%	0,00%	0,00%
DICTATION	27	31	3	6	0	0
/33	81,82%	93,94%	9,09%	18,18%	0,00%	0,00%
REPETITION	7	21	7	5	0	1
/33	21,21%	63,64%	21,21%	15,15%	0,00%	3,03%
READING	11	22	6	6	0	0
/33	33,33%	66,67%	18,18%	18,18%	0,00%	0,00%