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

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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. $2x10^1$ and $5x10^0$ 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, *a*nd 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 ($\text{ADAPT}^{\text{BASIC}}$) and the advanced ($\text{ADAPT}^{\text{ADV}}$). 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 $\text{ADAPT}^{\text{BASIC}}$ 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 $\text{ADAPT}^{\text{ADV}}$ 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, Everet, 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 pined 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, for 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			
100	60	*246*	25
200	51	*240*	24
500	49	*450*	24
300	48	*198*	23
400	46	*810*	23
600	43	*980*	22
700	43	*367*	21
800	40	*190*	20
900	39	*452*	20
603	32	*524*	19
307	31	*730*	19
504	31	*731*	19
809	31	*985*	19
402	30	*360*	18
905	29	*520*	18
108	26	*670*	18
206	26	*819*	18
701	26	*673*	16

SECOND GRADE					
1000	61	*8190*	29	*3452*	20
2000	53	*1524*	28	*8367*	19
4000	52	*6900*	28	*9070*	19
6000	51	*7009*	28	*3402*	18
3000	50	*7800*	28	*4030*	18
5000	50	*4730*	27	*4031*	18
8000	50	*9600*	27	*6080*	18
7000	48	*6980*	26	*7019*	18
9000	46	*9670*	26	*8090*	18
2008	40	*2198*	24	*1024*	17
1004	35	*1504*	23	*4731*	17
8100	32	*6985*	23	*7809*	17
8300	31	*7819*	23	*3052*	16
1500	30	*8197*	23	*5040*	16
2100	30	*9673*	23	*9073*	15
3002	30	*5240*	21	*2098*	13
4700	30	*5246*	21	*5046*	13
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 bewteenness 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*.

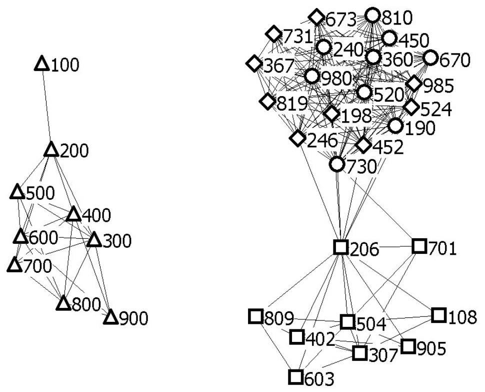

Figure 1: Graph for the relation between numerals in first grade children's productions.

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)

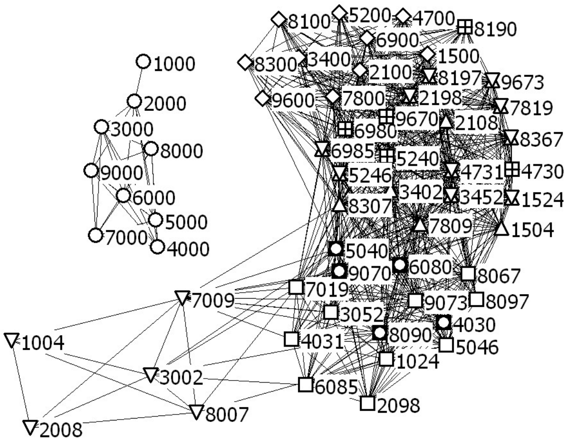

Figure 2: Graph for the relation between numerals in second grade children's productions.

Frequency analysis, visual exploration (Figure 3), Johnson's hierarchical clustering, structural equivalence from Euclidean distances and tie betweeness 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.

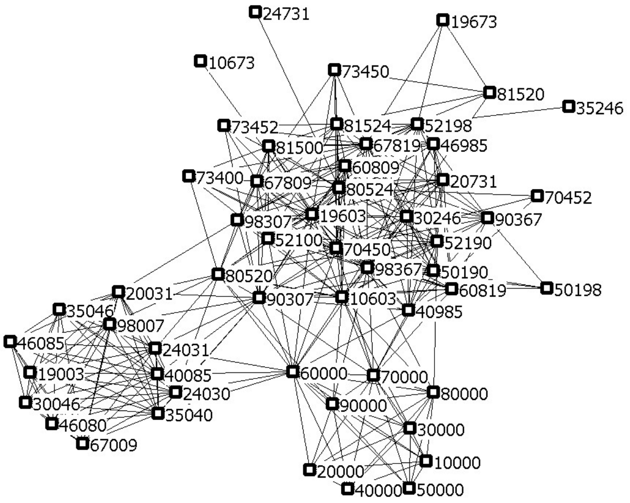

Figure 3: Graph for the relation between numerals in third grade children's productions.

Table 2: Numeral clustering for third grade.

Numeral	Johnson	CONCOR	Euclidean	Betweenness
10000	1	1	1	1
20000	1	1	1	1
30000	1	1	1	1
40000	1	1	1	1
50000	1	1	1	1
60000	1	5	1	1
70000	1	1	1	1
80000	1	1	1	1
90000	1	1	1	1
20031	2	2	2	2
30046	2	2	2	2
40085	2	2	2	2
10603	3	3	3	3
60809	3	3	3	3
90307	3	5	3	3
50190	3	3	4	3
70450	3	3	3	3
80520	3	3	3	3
10673	3	3	3	4
20731	3	3	3	3
30246	3	3	3	3
40985	3	3	3	3
50198	3	3	4	3
60819	3	3	3	3
70452	3	3	3	3
80524	3	3	3	3
90367	3	3	3	3
19003	2	2	2	2
67009	2	2	2	2
98007	2	2	2	2
24030	2	2	2	2
35040	2	2	2	2
46080	2	2	2	2
24031	2	2	2	2
35046	2	2	2	2
46085	2	2	2	2
52100	3	4	3	3
73400	3	4	3	3
81500	3	4	3	3
19603	3	4	3	3
67809	3	4	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 *trecientos* 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 *axbxx* 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. *Neuropsicología*, 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.