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# The roles of punctuation marks while learning about written numbers

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**Abstract** Twenty-three kindergarten and first grade children were asked to articulate the meaning and the need for punctuation marks in a list of numerals showing prices for a list of items. Despite not having been schooled yet formally on the use and roles of numerical punctuation, many children gave similar explanations regarding the purpose of punctuation marks in numerals, including: to separate, to mark the type of number (e.g., price), to denote value, to make it a different number, and to read the number differently. Each of these explanations is a partial description of the conventional use of these marks within written numbers. These findings provide evidence that children are, in fact, creating and recreating ideas about different aspects of written numbers such as the role of punctuation marks before necessarily being able to fully articulate how written numbers work and before being formally taught, though they have obviously been exposed from an early age to these particular aspects of written numbers.

**Keywords** Written numbers · Written number system · Punctuation marks · Young children

## 1 Introduction

This paper explores young children's reflections regarding the roles of punctuation marks within written numbers. These minuscule marks on paper hold great meaning and utility. Consider the confusion that could arise from leaving out a decimal point, reporting a price on an item in a store as 991 as opposed to 9.91. Further, consider the relative simplicity of

In keeping with the context in which the interviews reported in this paper occurred (in the United States of America [USA]), unless otherwise noted, throughout this paper we consider commas as marking place value within whole numbers (in some other countries, this role is taken up by periods) and periods as marking a separation between whole numbers and decimal fractions (in some other countries, this role is taken up by commas). This research was carried out through the support of Tufts University's Faculty Research Award Committee (FRAC) program. Angie Collins, McKinne Dunn, Anja Pearson, and Patty Chen assisted in the data collection, analysis, and manuscript preparation.

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being able to order numbers knowing their place value through the added information provided by a comma. Judge, for instance, the difference between seeing the numeral[1] 1000000000 or 1,000,000,000. The placement of the commas allows us to easily group sets of digits, quickly provide a verbal description for the numeral, and compare different written numbers with relative simplicity.

Punctuation marks are an integral part of written numbers. However, the dearth of research on children's learning of them within written numbers (as opposed to children's learning and understanding of punctuation marks within written language) leads to many questions: why are we not paying attention to them? What are children's ideas about these marks? How do children understand their role and how do they use them? In this paper we will argue that understanding children's spontaneous ideas about these marks can prove enlightening for understanding their developing numeracy. Children encounter and interact with these marks within written numbers on a regular basis. We wonder, therefore, what children think about them and how they appropriate them. In terms of children's cognition and instruction more generally, exploring and understanding children's ideas about the roles of punctuation marks in numerals could present us with the groundwork from which to design teaching situations and didactic sequences that take into account children's nascent, developing, and spontaneous ideas and understandings. It is not news that "the central task of a constructivist theory of learning is to establish, at a fine grain of detail, how novice knowledge systems" work (Smith, diSessa, & Roschelle 1993–1994, p. 138), and that "prior knowledge is the primary resource for acquiring new knowledge" (p. 151). Further, we have been urged to "encourage students to express their beliefs, keeping in mind that deviations provide precious opportunities for us to glimpse the students' perspectives" (Confrey 1991, p. 122) and to reflect on the following: "apparent errors, discrepancies from the observer's expectations, provide particularly useful opportunities for one to imagine what a student's problematic might be like... in examining students' problems and methods of solution, one has an opportunity to reconsider the mathematics involved" (p. 137). Our descriptions in this paper of children's ideas about punctuation marks in written numbers address this need to know what perspectives and beliefs children already have, before receiving any formal instruction, to understand connections to their own uses of these marks and to their later understandings, and to design teaching interventions that respond to these ideas.

In the area of written language, there has been considerable research both on children's construction and use of punctuation marks, as well as on children's reflections regarding the roles of punctuation marks (e.g., Cazden, Cordeiro, & Giacobbe 1985; Cordeiro 1988; Cordeiro, Giacobbe, & Cazden 1983; Edelsky 1983; Ferreiro and Pontecorvo 1999; Ferreiro, Pontecorvo, Ribeiro Moreiro, & Garcia Hidalgo 1996; Ferreiro and Zucchermaglio 1996). In the area of written numbers, we are far behind in this realm, even though these marks are important and frequently used.

Even though these marks are not part of the explicit mathematics curriculum that young children are exposed to (i.e., children in Kindergarten and first grade, such as those included in this study, are not explicitly taught about the roles and uses of these marks within numerals in the USA), what kinds of ideas do they have about their use? In initial explorations, we have found that young children do in fact use these marks spontaneously,

[1] Throughout this paper, we will use "written numbers" and "numerals" as synonyms.

and reflect on their role. Thomas, a six-year-old Kindergarten student in the USA (see Brizuela 2004), referred to punctuation marks that he included spontaneously in written numbers as organizing "*batches*" of digits. For Thomas, these batches were groups of three digits. In his use and reflections about punctuation marks, Thomas highlighted how these marks can help us to organize numerals and interpret the different positions occupied by digits. Thomas also highlighted, in interviews, how the marks helped him to know how to read and interpret numbers. In his case, it facilitated comparisons among written numbers and the interpretation of those written numbers. This is added justification for the relevance of this study and paper: we have anecdotal evidence that children think about and use these marks spontaneously, but we do not know what these children think about them or how they use them in any systematic or detailed way.

The theoretical grounding for this research is provided by Piagetian and constructivist research that focuses on the one hand on unearthing children's spontaneous ideas about different phenomena, finding them to be guides not only for children's own ways of thinking but also for us as educators and researchers (e.g., Confrey 1991; Ferreiro 1986; Smith, diSessa, & Roschelle 1993–1994; Vergnaud 1988), and focuses on the other hand on children's construction of conventional symbolic systems, taken as cultural objects that children interact with on a daily basis and gradually reconstruct (e.g., Brizuela 2004; Ferreiro 1996; Ferreiro and Teberosky 1979; Sinclair 1988; Sinclair and Scheuer 1993; Sinclair and Sinclair 1983, 1984).

The specific investigation described in this paper is inscribed within a line of research that has documented children's uses and understandings of written numbers and the written number system, such as that developed by Scheuer and Anne and Hermine Sinclair (e.g., Scheuer 1996; Scheuer, Merlo de Rivas, & Tieche-Christinat 2000; Sinclair 1988; Sinclair and Scheuer 1993; Sinclair et al. 1983; Sinclair and Sinclair 1984; Sinclair and Tieche-Christinat 1992). This research has shown that children's appropriation of written numbers is a constructive process, in which children develop their own ideas, which are many times surprising to adults. In addition, it is theoretically close to work developed by Alvarado (e.g., 2002; Alvarado and Ferreiro 2000, 2002), who has documented children's original construction of written numbers. Alvarado's research provides evidence for children's attempts to create their own logic regarding the number system, showing children who use zeros to stand in for parts of two-digit numbers they are not sure of how to represent, or rotating digits in the tens place of a number, but not in the units place, to indicate a different value for the digit. All of this research has originally been inspired by that of Ferreiro (e.g., 1986; Ferreiro and Teberosky 1979) in the area of written language. In this work, Ferreiro first documented children's constructive appropriation of written language and the hypotheses they develop for how written language "works."

Our research on children's reflections regarding the role of punctuation marks clearly acknowledges that these are a part of the cultural repertoire of conventional symbols that children interact with. Given that children interact with these spontaneously from an early age, should we not pay more attention to the way in which children use and interpret them? As recognized by Ferreiro some time ago, the fact that these marks are "cultural objects" does not preclude their construction and gradual appropriation (Ferreiro 1996).

This paper addresses two research questions:

- How do young children interpret punctuation marks (i.e., commas and periods) within written numbers?
- What role do young children ascribe to these marks within written numbers?

## 2 The constructive appropriation of written numbers and the numerical writing system

Given that we are focusing on punctuation marks *within written numbers*, it is important for us to clarify what we know about children's appropriation of written numbers and the numerical writing system (NWS)[2]. Research has shown this appropriation process not to be automatic; it is a gradual process. There is a progression in the types of notations children use when they represent quantities (e. g., Hughes 1986; Sastre and Moreno 1976; Sinclair 1988; Sinclair and Scheuer 1993; Sinclair and Sinclair 1984). In appropriating the NWS, children need not only to appropriate the conventional forms for numbers, but also the logic that underlies the relationships among the written numbers in the system. The written number system has a logic and rules of its own (Ferreiro and Teberosky 1979; Martí 2003; Martí and Pozo 2000). Children's interactions with the rules and logic, and their re-creation of them, occur whether or not their understandings of written numbers and the NWS are conventional, and whether or not we pay attention to these interactions or children's recreations.

Children's understandings about written numbers and the NWS need not be fully developed or conventional in order for them to develop representations for these understandings. Furthermore, there exists an interaction between both processes, as the notations being constructed have an impact on the concepts and meanings being constructed, and vice versa. This position is reflected by Nunes and Bryant (1996) and by Cobb (2000), who refer to the relationship between symbol use and mathematical meaning as reflexive (a position also shared, more generally, by Olson 1994 and Uttal 2000). Previous proof for a gradual, constructive process in the realm of written numbers and the NWS, such as that described above, provides an added rationale for the importance of looking closely at children's nascent ideas about different aspects of written numbers and the NWS, such as punctuation marks.

While interacting with conventional external representations, such as punctuation marks withinwritten numbers, children develop hypotheses, theorems, or theories[3] for how they function. These hypothesis, theorems, or theories are partial views of a larger and more complex phenomenon that children cannot totally grasp, although they are gradually approximating it (e.g., Ferreiro and Teberosky 1979; Smith et al. 1993–1994). In this paper we explore what hypotheses, theorems, or theories children hold about punctuation marks within written numbers.

[2] Throughout this paper, we will distinguish between "written numbers" and the NWS. Written numbers will be considered elements of the NWS. In turn, the NWS is comprised of those elements as well as the relations among those elements.

[3] Theorems-in-action have been described as "mathematical relationships that are taken into account by students when they choose an operation or a sequence of operations to solve a problem" (Vergnaud 1988, p. 144), which are usually not expressed verbally, most of them are not explicit, and they may even be wrong. Other researchers have referred to these as hypotheses (Ferreiro 1986) or theories (Karmiloff-Smith and Inhelder 1974). Ferreiro (1986) has used the term "hypothesis" to refer broadly to ideas or systems of ideas constructed by children to explain the nature and way of functioning of written language as an object of knowledge.

## 3 Punctuation marks, the numerical writing system, and written numbers

How do punctuation marks relate and connect to the NWS? The NWS has two main features that define how it works: base ten and place value. There are a finite quantity of elements that comprise the system (ten elements, namely: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9), and these elements can be found, at times, occupying different positions in the written number. Given that these ten elements in the system do not change in terms of their figurative presentation (i.e., in terms of their orientation, size, or thickness), the elements acquire different values depending on the position they occupy within the numeral. In contrast to the NWS, in the alphabetic writing system (AWS), the figurative appearance of letters can be changed by making them upper or lower case, italicised, underlined, or bold, for instance.

It is in facing the complexity of determining place value and the decimal number system that young children can come to use commas and periods within written numbers. If children deal only with *whole* numbers below one thousand, they will not need to deal with these punctuation marks. While whole numbers do not change meaning if one does not use punctuation, these marks do make the numerals easier to read and organize mentally. Punctuation marks within whole numbers also occasionally change pronunciation (1,200 is one thousand two hundred while 1200 might be read as twelve hundred). These differing placements of punctuation marks can also lead to differing conceptualizations regarding numbers – do children think of twelve hundred and one thousand two hundred as being equivalent in some dimension?

Punctuation can also be expected or required depending on the context. For instance, in the sciences we often speak of *significant digits* as representing the exactness of a measurement. This kind of *requirement* also comes up in dealing with punctuation in written numbers in daily life: currency, where a decimal point followed by two digits is both standard and often considered necessary, as indicating how many cents something is worth. This will be especially important given the context of prices that was used in the interviews reported in this paper. In the case of decimal fractions – including the cents part of a price – the punctuation marks clearly separate parts and types of numbers (i.e., dollars from cents, whole numbers from decimal fractions).

Historical analyses of the development of numerical notations highlight the introduction of punctuation marks within numerals for two distinct uses: (1) to group digits in numeration; and (2) for marking or separating the whole and decimal parts of numerals (Cajori 1928). Cajori explains, for instance, that, "in the writing of numbers containing many digits it is desirable to have some symbol separating the numbers into groups of, say, three digits" (p. 57).

In terms of specific marks, the various symbols used throughout the history of numerical notations to group digits have been, most frequently, periods, commas, dots, vertical bars, arcs, colons, and semi-colons. Remnants of these practices are observed contemporarily in different countries' usage of different punctuation marks for different purposes (for instance, to separate groups of three digits within whole numbers, commas are used in the USA and periods are used in some other countries. To separate whole numbers from decimal fractions, periods are used in the USA and commas are used in some other countries).

## 4 Role of commas and periods and their relationship to the NWS

As mentioned, historically, the specific mark used has varied and has been arbitrary – the important issue was to produce a mark, not what particular mark to make. Similarly, the specific mark used nowadays in written numbers and by children is not of relevance to us – whether it is a comma, a period, a hyphen, a space, or a semi-colon. What is relevant to us is the role that these marks acquire. Similar to their historical emergence, nowadays there are two roles for commas and periods in numerals: to stress place value (what historically Cajori called separating numbers into groups of digits), and to separate whole numbers and decimal fractions.

### 4.1 Marks used for stressing place value

The mark used for stressing place value – that is, to separate digits in the whole number part of the numeral into groups of three – is not essential to the NWS. The presence or absence of this mark in the numeral *does not alter meaning*. Whether we write 1000 or 1,000, we still know we are referring to one thousand, for instance.

### 4.2 Marks used for separating whole numbers and decimal fractions

The second mark we focus on, however, *is* essential to the NWS. The mark separating whole numbers from decimal fractions *profoundly alters meaning*. The absence of this mark turns a numeral into a different one. If we write 9.75 (nine seventy-five), there is a whole quantity nine plus a fractional quantity of seventy-five hundredths. If we write instead 975 (nine hundred seventy-five), there is a whole quantity nine hundred seventy-five.

## 5 Status of punctuation marks within the NWS

Lee and Karmiloff-Smith (1996) argue that external representations include writing, numerical notations, drawings, maps, and any form of graphic marks created intentionally. These kinds of external representations are characterized by having an existence independent of their creator, having a material existence that guarantees their permanence, and constituting organized systems. According to Martí and Pozo (2000), in order to be considered a system, there must at least be a relationship between a graphic mark and what it represents. Nemirovsky (1994) further adds that a symbol system has a set of rules that govern its functioning.

The two marks we deal with in this paper have different roles within the NWS. We consider that the mark that separates whole numbers from decimal fractions *is* an integral part of the NWS, as its presence/absence alters the meaning of the numeral. We consider the mark used to highlight place value, however, an autonomous subsystem that does not affect the meaning of the numerals themselves: there are a set of rules (in Nemirovsky's 1994 sense) that govern the functioning of this mark (for instance, we need to place these marks every three digits starting from the units place of the numeral or right-most end of the numeral and moving towards the left-most end of the numeral), but, as mentioned, their presence/absence does not affect the value and meaning of the numerals themselves. Their presence *facilitates, but does not alter, interpretation*.

The relationship with the NWS of the mark that stresses place value in numerals is parallel to the status that Ferreiro and Zucchermaglio (1996) ascribe to punctuation marks in the alphabetic writing system (AWS). In this sense, these authors state that,

> Punctuation marks introduce graphic elements that are alien to the main principles of an alphabetic writing system. Children must deal with them as an autonomous subsystem that does not affect the letters themselves (except in the distribution of lower and capital forms of the letters). (p. 179)

## 6 Summary

Investigations within written language highlight how much we have ahead of us fully to comprehend and articulate the particular uses, understandings, and processes that children go through while they are learning and appropriating punctuation marks within written numbers. Within written language, these marks are equally small; as in written numbers, they hold great meaning and utility. In this realm, they have received considerable attention and research has focused for many years on their appropriation and learning by children, including children's reflections regarding their roles (e.g., Cazden et al. 1985; Cordeiro 1988; Cordeiro et al. 1983; Edelsky 1983; Ferreiro and Pontecorvo 1999; Ferreiro et al. 1996; Ferreiro and Zucchermaglio 1996; Parkes 1978, 1992; Sampson 1985).

For punctuation marks within written numbers, numerous questions linger for future research: can we identify a process in their appropriation among young children? What roles do young children ascribe to punctuation marks within written numbers? In children's use of punctuation marks in written numbers, what, if anything, are children implicitly aware of regarding the structure and functioning of written numbers and the NWS?

This paper deals with only some of the above questions, acknowledging the need for future studies that explore these issues in further depth. We are currently exploring children's uses of punctuation marks (Brizuela and Cayton, in preparation). In this paper, we address two research questions:

- How do young children interpret punctuation marks (i.e., commas and periods) within written numbers?
- What role do young children ascribe to these marks within written numbers?

## 7 Materials and methods

### 7.1 The sample

The interviews that form the corpus of data for this paper were carried out in two Kindergarten (children need to be 5 years old upon entering Kindergarten) and two first grade (children need to be 6 years old upon entering first grade) classrooms at a public school in the Boston, Massachusetts area (in the USA). The public school at which the interviews took place can be considered representative of the general population of the Boston area (31% non-White students, and 54.4% low-income family students, as defined by the Massachusetts Department of Education). Although all Kindergarten and first grade students at the school were invited to participate, only those whose parents responded to the invitation and consented to their participation were included in the sample. This resulted in a sample of five Kindergarten and 18 first grade students – a total of 23 students. All parents consented to children's first names being used for the purposes of research.

The children were exposed to a traditional mathematics curriculum, guided by textbook instruction. Direct teaching about punctuation marks is not included in the elementary school mathematics curriculum, but they are *implicitly* included in written numbers. Moreover, children in this age range (roughly 5–7 years of age) are not necessarily expected to deal with numbers beyond 999, or with decimal fractions. They are, however, expected to introduce appropriate end marks in their written texts. Punctuation marks receive attention within the language arts curriculum outlined by the state of Massachusetts at the time this research took place. They are explicitly addressed in two "strands" within the language arts curriculum: language and composition. Within the language strand, there exists for Kindergarten and Grade 1 students a curriculum standard that deals with the structure and origins of modern English. Within this standard, Kindergarten children are expected to *introduce appropriate end marks such as periods and question marks*, and Grade 1 students are expected to *introduce and identify appropriate end marks*. Within the composition strand, there exists a curriculum standard dealing with English conventions. For this standard, students in Grade 1 are expected to *use appropriate end marks such as periods, question marks, and exclamation marks*. Kindergarten students are not expected to achieve any particular standard regarding punctuation marks within the composition strand.

### 7.2 The interviews

The interviews were carried out as clinical interviews (see Piaget 1976). According to Piaget, in the clinical interview the interviewer must know how to observe, "that is to say, to let the child talk freely" (p. 9). These individual interviews were described to the children in this study as conversations about "what you know and think about numbers." During the interviews, each child was presented with a series of questions. The questions structured the interviews but also provided the flexibility necessary to a clinical interview. The interviews focused, not on a particular answer we were seeking from the children, but on the thinking and understanding that went into solving the various tasks. Following the clinical interview method, each child was presented with potentially conflicting situations during the course of the interviews, and the contradictions in the justifications or thinking were made explicit and explored. The children were eager to participate in the interviews, calling them a game and perhaps anticipating the individual attention they would be receiving.

There were three broad sets of questions asked. All questions focused on a price context. Prices were chosen as the context in which to explore our research questions, since prices can incorporate both commas and periods in a style familiar to the child. We assumed that children would naturally and spontaneously have interacted with punctuation marks within written numbers in price contexts. During the interviews, however, written numbers with no price context were also presented if it seemed that their introduction and discussion could help further clarify children's ideas. In this paper, we only report on children's responses to Part 3 of the interview, detailed below.

The first set of questions (Part 1) focused on children's *interpretation* of a list of prices (see Table 1) presented in an advertisement leaflet. The second set of questions (Part 2) focused on children's *production* of a list of prices (see Table 2). The names of products and their price were read out to the children, as indicated in Table 2. During the last part of the interview (described in Part 3, below), children were asked specific questions about the roles of the periods and commas they saw in Part 1 of the interview. If they themselves included punctuation marks in the numerals they produced in Part 2 of the interview, they were asked about these as well.

**Table 1** Items and prices shown to children during Part 1 of the interview

| Item/product shown | Price shown |
|---|---|
| Orange juice | 4.95 |
| Coke cans | 3.65 |
| Cold medicine | 4.00 |
| Color printer | 52.90 |
| Telephone | 38.50 |
| Desk chair | 379.00 |
| Digital camera | 869.00 |
| Computer | 10,499.00 |
| Play structure | 5,799.00 |

### 7.3 Part 3 of interview

This final part of the interview is the crux of this paper. After going through Part 1 and 2 of the interview, children were asked about the periods and commas seen in the advertisement leaflet. Some of the children who themselves produced punctuation marks during Part 2 of the interview were also asked about these numerals they wrote. At times, additional numerals were introduced, with variations in the placement and inclusion or not of punctuation marks, in order to develop a better sense of children's ideas and understandings. Not all of these numerals were prices. At times, the interviewer produced these numerals, and at other times the children were asked to produce these additional numerals. Children were asked questions such as:

- Why do you think they included this period/comma here?
- Why did you include this period/comma here?
- What would happen if the period/comma were not included?
- What would happen if I added a period/comma?

The interviews were carried out individually. Each one of the interviews was videotaped and then transcribed verbatim. In addition, all notations made during the interview formed part of the data collected. If the children mentioned a context, situation, or problem other than those brought up, their ideas were followed up. The children were asked to show on paper each one of the ideas they presented and were encouraged to make as many notations as possible related to their understandings, as well as to explain the notations they made.

**Table 2** Items and prices read to children during Part 2 of the interview

| Item/product name read | Price read | How price was read |
|---|---|---|
| Yoghurt | 4.95 | Four ninety-five |
| Magazine | 7.50 | Seven fifty |
| Chocolate cake | 10.00 | Ten |
| Videotape | 25.80 | Twenty-five eighty |
| Camera | 100.00 | One hundred |
| Table | 247.20 | Two-hundred forty-seven twenty |
| Bed | 3,200.00 | Three thousand two hundred |
| Bicycle | 2,425.50 | Two thousand four hundred twenty-five fifty |

### 7.4 The analysis

The data from the interviews will focus on the roles children ascribed to punctuation marks within numerals. The analysis of the data involved three general stages. In *Stage 1*, we carried out an exhaustive review of the transcripts and notations produced in the 23 interviews. In *Stage 2*, we sought to identify the roles that children ascribed to punctuation marks in numerals. For this purpose, we followed the two major uses for punctuation marks mentioned in historical analyses of the development of numerical notations: to group digits in numeration and for marking or separating the whole and decimal parts of numerals (Cajori 1928). While the transcripts and notations were being reviewed, recurrent responses, behaviors, and notations were identified. This level of analysis resulted in identifying the major roles children ascribed to the use of punctuation marks in numerals. The major roles were considered to be those with the most frequent responses. In addition, atypical meanings attached to notations were also identified, even if only one child exhibited them. In *Stage 3,* once recurrent and major themes had been identified, frequencies were calculated for each one of them. Throughout the interviews, children, at times, presented responses that fell into more than one category. If children mentioned a role more than once, only one recurrence of the role was tallied. This resulted in a total sample size of $N$=23 for each one of the roles. The recurrent and atypical responses, behaviours, and notations became the categories shown in Table 3.

## 8 Results

### 8.1 The roles young children ascribed to punctuation marks within the NWS

An analysis of the data from the 23 interviews carried out with Kindergarten and Grade 1 students led us to identify the following roles ascribed to punctuation marks within the context of producing and interpreting numerals for prices:

1. To separate
2. To mark type of number (e.g., price)
3. To denote value
4. To make it a different number
5. To read number differently

Table 3 shows the frequency and percentage distribution for each one of these categories. A first reading of the list of roles mentioned by young children underscores how each one of these roles is an accurate appreciation of the roles punctuation marks do in fact play within written numbers and the NWS. Moreover, each one of the above roles is connected to other roles in different ways. For instance, denoting value (role 3, above) could be related to making numbers different (role 4, above): if the value of a number changes, this turns it into a different number. Our decisions for identifying these roles and for classification of children's responses relied on children's own words. Most of these roles could be considered complementary. For instance, as just mentioned, as adults we could consider that denoting a different value for a number necessarily implies making a numeral different. However, we cannot assume that this implied necessity is such for children. Therefore, we maintained roles as separate whenever children referred to them differently, even if we saw some connection between their different statements. In addition, some

**Table 3** Frequency and percentage distribution for responses describing the roles ascribed to punctuation marks within the NWS

| Name | Grade | Role assigned to punctuation marks in numerals | | | | | |
|---|---|---|---|---|---|---|---|
| | | To separate | To mark type of number | To denote value | To make it a different number | To read number differently | Do not mention any role |
| Jonathan | K | | | X | | | |
| Joseph | K | | | | | | X |
| Marissa | K | | X | X | | | |
| Michael | K | X | X | | | | |
| Sheila | K | | | | | | X |
| Allen | G1 | X | X | X | | | |
| Adrianna | G1 | X | X | | | | |
| Brenna | G1 | X | X | | | | |
| Chris | G1 | X | | | X | | |
| Dakota | G1 | X | | | X | | |
| Darky | G1 | X | X | | | | |
| Jason | G1 | | | | | | X |
| Joe | G1 | X | X | | | | |
| Kassandra | G1 | | X | X | X | | |
| Kristen | G1 | X | | | | | |
| Lucas | G1 | X | X | | X | | |
| Manasse | G1 | X | | | X | | |
| Martine | G1 | | X | X | | | |
| Matthew | G1 | | | | | | X |
| Monique | G1 | | | | | X | |
| Rebecca | G1 | | | X | X | | |
| Taylor | G1 | X | X | | X | | |
| Tianna | G1 | | X | X | | | |
| TOTAL | 23 | 12 | 12 | 7 | 7 | 1 | 4 |
| % | 100 | 52 | 52 | 30 | 30 | 4 | 17 |

Responses are counted over a total of 23 children who participated in the interviews

children mentioned more than one role for punctuation marks. We counted each one of the different roles mentioned by children, tallying each role only once for each child.

Most of the children in the sample mentioned that the role of punctuation marks within the NWS is to separate and to mark the type of number that we are referring to (for instance, a price, as was the case for the context presented to the children in the study). About a third of the children also mentioned the roles of denoting value and making it a different number. Only one child alluded to the role of punctuation marks as allowing us to read numerals differently. Furthermore, only four of the 23 children (19%) did not mention any role in their interviews, thus indicating that most of the children do have hypotheses for how these marks are used within written numbers. The following are some examples of the kinds of verbal explanations provided by children whose responses fell into each one of these categories. In keeping with the theoretical framework presented in the introduction of this paper (e.g., Ferreiro 1986; Karmiloff-Smith and Inhelder 1974; Vergnaud 1988), we will be referring to children's ideas about punctuation marks as *hypotheses* (Ferreiro 1986).

### *8.1.1 To separate*

Children frequently brought up the role of separation. This could be expected to some extent given the specific context of prices in which the children were interviewed. In prices, there is a constant presence of punctuation marks to separate whole dollars from the cents part of the price. Even if there are zero cents present, that is, if there exists a whole amount of dollars, prices include a punctuation mark and two zeros indicating zero cents. Children considered punctuation marks important to separate the "dollars" part of the numeral from the "cents" part of the numeral. These young children seem to be aware that these parts of numerals should not be confused. They seem to be aware that they should be kept separate in order to avoid confusions. It is clear to them that dollars are not cents, and vice-versa.

The way children stress the role of separation indicates an implicit understanding and awareness on their part regarding different parts of numerals, and different units or structures within numerals: whole parts of numerals, or "dollars," placed to the left of punctuation marks, and decimal fractions, or "cents," placed to the right of punctuation marks.

Examples:

> "[Punctuation marks are for] separating the numbers; first it [the punctuation mark, in this case the period] tells the dollars with the dot there to separate the cents from the dollars." (Lucas, Grade 1)

> "[Punctuation marks are there] just to separate the numbers; so they don't put the number with the other number mixed together." (Manasse, Grade 1)

As stated earlier, according to Cajori (1928), this was one of two purposes for which punctuation marks were originally introduced in written numbers. The fact that 12 of the children in the sample (52%) mention this role could be related both to the context in which the interviews took place, as well as to children's gradual appropriation of the underlying rules for the use of punctuation marks. Punctuation marks are also used "to separate" within written language, thus, we could think of children as potentially holding the following hypothesis: "when a punctuation mark is present (whether in written language or written numbers), it is used to separate." Children at this age have not necessarily been told or taught about this use of punctuation marks in numerals. In spite of this, they are very aware of it.

### *8.1.2 To mark type of number*

Children whose responses fell in this category explicitly stated that the placement of punctuation marks made numerals a different *type* of number. For instance, a punctuation mark made a number a price. It is likely that this role was particularly highlighted given the context in which the interviews took place.

Examples:

> "[Commas and periods are used] for cents and dollars." (Adrianna, Grade 1)

> "Periods are for prices." (Tianna, Grade 1)

The same number of children (12 children, or 52% of the children in the sample) mentioned this role as the previous one. This prevalent hypothesis reminds us that children are aware of more than we may give them credit for. Children are aware that there are different types of number; for instance, there are numbers that are prices, and there are other

numbers that are not prices. They realize that these differences need to be marked in some way, and that punctuation marks are one way to mark this difference. Alvarado's research (2002; Alvarado and Ferreiro 2000, 2002) provides us with other examples that show that marking differences explicitly in some way is important to children: she describes young children rotating digits in order to indicate that they are in the tens place of a two-digit number (place not being a sufficient marker for them at this point) and not the units place.

### *8.1.3 To denote value*

Children who referred to the value of the number spoke about punctuation marks affecting whether the numeral was bigger or smaller. The presence or absence of a punctuation mark could make the value of a number change. The statements made by children in this sample fell short of alluding to place value, but they do make reference to the fact that the presence of punctuation marks distinguishes smaller and larger numbers.

Examples:

> "I think the period means that there needs to be kind of like lower numbers, then the comma needs bigger numbers to put the comma in." (Allen, Grade 1)

> "[You put a comma in] because it is a big number....if you didn't put the comma, it wouldn't mean big number." (Martine, Grade 1)

> "[You use commas] 'cause it's a bigger number; you use commas for a bigger number." (Marissa, Kindergarten)

Seven children (30% of the children in the sample) referred to this hypothesis. With this hypothesis (i.e., "if there is a punctuation mark it means it is a bigger number") children highlight how they are implicitly aware of the use of punctuation marks for larger numbers, beyond 999. They seem to have implicitly classified numbers as "smaller" and "larger." Past research has indicated that children focus on the number of digits as marking a number's magnitude (e.g., Brizuela 2004; Scheuer 1996), at first neglecting to focus on the order of the digits and place value. With this hypothesis, children seem to indicate that they are paying attention to other cues as well, such as whether or not there are punctuation marks within the written number. We may wonder, in this regard, whether children may associate more marks with higher value. This hypothesis could be related to the other use that Cajori (1928) points to in relation to the original, historical introduction of punctuation marks in written numbers: to group digits in numeration; only when numbers are larger do we need to group digits in numeration.

### *8.1.4 To make it a different number*

Children who alluded to this role explained that including a punctuation mark within the numeral changes the number, making it a different number. These children allude to a change of *meaning* in the number. This category is related to the previous one, the marking of value through punctuation marks. However, these children did not speak explicitly of *value*, instead saying that the placement of a period or comma makes a numeral *different*. This category could also be related to using punctuation marks to mark a different *type* of number. It is also an indication of an implicit awareness of the impact of the placement of a punctuation mark within a numeral.

Examples:

"A comma changes a number...[the period is] to let you know that that's four dollars [and ninety-five cents] and it's not four hundred and ninety five dollars." (Chris, Grade 1)

"[If people put commas and periods in a number] it would be a different number. Because if this didn't have the period, it would be four hundred dollars. If you put a period, it would be four dollars." (Taylor, Grade 1)

Seven children (30% of the children in the sample) referred to this hypothesis. As stated regarding the hypotheses "to mark type of number" and "to denote value," to which the current hypothesis (i.e., "to make it a different number") is related, children look for explicit ways in which to distinguish and differentiate numerals: whether it is how many digits they include in a numeral (e.g., Brizuela 2004; Scheuer 1996), the rotation of some of the digits but not others (e.g., Alvarado 2002; Alvarado and Ferreiro 2000, 2002), or the inclusion of additional marks, such as punctuation marks, within a numeral.

*8.1.5 To read number differently*

This role differs from the previous one in that children explicitly allude to a different *reading* for the numeral, without alluding to the numeral being different. In the previous role, children stated that the numeral was different, but did not allude to the reading of the numeral. Only one child alluded to this role of punctuation marks. This was unexpected for us, given that an earlier interview (see Brizuela 2003, 2004) reported a 6-year-old Kindergarten student who gave a lot of importance to the role of punctuation marks to aid in the reading of numerals (for instance, to know when to say thousand, when to say million, or hundred). Punctuation marks within the NWS can be considered to play a linguistic role, in that they guide us in pronouncing and understanding the numeral. It is between each comma and before each decimal point that we make distinctions in our pronunciations of the numeral being read. For instance, as mentioned earlier 991 would be read as nine-hundred ninety-one and 9.91 will definitely be read as nine ninety-one: the placement of the comma marks a distinction in our reading of the numeral.

Example:

"[A] comma changes how to read a number." (Monique, Grade 1)

## 9 Discussion

External representations form part of a cultural repertoire that children constantly interact with. Punctuation marks in written numbers form part of this cultural repertoire. Ignoring children's ideas and uses of them, assuming, perhaps naïvely, "that if they have not been taught about them, they know nothing about them" only places us at a disadvantage regarding our understandings about children's mathematical learning and development and how best to approach their instruction.

Each of the five different roles for punctuation marks within numerals mentioned by children interviewed in this study (i.e., to separate; to mark type of number; to denote value; to make it a different number; and to read number differently) is a partial description of the conventional use of these marks within written numbers. Children's verbalizations about the roles of punctuation marks within written numbers show that they know more about how

the system operates than we might have thought possible. Their verbalizations about the roles of punctuation marks are quite articulate and underscore the importance both of listening to their ideas and perspectives (e.g., Confrey 1991), as well as considering the importance of highlighting punctuation marks in the early childhood and elementary mathematics curriculum.

At the outset of this paper, we argued that understanding children's spontaneous ideas about these marks could prove enlightening for understanding their developing numeracy. In listening to their verbalizations about the roles of punctuation marks, children showed that they had an implicit understanding and awareness regarding different parts of numerals, and different units or structures within numerals (whole parts of numerals or dollars on one hand and decimal fractions or cents on the other hand). Further, while their statements did not directly allude to place value, they made reference to punctuation marks distinguishing smaller and larger numbers. More generally, children are aware that placing a comma or period in a numeral has an impact on this numeral. This aspect could have implications for their use of punctuation marks: their uses of these marks will likely be intentional actions to convey some particular meaning. Research has shown children to convey meaning in surprising ways (see Alvarado 2002; Alvarado and Ferreiro 2000, 2002; Brizuela 2004). Children might recur to similar uses of punctuation marks in their productions of numerals.

The data presented in this paper are limited in their scope: they refer only to children's explanations about the roles of punctuation marks. As mentioned earlier, a thorough investigation needs to include an analysis of their *use* of punctuation marks, which we hope to tackle in the future (see Brizuela and Cayton, in preparation). However, in spite of these limitations, the children interviewed in this study still provide us with vivid and accurate descriptions of the role of these marks in conjunction with numerals. Once again, we are reminded of how children actively construct understandings about our notational systems and all of their graphical aspects, however miniscule and insignificant they may seem to the naked eye.

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