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# Interaction between lexical and syntactic structures in transcoding from verbal to Arabic numerals

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**Keywords:** Numerical transcoding; number processing; number representation; network analysis.

## Abstract

We explore the relationship between the lexical structure and the syntactical structure of numerical expressions in number transcoding from the oral verbal format to the Arabic digital format. The experimental setup included asking six to eight-year old Spanish-speaking children attending elementary school to write in Arabic format a set of dictated numerals. The method of analysis includes the construction of a relational representation of children's production and the use of clustering techniques to identify patterns. The model relates children and dictated numerals by children's accomplishment and generates a subsidiary similitude relation between dictated numerals with patterns that show differentiated structures. We find that the presence or absence of a verbal expression for the Hundred position digit in the dictated numeral marks one of the structures. The second structure comes from the role of two digit numbers (e.g. 20 or 34): homogeneous in the Decade position and heterogeneous in the Thousand position. We interpret these results as consistent with the semantic-lexical internal number representation model by R.J.D. Power and M.F. Dal Martello, *The dictation of Italian numerals, Language and Cognitive Processes*, 5, 237-254; 1990.

## Introduction

McCloskey, Caramazza and Basili made in 1985 (McCloskey, Caramazza, & Basili, 1985) a pioneering proposal in adult neuropsychology of cognitive mechanisms in number processing and calculation. They posted the existence of a number comprehension mechanism, a number production mechanism and a calculation system with a numerical internal representation. The number comprehension mechanism translates a numerical input into the internal representation and the number production mechanism translates from the internal representation into the output format required. Comprehension and production mechanisms process both verbal and Arabic numerals and distinguish lexical-processing and syntactic-processing components. Lexical processing involves comprehension or production of individual elements in a number. Syntactic processing involves the relations among numerical elements

in order to comprehend or to produce a number as a whole. The number internal representation in this model is semantic-abstract, with numbers expressed in basic quantities associated to abstract forms of the base-10 representation (e.g.  $2 \times 10^1$  and  $5 \times 10^0$  for *twenty five*). The model specifies that the internal representation activates the syntactical production mechanism and that the highest power of ten in the central representation generates a syntactic frame with the appropriate number of slots or positions for the production of the Arabic numeral. This representation is independent of the structure of verbal representation. The semantic base-10 representation implies that the peculiarities of verbal stimulus do not exert any influence on the Arabic production mechanisms.

Number transcoding, defined as translating a numeral from one code to another one, has been used to explore number processing in impaired subjects and adolescents with mild retardation (Barrouillet, Camos, Perruchet & Seron, 2004; Granà, Lochy, Girelli, Seron, & Semenza, 2003; McCloskey, 1991; McCloskey & Caramazza, 1987; McCloskey *et al.*, 1985; McCloskey & Macaruso, 1995; Seron & Noël, 1995) and in groups of children (Barrouillet *et al.*, 2004; Power & Dal Martello, 1990; 1997; Seron & Fayol, 1994). From these works two main explanatory models for number processing in children arise: One proposes the existence of a semantic representation of numerical quantities, which can be either semantic-abstract (Macaruso, McCloskey & Aliminosa, 1993; McCloskey, 1991; McCloskey *et al.*, 1985) or semantic-lexical (Power & Dal Martello, 1990); the other perspective proposes an asemantic model where number processing results from assembling rules or algorithms (Deloche & Seron, 1982, 1987; Barrouillet *et al.*, 2004). Some models propose both routes.

In the semantic-lexical model posted by Power and Dal Martello (1990) working with children "the form of the representation reflects the structure of the subject's verbal numeral system." To these authors the internal representation is due to the interpretation of the verbal numeral and its internal structure tied to the verbal code. They propose sum and product structures as the main relationships between numerical concepts and, from the subject perspective, an overwriting rule for the sum operator and a concatenation rule for the product in Arabic

production. In this model a product relation produces numerals as 200 and 2000 from primitive numerical concepts as Ones, Teens, Tens and Hundred, and a sum relation to obtain composed numerals as 220, 2020, 20220. For Power and Dal Martello (1990) “Every non-primitive number is represented as the sum or product of two unequal numbers”. They show that syntactic errors, related to the numeral structure (e.g. 20045 for *two hundred forty five*), are more frequent than lexical errors related to the exchange of digits (e.g. 255 for *two hundred forty five*).

An asemantic model that predicts children production was developed by Barrouillet *et al.*, (2004), “ADAPT: A Developmental, Asemantic and Procedural Model for Transcoding from Verbal to Arabic Numerals”, with two versions: the basic (ADAPT<sup>BASIC</sup>) and the advanced (ADAPT<sup>ADV</sup>). The first version describes the transcoding process for numerals up to 99 and the second up to six digit numbers. The main proposal of the ADAPT<sup>BASIC</sup> model is that when a verbal string for transcoding corresponds to a representational unit stored in Long Term Memory (LTM), this string is processed as such, whereas its transcription is the result of the direct memory retrieval of its digital form. In the ADAPT<sup>ADV</sup> version, an algorithm is used to explain transcoding from the verbal numeral format to the Arabic digital format. For writing numerals the model assumes that the verbal expression is coded in a phonological code and analyzed by a parser. The results of the analysis are processing units that can be either elements whose digital transcription can be directly retrieved from LTM or separators, as Hundred and Thousand. These processing units trigger the transcoding rules that in a serial process generate either slots, digits or digit chains. (Barrouillet *et al.*, 2004)

The present work heads number processing by identifying patterns of relationship between the lexical (phonetic) structure of verbal expressions and one syntactical structure of the Arabic expressions in children’s production transcoding numbers from the oral verbal to the Arabic digital format. Our model includes a positional analysis using similarity, structural equivalence (Borgatti, Everett, Freeman, 2002; Johnson, 1967; Wasserman & Faust, 1994) and betweenness (Freeman, 1979; Girvan & Newman, 2002). The novelty of this analysis is the use of a relational representation children’s production. The most relevant findings are two syntactic structures: One pinned to the presence or absence of a verbal expression in the Hundred position of the dictated numeral, and other one which differentiates Decade forms (e.g. 20 or 70) and Decade-Unit forms (e.g. 34 or 76) when they are at Thousand position (e.g. 30.432 or 37.432).

## Method

In this section we present the experimental setup and the model of analysis used in this study.

## Participants

The experimental setup included the dictation of numerals to 207 children attending first, second and third grades of elementary school in Colombia. First grade children (65) were 6 years and 8.3 months old with standard deviation SD=2.9 months, second grade children (74) were 7 years and 7.0 months old (SD=3.0 months) and third grade children (68) were 8 years and 7.8 months old (SD=3.0 months).

## Experimental procedure

The experiment consisted of asking children to transcode a set of dictated numerals from the oral verbal format to the Arabic one. Numerals were dictated in Spanish in a 20-minute testing session to each child. Dictated numbers were of a higher order than those traditionally taught at the corresponding school grade. Four dictation lists with the same set of numbers were generated randomly in each grade and assigned randomly to each child. The set of numbers included all lexical and syntactic forms for three, four and five digit numerals in Arabic code. The notation used to classify numerals is: *a*, *b*, *c*, *d* and *e* letters which represent the digital forms different from zero and correspond to the basic quantities of the numeral in the Arabic format (ex. 3789 is *abcd*). In all of the cases *a* represents the highest order quantity of the Arabic format. The 0 digit represents a null quantity. We use *x* to represent either a basic or a null quantity.

## Method of analysis

Network analysis perspective uses graphs to represent and study complex systems in terms of relations between elements or parts. It gives a detailed account of structural and dynamical properties of systems by identifying patterns at the microscopic level and macroscopic phenomena. (Freeman, 2004; Wasserman & Faust, 1994)

Our model of analysis defines ties between numerals in terms of correlations in children’s production: Two numerals are tied with a strength equal to the number of children with production syntactically and lexically correct or incorrect for both numerals. The relation defined in this way does not have internal structure and therefore it is suitable for exploring elementary structures and patterns. As the relation expresses similarity, we use graph visual representations (Freeman, 2005), Johnson’s hierarchical clustering (Johnson, 1967), structural equivalence (Breiger, Boorman, & Arabie, 1975; Burt, 1976) and tie betweenness for cohesive subgroups (Girvan & Newman, 2002). These techniques have been implemented in computer codes as Netdraw (Borgatti, 2002) and UCINET (Borgatti, Everett & Freeman, 2002).

**Visual exploration:** Low dimensional graph representations of networks are often used to organize nodes and ties in landscapes where the location of a node is related to its actual location in the network. We use a spring embedded model with node repulsion, equal edge length and similitude

by geodesic distances. (Borgatti, 2002; Freeman, 2005; Wasserman & Faust, 1994)

**Proximity clustering:** Johnson's hierarchical clustering identifies clusters from correlations. (Borgatti, Everett, & Freeman, 2002; Johnson, 1967; Wasserman & Faust, 1994) It uses similarities or dissimilarities to find a series of nested partitions by departing from N partitions, each one with a node, and joining partitions in successive steps according to their relative distance from adding individual distances to other nodes.

**Structural equivalence:** Nodes with structurally equivalent positions in the network have identical relational profiles and are tied to the same nodes. We use two techniques to identify structural equivalence: Convergence of iterated correlations between profile vectors (CONCOR), based on Pearson's correlation (Borgatti, Everett, & Freeman, 2002; Breiger, Boorman, & Arabie, 1975; Lerner, 2005; Wasserman & Faust, 1994), and the Euclidean distance from each node to all other nodes (Borgatti, Everett, & Freeman, 2002; Burt, 1976; Wasserman & Faust, 1994).

**Clustering by tie betweenness:** Freeman (1979) defined betweenness centrality for a vertex or node as the number of shortest paths between any other two nodes passing by the node. Girvan and Newman (2002) extended this concept in order to identify cohesive subgroups by removing ties or links with the highest values of betweenness. This method relies on the fact that a tie linking two non-overlapping clusters must have the highest betweenness in the graph. In our analysis we combine successive weak strength and high betweenness ties removal to identify clusters.

## Results

The results from applying the selected analysis techniques to children's production are presented for each grade including frequency analysis, visual exploration, proximity clustering, structural equivalence and tie betweenness.

First grade children's production included 1.047 (44.7%) correct answers from 2.340 dictated numerals (36 numerals to 65 children). The highest frequency of correct answers was for naught numerals (40%), then for *a0c* (25%), *ab0* (18%) and *abc* (17%) numerals. Table 1. The mean of correct answers for child is 29 (SD 11); for naught numerals 47 (SD 6.5), *a0c* 29 (SD 2.5), *ab0* 21 (SD 2.6), and *abc* numerals 20 (SD 2.7). All clustering techniques confirm the existence of three subgroups: 1) *a00*; 2) *a0c*; 3) *ab0* and *abc*. Figure 1 shows the graph obtained with Netdraw (Borgatti, 2002). The ties between numerals in the graph have at least 53 children each. Shapes of nodes indicate numeral classification: *abc*, *ab0*, *a0c*, *a00*.

Second grade children's production included 1.613 correct answers from 4.366 dictated numerals (37.0%). The highest percentage of correct answers was for naught numerals (*a000*) (78.8%), then for *a00d* (49.9%), *ab00* (45.8%), *abc0* (39.7%), *abcd* (34.0%), *a0c0* (27.4%) and *a0cd* numerals (24.2%). See Table 1. The mean and standard deviation (SD) of correct answers per child are: for naught numerals 51.2 (SD 4.2), for *a00d* 32.4 (SD 3.8), for

*ab00* 29.5 (SD 1.4), for *abc0* 25.8 (SD 4.1), for *abcd* 22.1 (SD 3.2), for *ab0d* 19.8 (SD 4.1), for *a0c0* 17.8 (SD 1.8) and for *a0cd* numerals 15.7 (SD 3.1). Numbers with verbal expressions in the Hundred position (*abxx*) have 38.2% of correct answers and numbers without verbal expression in the Hundred position (*a0xx*) have 31.4%. For *abxx* numerals the mean of correct answers per child is 24.8 (SD 4.5) and for *a0cx* numerals 16.4 (SD 2.5).

Table 1: Frequency of correct answers

FIRST GRADE				SECOND GRADE					
100	60	246	25	1000	61	8190	29	3452	20
200	51	240	24	2000	53	1524	28	8367	19
500	49	450	24	4000	52	6900	28	9070	19
300	48	198	23	6000	51	7009	28	3402	18
400	46	810	23	3000	50	7800	28	4030	18
600	43	980	22	5000	50	4730	27	4031	18
700	43	367	21	8000	50	9600	27	6080	18
800	40	190	20	7000	48	6980	26	7019	18
900	39	452	20	9000	46	9670	26	8090	18
603	32	524	19	2008	40	2198	24	1024	17
307	31	730	19	1004	35	1504	23	4731	17
504	31	731	19	8100	32	6985	23	7809	17
809	31	985	19	8300	31	7819	23	3052	16
402	30	360	18	1500	30	8197	23	5040	16
905	29	520	18	2100	30	9673	23	9073	15
108	26	670	18	3002	30	5240	21	2098	13
206	26	819	18	4700	30	5246	21	5046	13
701	26	673	16	5200	30	6085	21	8067	13
				3400	29	8307	21	8097	13
				8007	29	2108	20		

THIRD GRADE					
40000	50	19603	39	90307	35
50000	50	40985	39	73450	34
20000	48	60819	39	10673	33
10000	47	67819	39	20031	33
70000	47	73400	39	60809	32
30000	46	98307	39	73452	32
52198	45	52190	38	70452	31
80000	45	70450	38	46085	30
20731	44	80524	38	35040	29
50190	44	81524	38	40085	29
52100	44	90367	38	30046	28
24731	42	10603	36	24030	27
50198	42	35246	36	46080	27
90000	42	46985	36	19003	25
60000	41	67809	36	24031	25
81500	41	19673	35	35046	25
30246	40	80520	35	67009	23
98367	40	81520	35	98007	23

Frequency analysis, Johnson's hierarchical clustering, structural equivalence from Euclidean distances and tie betweenness indicates the existence of four main subgroups: Naught numerals, *a00d*, *a0cx*; and *abxx* numerals. However, structural equivalence from CONCOR gives four subgroups: two for naught numerals (one containing *3000*, *6000*, *8000* and *9000*), one for *a0xx* and one for *abxx* numerals. Results from CONCOR have to be considered because the main ability of this technique is to recognize

patterns. Figure 2 shows the graph obtained with Netdraw (Borgatti, 2002). The ties between numerals in the graph have at least 55 children each. Shapes of nodes indicate numeral classification: *abcd*, *abc0*, *ab0d*, *ab00*, *a0cd*, *a0c0*, *a00d*, *a000*.

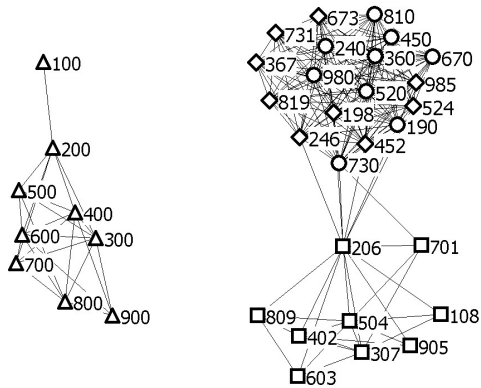


Figure 1: Graph for the relation between numerals in first grade children's productions.

Third grade children's production included 1.992 correct answers from 3.672 dictated numerals (54.3%). The highest achievement was for naught numerals (*a0000*) (73.8%). Numerals with verbal expression in the Hundred position (*axcxx*) are more frequently correct (55.8%) than numerals without verbal expression on this position (*ax0xx*) (39.7%), excluding naught numerals. The mean of correct answers per child for *axcxx* numerals is 38.2 with SD 3.8 and for *ax0xx* is 27.9 with SD 3.3. (See Table 1)

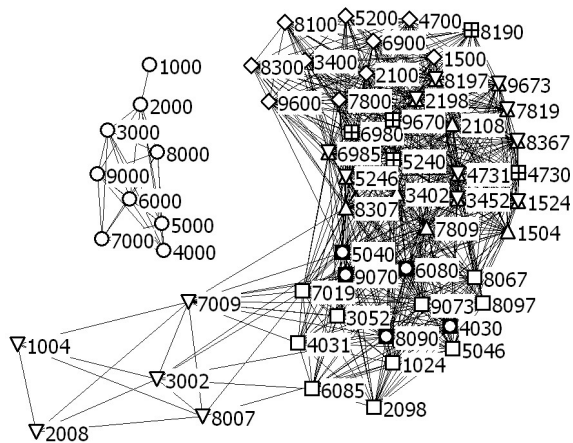


Figure 2: Graph for the relation between numerals in second grade children's productions.

Frequency analysis, visual exploration (Figure 3), Johnson's hierarchical clustering, structural equivalence from Euclidean distances and tie betweenness are consistent with the existence of three main subgroups: Naught numerals, *ax0xx* and *axcxx* numerals. Structural equivalence from CONCOR gives six subgroups: Naught numerals excluding 60000; *ax0xx* excluding naught numerals; *axcxx* excluding 90307, 24731 and 35246; 90307; 60000 and

24731; and 35246 (See Table 2). This classification is consistent with a differentiation between *axcxx* and *ax0xx* numerals.

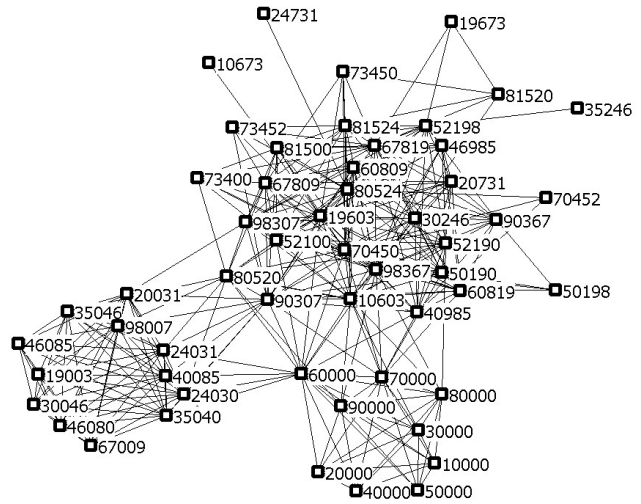


Figure 3: Graph for the relation between numerals in third grade children's productions.

Table 2: Numeral clustering for third grade.

Numeral	Johnson	CONCOR	Euclidean	Betweenness	Numeral	Johnson	CONCOR	Euclidean	Betweenness	Numeral	Johnson	CONCOR	Euclidean	Betweenness
10000	1	1	1	1	10603	3	3	3	3	19003	2	2	2	2
20000	1	1	1	1	60809	3	3	3	3	67009	2	2	2	2
30000	1	1	1	1	30000	1	1	1	1	98007	2	2	2	2
40000	1	1	1	1	40000	1	1	1	1	24030	2	2	2	2
50000	1	1	1	1	50000	1	1	1	1	35040	2	2	2	2
60000	1	5	1	1	60000	1	5	1	1	46080	2	2	2	2
70000	1	1	1	1	70000	1	1	1	1	24031	2	2	2	2
80000	1	1	1	1	80000	1	1	1	1	35046	2	2	2	2
90000	1	1	1	1	90000	1	1	1	1	46085	2	2	2	2
20031	2	2	2	2	20031	2	2	2	2	52100	3	4	3	3
30046	2	2	2	2	30046	2	2	2	2	73400	3	4	3	3
40085	2	2	2	2	40085	2	2	2	2	50198	3	3	3	3
					60819	3	3	3	3	81500	3	4	3	3
					70452	3	3	3	3	19603	3	4	3	3
					80524	3	3	3	3	67809	3	4	3	3
					90367	3	3	3	3	98307	3	4	3	3
										52190	3	4	3	3
										73450	3	4	3	3
										81520	3	4	3	4
										19673	3	4	3	4
										24731	3	6	5	4
										35246	3	7	3	4
										46985	3	4	3	3
										52198	3	4	3	3
										67819	3	4	3	3
										73452	3	4	3	3
										81524	3	4	3	3
										98367	3	4	3	3

## Discussion

First grade results show the existence of three subgroups of numerals in children's production: naught numerals, *a0c* and *abx* numerals. None of the analysis techniques shows any internal structure in the subgroups indicating that each one is homogeneous. Power & Dal Martello (1990) also

found differences in children's production between numerals ending in *00* (*a00*), numerals with internal zero (*a0c*), and numerals without internal zero (*ab0*, *abc*). Seron and Fayol (1994) predicted the following order of acquisition  $a00 > a0c > abc = ab0$ . They did not find other significant difference between the proposed forms. Their results are consistent with a higher frequency of errors for *ab0* and *abc* numerals than for *a0c* numerals. For Barrouillet *et al.*, (2004) the Decade-Unit form (*bc*) in *abc* numerals and the Decade form (*b0*) in *ab0* numerals are retrieved from LTM as representational units and the error rate did not present any significant difference between the two forms in three and four digit numbers. In our results *ab0* and *abc* numerals are both similar and equivalent.

For second grade, results indicate the existence of four main subgroups: 1) naught numerals, 2) *a00d*, 3) *a0cx*, and 4) *abxx*. One clustering technique, CONCOR, indicates that *a00c* and *a0cx* numerals should belong to the same subgroup, in agreement with Figure 2. Additionally, in our study the *a00d* numeral with the highest rate of correct answers was *2008*, which has the same structure as the number of the year when the experimental testing was done. We consider that this fact might have influenced the production of *a00d* numerals.

We interpret these results as that the presence or absence of a verbal expression in the Hundred position of the dictated numeral determines the digital production. In the case of Spanish, three types of expressions are assigned to the Hundred verbal expression: *cien* for one hundred, *quinientos* for five hundred and *cientos* accompanied by a prefix in all other cases as in *treientos* for three hundred. Note that *a1xx* numerals were more frequently correct than *abxx* ones (Table 1.).

An important difference between our results and Barrouillet *et al.*, (2004) is that they found higher rates of errors for the Unit form *0d* in *ax0d* than for the Decade form *c0* in *axc0* and the Decade-Unit for *cd* in *axcd*. Our results indicate the opposite situation in agreement with Power and Dal Martello (1990) and Seron and Fayol (1994).

In third grade production frequency analysis, visual exploration, Johnson's hierarchical clustering, structural equivalence and tie betweenness indicate the existence of three main subgroups: Naught numerals, *ax0xx* excluding naught numerals, and *axcxx* numerals. Note that *ax1xx* numerals were more frequently correct than *abxx* ones (Table 1.). Additionally, *ab00e* numerals obtained the lowest frequency of correct answers, in contrast with *a00d* numerals that obtained a high frequency in second grade children's production.

However, CONCOR neatly differentiates between *abcxx* and *a0cxx* numerals. This result is not consistent with Barrouillet *et al.*, (2004) proposal for Decade-Unit and Decade forms as being retrieved directly from LTM. Instead, it might be explained by considering that the difference between these forms is the number of operations for their construction (one product for Decade forms and one product and one sum for Decade-Unit forms), as

proposed by Barrouillet *et al.*, (2004) for complex Decade forms in French (e.g. *soixante-dix* for seventy and *quatre-vingt-dix* for ninety) or by Power and Dal Martello (1990).

## Conclusions

First, the presence or absence of a verbal expression in the Hundred position of dictated four and five digit numerals generate differentiated structures in children's written production. This result indicates that the lexical (phonetic) structure in the oral verbal format interacts with the syntactic structure of Arabic digits in children's production in number transcoding.

Secondly, the difference found between *abcxx* and *a0cxx* numerals in children's production calls for new explicative efforts.

Finally, the method of analysis used gives valuable information that can not be obtained from frequency analysis or simple statistics.

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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), 368-394.
- Borgatti, S. P. (2002). *NetDraw: Graph Visualization Software*. Harvard, MA: Analytic Technologies.
- Borgatti, S.P., Everett, M.G., & Freeman, L.C. (2002). *Ucinet for windows: Software for Social Network Analysis*. Harvard, MA: Analytic Technologies.
- Breiger R., Boorman S., & Arabie P. (1975). An algorithm for clustering relational data, with applications to social network analysis and comparison with multi-dimensional scaling. *Journal of Mathematical Psychology*, 12, 328-383.
- Burt, R. (1976). Positions in Networks. *Social Forces*, 55, 93-122.
- Deloche, G., & Seron, X. (1982). From Three to 3: A differential analysis of skills in transcoding quantities between patients with Broca's and Wernicke's aphasia. *Brain*, 105, 719-733.
- Deloche, G., & Seron, X. (1987). Numerical transcoding: A general production model. In G. Deloche & X. Seron (Eds.), *Mathematical disabilities: A cognitive neuropsychological perspective*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Freeman, L. C. (1979). Centrality in Social Networks: Conceptual Clarification. *Social Networks*, 1, 215-239.
- Freeman, L.C. (2004). *The development of Social Network Analysis. A study in the sociology of science*. Vancouver: Empirical press.

- Freeman, L.C. (2005). Graphic techniques for exploring social network data. In S. Wasserman, J. Scott and P. J. Carrington (Eds.) *Models and methods in social network analysis*. Cambridge, UK: Cambridge University Press.
- Girvan, M., & Newman, M. E. (2002). Community structure in social and biological networks. *Proc. Natl. Accad. Sci. USA* 99, 7821-7826.
- Granà, A., Lochy, A., Girelli, L., Seron, X., & Semenza, C. (2003) Transcoding zeros within complex numerals. *Neuropsychologia*, 41, 1611-1618.
- Johnson, S. C. (1967) Hierarchical clustering schemes. *Psychometrika*, 32, 241-253.
- Lerner, J. (2005) Role assignments. In Brandes, U., & Erlebach, T. (2005). *Network Analysis: Methodological Foundations*. Lecture Notes in Computer Science. Tutorial. Berlin: Springer-Verlag.
- Lochy, A., Pillon, A., Zesiger, P., & Seron, X. (2002) Verbal structure of numerals and digits handwriting: New evidence from kinematics. *The quarterly Journal of Experimental Psychology*, 55A (1), 263-288.
- Macaruso, P., McCloskey, M., & Aliminosa, D. (1993). The Functional Architecture of the Cognitive Numerical-processing System: Evidence from a Patient with Multiple Impairments. *Cognitive Neuropsychology*, 10(4), 341-376.
- McCloskey, M. (1991). Cognitive mechanisms in numerical processing: Evidence from acquired dyscalculia. *Cognition* 44, 107-157.
- McCloskey, M., & Caramazza, A. (1987). Cognitive mechanisms in normal and impaired number processing. In G. Deloche & X. Seron (Eds.) *Mathematical disabilities: A cognitive neuropsychological perspective*. Hillsdale, NJ: Erlbaum.
- McCloskey, M., Caramazza, A., & Basili, A. (1985). Cognitive mechanism in number processing and calculation: Evidence from dyscalculia. *Brian and Cognition*, 4, 171-196.
- McCloskey, M. & Macaruso, P. (1995). Representing and using numerical information. *American Psychologist*, 50, 331-363.
- Noël, M. P., & Seron, X. (1995). Lexicalization errors in writing Arabic numerals: A single case study. *Brain and Cognition*, 29, 151-179.
- Power, R. J. D., & Dal Martello, M. F. (1990). The dictation of Italian numerals. *Language and Cognitive Processes*, 5, 237-254.
- Power, R. J. D., & Dal Martello, M. F. (1997). From 834 to Eighty Thirty four: The reading of the Arabic numerals for Seven-years-old children. *Mathematical Cognition*, 3(1), 63-85.
- Seron, X., & Fayol, M. (1994). Number transcoding in children: A functional analysis. *British Journal of Developmental Psychology*, 12, 281-300.
- Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge: Cambridge University Press.