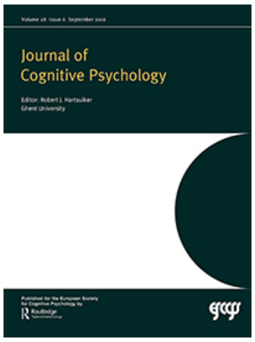

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Symbolic representation of the number three: a study with three-year-old children from contrasting socioeconomic environments

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ABSTRACT
The goal of the present study was to compare a range of aspects in children's symbolic knowledge about the number three among two groups of three-year-olds from contrasting socioeconomic backgrounds. Every child was presented with five tasks that focused on the number three and that had cognitive demands of different complexity: expressing their age, reciting the conventional number series up to three, quantifying a collection of three, and two tasks requiring the use of visually presented quantitative information.The results showed the same order of difficulty of the tasks in both socioeconomic groups and a clear performance difference depending on socioeconomic background. These findings show that symbolic knowledge about the number three does not come in an *all or none* fashion. Rather, different aspects of this symbolic competence become apparent in response to different tasks, and seem to depend largely on the socioeconomic environment in which children develop.

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Symbolic knowledge; number cognition; socioeconomic differences

A large body of research suggests that discriminating among arrays of up to three elements is an ability that relies heavily on biological factors and is independent of language and education, being evidenced even among newborns (Antell & Keating, 1983; Ceulemans et al., 2012; Feigenson & Carey, 2005; Starkey & Cooper, 1980; Starkey, Spelke, & Gelman, 1990; Van Loosbroek & Smitsman, 1990). Discriminating collections of three elements from collections of two or four elements implies a quantitative precision that is not required for discriminating between one and two elements because this last operation could be based on the qualitative distinction between singular and plural. For this reason, we underscore the special status of quantities that are made up of three elements when attempting to understand early quantitative cognition. An unanswered question in developmental literature is how children approach collections of three elements once they begin to use specific external symbolic representations for this quantity, whether they are visual (e.g. dots), oral (e.g. words "three" or "one, two, three"), or gestural (e.g. finger patterns). We will refer to the use of these specific external cultural representations as "symbolic representations". The present study aims to explore the ways in which children from different socioeconomic environments approach a variety of number tasks of different complexity that involve symbolic representations of three at an age when they already use gestures and oral language quite frequently in their social interactions. Our interest will be focused on comparing each child's performance across a variety of tasks that involve symbolic representations of the number three in different ways, posing a gradient of challenges, an approach that has rarely been adopted in the literature.

Children's appropriation of symbolic representations for small numbers

At an early age, children tend to understand that number words are different from other descriptive words (such as "red", "big", or "happy"). They do not use number words to describe the particular traits of individual objects (Geary, 1994; Gelman & Gallistel, 1978; Markman, 1979; Sinclair, 2005); they list number words or use these words to enumerate objects and actions or when referring to magnitudes. In most cultures, the action of reciting the conventional number series, beginning with "one", is a widespread number-related activity (Bishop,

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1991). However, children aged two or three who can recite the number series up to 10 or beyond often fail to assess the cardinality of small collections, including those that are formed by one, two, or three elements (Condry & Spelke, 2008; Sarnecka & Carey, 2008; Wynn, 1990, 1992). By age four, many children are able to subitise such quantities (that is, say the exact quantity of the set at a glance) and to extract the quantity of slightly larger sets based on counting (Fuson, 1988; Saxe, Guberman, & Gearhart, 1987).

The development of cardinal knowledge at these ages has been investigated by using a variety of experimental tasks such as asking the child to pick up a given quantity of elements from a larger set, to state the quantity of objects that are displayed on a card, or to indicate the correct collection of elements for a verbally given number (Carey, 2009; Gelman, 1993; LeCorre, Brannon, Van de Walle, & Carey, 2006; LeCorre & Carey, 2007; Saxe et al., 1987; Wynn, 1990, 1992, among others). Developmentally, children first succeeded at these tasks when collections of only one item were involved, then for sets of two items, and subsequently with three, well before they were able to manage collections made of four elements. Based on these results, Carey (2009) coined the expressions "one-knowers", "two-knowers", and "three-knowers" to refer to children who succeeded in cardinal tasks that involve one, two, and three elements, respectively. Similarly, she used the expression "no numeral-knowers" to refer to children who did not associate cardinal values with number words. According to Wynn (1990, 1992), there is a span of around one and a half years from the time children succeed with collections of one item to when they succeed with collections of four or more items.

Following this approach, Huang, Spelke, and Snedeker (2010) found that when children who used the number word "three" in a cardinal sense were trained to distinguish sets of four elements from other set sizes that involved the same category of objects, they easily generalised this new ability to sets that were formed by other categories of objects. In contrast, children who used and understood the number word "two" in a cardinal sense and were trained in a similar way showed greater difficulties in generalising their training regarding the number word "three" to sets that involved other categories of objects. This study highlights that using three (*versus* one or two) in a cardinal way is a special kind of achievement that can lead to accomplishments not necessarily available with smaller numbers. A similar result stems from an observational case study that showed a delay of three months between a 22-month-old child's first documented use of "two" (for two fingers standing for two rides, which she spontaneously and rapidly generalised to cardinalise a broad variety of collections made up by two-manipulative and visual objects of different sizes, appearance, and social function, in homogeneous or heterogeneous collections) and her first use of "three" (Scheuer & Sinclair, 2009).

Overall, the results of these studies indicate that children aged two or three only gradually and slowly become able to assign a cardinal value to the first number words in the counting sequence. The age of three is especially interesting because it marks an intermediate point between children's first uptake of symbolic number representations and their use to express cardinality. At the same time, these studies also indicate that knowledge of the number three is a special achievement for children but that we still know little about how this achievement interacts with their use of symbolic representations for three, like dots. In fact, most of these recent studies seem to investigate early development of number knowledge as if it were a cumulative process that progresses step by step along the number line. In other words, as if children "grasped" numbers successively one by one starting from one, and as if each number was grasped once and for all. However, a longstanding tradition has provided evidence that the development of number understanding is multidimensional and does not consist only of which numbers are mastered in a single task. Rather, what matters are the kinds of gaps that arise when the child is observed or is asked to deal with different tasks (Fuson, 1991; Saxe et al., 1987; Wagner & Walters, 1982). Thus, a more comprehensive study of children's grasp of a particularly relevant number such as three calls for exploring how they deal with it in various tasks, both simpler and more complex than quantifying a collection of three. From our point of view, the use of a symbolic representation implies being able to transfer the quantitative information conveyed by means of such a symbolic representation in order to operate in another related situation. This requires understanding that the representation provides quantitative information, and that such quantitative information is relevant to guide action.

Using symbolic representations in numerical and spatial domains

Some studies conducted in the spatial domain provide an inspiring framework to approach the relationship between mere recognition and understanding of symbolic representations in the numerical one. DeLoache and her colleagues (DeLoache, 1991, 1995; DeLoache & Burns, 1994; DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998) have shown that developing an understanding of symbolic representations of space (such as images, photographs, or drawings) is a slow learning process. In fact, from 18 months children *can recognise* the referent such as an object in a room shown in an image or photograph. However, until approximately the age of three, children have difficulties *using* the spatial information included in a representation to solve a problem concerning a referent that is not present, such as finding a hidden object in a room. At three years of age, according to DeLoache, most children have the ability to understand that the spatial information provided in an external representation can be used to solve a problem in another referent. Recent studies indicate that these age trends vary across socioeconomic status (SES), with a delay of a year for children from a low SES group with respect to those from a middle SES group (Salsa, 2013).

In this study, we wanted to focus on the use of symbolic representations of number. We wondered if three-year-old children are able to use the quantitative information conveyed by a visual display to solve a problem as well as the extent to which this ability is related to other numerical abilities. Given that symbolic development in the number domain is highly dependent on the input the child receives and such input is mediated by SES (Jordan & Levine, 2009), we also wondered if children's ability to use visual number representations symbolically varied according to SES.

Socioeconomic variation in children's numerical knowledge

The influence of socioeconomic contexts on early numerical knowledge has mostly been studied by comparing children from middle *versus* low (or very low) SES groups in terms of their global performance on large batteries of numerical tests. In most of these studies, which were carried out in English-speaking countries, the youngest children considered have been four-year-olds, with only a few studies including younger children aged two or three (e.g. Anders et al., 2012; Gunderson & Levine, 2011; Saxe et al., 1987; Starkey & Klein, 2006; see Starkey & Klein, 2008 and Jordan & Levine, 2009 for reviews). Overall, children from a middle SES typically obtained higher global scores than children from a low SES (Anders et al., 2012; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Starkey & Klein, 1992, 2006). This gap was equivalent to about a year difference in age and was reported to remain stable or even broaden during preschool education. Transcultural studies (e.g. Davis & Ginsburg, 1993; Ginsburg, Posner, & Russell, 1981) indicated that contextual factors, such as schooling, influenced the ages at which different numerical abilities were acquired, but not the order in which they arose. Ginsburg, Choi, Lopez, Netley, and Chi (1997) suggested that the longest delays in the acquisition of numerical competence were not observed much among children from a low SES, but were mostly observed among children who belonged to very impoverished environments (very low SES). Only a handful of studies have sought to identify in which particular tasks participants from different SES groups were most likely to differ. At age four, SES differences were mostly found in complex activities that involved cardinality or simple arithmetic (Hughes, 1986; Saxe et al., 1987), especially for verbally presented calculations (Jordan, Huttenlocher, & Levine, 1992, 1994). Instead, no differences were found for relatively simple activities, such as enunciating the conventional number series or counting objects, which are activities that children of both socioeconomic populations (low and middle SES) seemed to master at this age (Sarama & Clements, 2011; Saxe et al., 1987; Thomson, Rowe, Underwood, & Peck, 2005; West, Denton, & Reaney, 2001). A limitation of these studies, however, is that they report the average performance for given tasks across items that involve different set sizes (e.g. collections of 2, 3, 5, 9, and 17 elements). Given that these studies rarely broke down children's performance as a function of set size, it is difficult to determine whether children from low SES groups lag behind their peers from middle SES groups even dealing with a very small number of elements such as three across a variety of numerical activities.

Aims and rationale of the study

The present study aims to explore how three-year-olds from different socioeconomic environments deal with a variety of tasks, all of them involving the number three but entailing different levels of complexity.

We chose five tasks that pose different number-related cognitive demands and are presumably present in young children's everyday environments (Nunes & Bryant, 1996; Young-Loveridge, 1989): (1) *an eminently social activity*, in this case expressing their age either gesturally or verbally; (2) *a verbal enumerative task*, in this case reciting the conventional number series up to three; (3) *a task that requires the verbal or gestural quantification of a visually presented array*, in this case quantifying three dots on a die; and (4) and (5), *two tasks that require the symbolic use of visually presented quantitative information*: using the quantitative information conveyed by three dots shown on a die in order to move a toy three steps forward along a segmented path and selecting the appropriate face on the die to indicate the number of steps the toy should advance (see the specific description of each task in the next section).

We anticipated that expressing their own age would be the easiest task, since three-year-olds are usually familiar with this social practice. Based on studies reporting that enumerative skills develop well before the ability to extract the cardinality of small sets, we predicted that the rate of success would be higher for the task of reciting the number series than for the quantification task. In turn, DeLoache's studies showing a gap between success in recognising a spatial representation and transferring the conveyed spatial information to operate in another situation led us to anticipate a higher success rate for the quantification task than for the two tasks that required the symbolic use of visually presented quantitative information (i.e. use and selection).

In order to explore the influence of children's environment on their performance, we chose to work with two groups of children with highly contrasting socioeconomic backgrounds: middle-high and very low. We anticipated that children from a higher SES group would have a clear advantage in the use and selection tasks, based on the contributions of two lines of research: (a) results showing SES effects in slightly older children's numerical performance for relatively complex tasks that require cardinality and simple arithmetical operations and (b) recent results that indicate that SES accounts for approximately a year's delay in the comprehension of symbol-referent relations in the spatial domain. With regards to the simpler tasks consisting of expressing their age and reciting the first three number words in the conventional order, we anticipated no differences across SES groups, given that these activities are presumably very familiar for children across socioeconomic contexts. We were intrigued as to whether differences would appear for the quantification task or not, given that, as we have mentioned above, its difficulty is intermediate, because the quantity of three can be assessed via subitising (providing an accurate verbal judgement, *three*, immediately, at a glance, Fischer, 1991) or via counting (Baroody, 1987).

Method

Participants

We interviewed 71 children aged 36–47 months from two schools that had contrasting socioeconomic characteristics. Thirty-eight children (22 boys, 16 girls, mean age = 43 months, SD = 3.09) attended a public school that is located in downtown (Barcelona, Spain) (population 1,700,000). Children who attend this school come mainly from middle-high SES families and, in 94% of the cases, begin attending school before the age of three. Moreover, 76% of these children's fathers and 81% of mothers had pursued university-level studies. Thirty-three children (16 boys and 17 girls, mean age 42 months, SD = 3.46) attended another school that is located in the periphery of Bariloche (Argentina) (population 120,000). This school is located in a very low SES neighbourhood; families who live in the school's neighbourhood have, in many cases, their "basic needs unmet" (according to the classification proposed by the *Instituto Nacional de Estadísticas y Censos* – INDEC).[1] For 65% of the children attending this school, parents had not completed the seven-year primary education, 23% had pursued secondary school, and 5% had advanced beyond that level (available information does not distinguish between mothers and fathers). Of these participants, 82% began attending school before the age of three.

At both schools, two age ranges were considered, with a span of six months. Half the children in each

[1]The demographic category "Unmet Basic Needs" (in Spanish: necesidades básicas insatisfechas, NBI), of current use in Argentina (INDEC, 1998), encompasses households that exhibit at least one of the following indicators of deprivation: (a) more than three people per bedroom (critical overcrowding); (2) inconvenient homes, such as rented rooms of precarious buildings; (3) absence of toilets, or toilets that lack flushing water; (4) households that include at least one child who does not attend school, despite being a school-age child; or (5) households that have more than four people per working family member, and in which the head of the family has not advanced beyond the second year of primary school.

school belonged to each age range. In the medium-high SES group, means age ranges were 40 months (SD = 0.92) and 46 months (SD = 0.55). In the very low SES group, mean ages were 39 months (SD = 1.91) and 45 months (SD = 1.30).

Tasks, materials, procedure, and coding

Children were interviewed individually in dedicated rooms at their schools. Each session lasted around 15 minutes and was videotaped. During these sessions, participants were presented with the tasks described in the previous section (see also Martí, Scheuer, & de la Cruz, 2013) in the following order.

Expressing age. In the context of establishing social contact with the interviewer, children were asked: "How old are you?" Responses to this direct query were scored as correct in those cases where the child said "three" or "one, two, three" and/or showed three fingers. Any other responses were regarded as incorrect, including those in which the child did not provide any response and those in which children gave the appropriate response in one semiotic mode but an inappropriate response in the other (e.g. the child said "five" while showing three fingers). Although these mixed responses might indicate that the child has an intermediate knowledge about the issue, we grouped them with the children who provided only incorrect responses due to the fact that mixed responses included incorrect information. This task could be considered "non numerical" because children can learn to associate a specific answer to a specific question without understanding the numerical meaning of their response. However, we consider that dealing with number words or gestures and associating them with the domain of age can be a way for the child to gain knowledge about numbers and their symbolic representation. Children, for instance, can relate the number word corresponding to their age to other situations where this word is used to represent the cardinality of a set. They also can realise that number words related to different people's age can change and be ordered.

The rest of the tasks presented are strictly numerical.

Quantification. Participants were presented with a wooden die with faces that displayed an empty face and one to five dots and were asked, for each of the faces: "How many dots are there?" The order of presentation of the faces was fixed; the participants first received the die face showing two visible dots, followed by trials showing one, three, five, four, and an empty face. The geometrical array of the dots on each side differed from those of a standard die in order to prevent participants from directly recognising such configurations and, thus, circumventing the quantification process. In the present study, we only analysed responses to the part of the task in which children were shown the face with three dots. Similar to the task of expressing their age, responses were scored as correct when the child said "three" or "one, two, three" and/or showed three fingers. Any other responses, including those in which the child did not provide any response and those in which children gave the appropriate response in one semiotic mode but an inappropriate response in another, were regarded as incorrect, as in the previous task. This task is similar to a task called "What's–on-this-Card" used to study what number word children produce in front of cards with depicted sets of objects (Carey, 2009; Gelman & Gallistel, 1978; Ginsburg & Russell, 1981; Wynn, 1992).

Use. Children were invited to play a simple game that involved the wooden die, a toy horse, and a rectangular 300 cm × 10 cm path, which consisted of 24 adjacent rectangular boxes. We also placed in the last box a little toy plate representing food. The basic structure of the game was as follows: the horse has to advance along the path to arrive at the food; the interviewer placed the die that showed a given number of dots on its upper side and asked the child to advance the horse along the path the same number of boxes as the number of dots that were displayed on the die. The interviewer carried out two demonstrations of the game (with two and one dots). Whenever the child either did not wait until the die was placed or did not look at the upper side of the die, the interviewer encouraged the child to do so. Each side of the die was presented twice (in the following order: two, one, three, five, empty face, four, one, empty face, three, four, two, and five). This task requires using quantitative information that is displayed on the upper side of a die – three dots – and transferring it to a different situation (i.e. advancing a toy horse the corresponding number—three—of discrete boxes along a linear path). This task is related to situations presented by DeLoache (1991, 1995). As mentioned in the Introduction, in these situations, children from two to four-years-old had to use the information presented in spatial representations of a room (such as drawings, photographs) to find an object hidden in the real room (thus transferring information from the symbolic representation to the referent). In the present study, our analysis was limited to the trials that involved three dots. A response was scored as correct when the child, in the first trial, advanced three boxes (e.g. from box six to box nine). The few cases of children advancing two boxes after making the toy horse step on the box on which it was already placed (e.g. moving from box six to box eight, after having the horse "step" on boxes six, seven, and eight) were also considered correct. All other responses were regarded as incorrect, including those in which the child did not provide any response.

Selection. In the same situation as the previous task, the horse is placed at different distances from the food (in the following order: two, one, three, four, and five boxes away from the food). For each trial, children were asked to show the face of the die corresponding to the number of boxes between the horse and the food. This task is closely related to the *use* task, but the question is formulated in a reciprocal way. In this case, children are asked to indicate the appropriate face of the die (the three dots face) according to the quantity of boxes (in our case, three) that separate the little horse and a plate of toy food. We wondered if the difficulty for children would be the same or not in both situations; we expected that our results might contribute to our understanding of whether the direction in which the symbolic relation operates (from visual symbol for three to referent, or vice versa) is a factor influencing children's symbolic performance at this age. In the present study we analysed only the situation when the horse and food were three boxes away from each other. A response was considered correct when the child took the die and selected and showed the die face with three dots. All of the other responses were regarded as incorrect.

Reciting the number series. Finally, a simplified version of the task of enunciating the number series was presented. The interviewer told the child: "Now, we are going to figure out how many steps the horse has made. I will point to each step that it has made, and you will count the steps. Here we go: one … ". The interviewer continued to point at successive boxes along the path until the child stopped producing a word number for every subsequent pointing. In the context of this study, children's responses to this task were scored as correct whenever they recited the series until three ("one, two, three" or "two, three" following the number "one" provided by the interviewer). Other responses were scored as incorrect, including those where the child remained in silence. This task requires children to have memorised the first three number words in their conventional order and to be able to retrieve them from memory upon request. Children can acquire some experience with this kind of task in a variety of contexts in which the first three numbers of the series are presented (e.g. games, counting, riddles, and preparation for action).

Children's videotaped responses to all of the tasks were scored independently by two of the authors. Judges agreed in 95% of the cases. Cases of disagreement were resolved through discussion.

Results

As we have seen in the description of each task, the responses were coded in a binary way (correct or incorrect). Our first analysis will focus on the comparisons between tasks. Given the binary nature of the coding and the fact that each participant solved all the tasks, we chose the nonparametric Cochran test to compare the rate of success between tasks. The second analysis will focus on the comparison between both SES groups for each task. In this case we chose Pearson's chi-square test to investigate if the rate of success in both unpaired samples was different or not. In all the analyses we calculated the effect size (phi) to have a supplementary measure of the importance of the differences (in general, phi < 0.20 indicates a small effect size, phi between 0.20 and 0.50 a moderate effect size, and phi > 0.50 a large effect size). We also considered children's patterns of success (failure *versus* success) subject by subject comparing the numerical tasks (reciting, quantification, use, and selection) two by two. This intra-individual analysis is interesting because it shows the frequencies of different patterns of success–failure presented by pairs of tasks and because it provides a complementary way to appreciate in more detail the order of difficulty of the tasks.

Children's rate of success on all five tasks

We will focus first on children's performance (rate of success) on the five tasks. We will report the results without distinguishing between children's age groups since age range comparisons did not yield differences in the whole population or within SES groups.

The results show that children's success rate varied greatly according to the task, Cochran's $Q(4) = 73.226$; $p < .001$. The means of correct answers for each task, ordered by success rate, were: *reciting* (.89), *expressing age* (.69), *quantification* (.61), *use* (.38), and *selection* (.36).

If we compare all the tasks two by two (see Table 1) we find that most comparisons yield significant differences and large effect sizes. The exceptions are *expressing age versus quantification*, and *use versus selection*.

If we focus on the four tasks that are strictly numerical (*reciting*, *quantification*, *use*, and *selection*), the results show that the order in terms of the rate of success is (1) *reciting*, (2) *quantification*, and (3) *use* and *selection*. In fact, the only comparison between tasks where there was no significant difference is between these last two tasks. The task where children were required to *state their age* shows a lower rate of success than *reciting* but a similar rate of success if it is compared with *quantification*. Our results, as stated in our predictions, show a clear difference in the rate of success between *reciting* and *quantification*, and between *quantification* and each of the two tasks that imply the use of quantitative information (*use* and *selection* tasks). *Expressing age* turned to be more difficult than what we had expected.

Performance on all tasks across socioeconomic groups

Children from a middle-high SES outperformed children from a very low SES across all tasks except in the *selection* task where the rate of success was quite low in both groups. Table 2 shows means across all tasks for both SES groups and statistic results.

When the relative difficulty of tasks is analysed within each SES group, results reveal that the tasks differed from each other both within the middle-high SES group, Cochran's $Q(4) = 46.203$; $p < .001$, as well as within the very low SES group, Cochran's $Q(4) = 34.882$; $p < .001$. If we compare both groups, the rate of success is different in all tasks except in the *selection* task. In spite of clear differences between both SES groups, even regarding the simpler (*expressing age* and *reciting*) or intermediate (*quantification*) tasks, the relative difficulty of tasks was the same for both groups, according to the order of success rates. In terms of the four strictly numerical tasks, *reciting* clearly presents the higher rate of success; *quantification* is higher compared to *use* and *selection*; and the differences between these last two tasks are not clear. Even though contrary to our expectations the success rate differences for the *expressing age* task across both SES groups are remarkable (rates of success are 89% for the medium-high SES group and 45% for the very low SES group), the order of the rate of success of the *expressing age* task compared to the numerical tasks is the same across both SES groups.

Intra-individual analysis of responses

To appreciate in more detail the relations among the four strictly numerical tasks (*reciting*, *quantification*, *use*, and *selection*) in both SES groups we performed an intra-individual analysis of response patterns comparing the four tasks two by two (see Table 3). In Table 3, the code 1–1 represents children who provided correct responses on both tasks; 1–0 represents children who provided correct responses on the first task but not the second; 0–1 represents children who provided an incorrect response on the first task and a correct response on the second; and 0–0 represents children who provided incorrect responses on both tasks.

The results of the intra-individual analysis follow some of the same trends of the results from the previous statistical analysis for the whole population and across SES groups. First, the differences in all tasks between the two SES groups is impressive when we compare the frequency of children from each SES group who succeeded in both tasks (pattern 1–1) or failed in both of them (pattern 0–0). Second, the order in the rate of success across tasks found through the statistical comparisons (*reciting* – *quantification* – *use* and *selection*) is the same as in the intra-individual analysis. In fact, in the first three comparisons (*reciting*/*quantification*, *quantification*/*use*, and *quantification*/*selection*), the presence of pattern 1–0 is clearly higher compared to pattern 0–1 (21 *versus* 2, 15 *versus* 6, and 21 *versus* 4, respectively). This difference confirms the order of difficulty of the tasks compared two by two. Only in the *use versus selection* comparison are both frequencies almost equal (10 *versus* 8); this data that is congruent with the results of the Cochran test (no significant difference between *use* and *selection*, Table 1).

Table 1. Differences between tasks measured by Cochran's test (*Q*) and effect size (phi).

Comparison tasks	Cochran's test result (*Q*)	*p* value	Effect size result (phi)
Reciting *vs.* Age	9.8	$p = .002$*	0.37
Reciting *vs.* Quantification	16.667	$p < .001$**	0.48
Reciting *vs.* Use	34.05	$p < .001$**	0.69
Reciting *vs.* Selection	36.1	$p < .001$**	0.71
Age *vs.* Quantification	1.636	$p = .201$ n.s.	0.15
Age *vs.* Use	16.133	$p < .001$**	0.47
Age *vs.* Selection	16.941	$p < .001$**	0.48
Quantification *vs.* Use	11.636	$p = .001$*	0.40
Quantification *vs.* Selection	12.462	$p < .001$**	0.41
Use *vs.* Selection	0.222	$p = .637$ n.s.	0.05

Note: n.s.: not significant, with $p > .005$; *$p < .005$; **$p < .001$ (for multiple comparisons Bonferroni correction must be applied. According to this adjustment, our critical *p*-value is the result of dividing between the alpha level (0.05) by the number of comparisons we have done).

These results show more extensive difference than the ones we expected, regarding even the simpler tasks.

Discussion

Our study is motivated by a phenomenon that has not been systematically explored: children acquire numerical knowledge through a host of everyday situations that involve very different cognitive demands. We have explored this among three-year-olds from markedly different SES groups by using a set of tasks that were related to cultural, symbolic representations of the number three. Our results show that three-year-olds exhibit difficulties in dealing with these symbolic representations in several situations, in marked contrast with the success demonstrated by infants with this same magnitude in discrimination tasks (Antell & Keating, 1983; Ceulemans et al., 2012; Starkey & Cooper, 1980; Starkey et al., 1990; Van Loosbroek & Smitsman, 1990). This suggests that babies' perceptual, presumably automatic and implicit knowledge for small quantities may not be particularly relevant when coping with situations that involve representing these same magnitudes symbolically. As Nunes and Bryant (1996) have pointed out, "there is no evidence connecting these reactions of the infants to perceptual displays and their later understanding of number" (p. 21). The relationship between these two systems of number knowledge (perceptual and symbolic) awaits further exploration (Dehaene, 1997; Jordan & Levine, 2009; Rodríguez & Scheuer, 2015).

A first set of results in our study, which deals with children's performance across tasks, suggests that three-year-olds' symbolic knowledge is multifaceted. The vast majority of our participants (89%) could recite the conventional number series up to three as they enumerated the boxes on the path. A smaller proportion were able to express their age or to quantify a set of three objects (69% and 61%, respectively), either verbally or by showing the appropriate finger gesture. Finally, around a third of the participants were able to use quantitative information. Thirty-eight percent of them were able to use the quantitative information that was conveyed by a visual array of three elements to advance a toy horse the corresponding number of steps along a path and 35% were able to select the face of the die with dots that corresponded to the boxes of the path separating two elements. These results confirm that reciting the number words in the conventional order precedes knowing that each number word refers to a particular cardinal value (Condry & Spelke, 2008; LeCorre & Carey, 2007). These results are confirmed by the intra-individual analysis when comparing both tasks; in fact, only two children failed when reciting and succeeded in the quantification task (i.e. presented the success pattern 0–1 described above).

An analysis of the cognitive demands that underlie the *use* and *selection* tasks may help us understand their difficulty, and compare them to other tasks. First, the *use* and *selection* tasks require the ability to abstract the cardinal value of a small collection of dots or adjacent boxes (in this case, three). Next, the child needs to transpose this

Table 2. Means of correct answers and statistic results across different tasks comparing both SES groups.

Task	Middle-high SES ($n = 38$)	Very low SES ($n = 33$)	χ^2 of Pearson	*p*-value	Effect size (phi)
Reciting	0.97	0.79	6.099	$p = .014$*	0.29
Age	0.89	0.45	16.004	$p < .001$*	0.47
Quantification	0.82	0.36	15.118	$p < .001$*	0.46
Use	0.55	0.18	10.305	$p = .001$*	0.38
Selection	0.42	0.27	1.703	$p = .192$ n.s	0.15

*Significant values: $p < .05$.

Table 3. Frequencies and percentages of children presenting different patterns of success and failure as a function of SES.

Pairs of tasks	Patterns of success/ failure	Middle-high SES ($n = 38$)	Very low SES ($n = 33$)	Total ($n = 71$)
Reciting/ Quantification	1–1	31 (82%)	10 (30%)	41 (58%)
	1–0	5 (13%)	16 (48%)	21 (30%)
	0–1	0 (0%)	2 (6%)	2 (3%)
	0–0	2 (5%)	5 (15%)	7 (10%)
Quantification/ Use	1–1	12 (32%)	5 (15%)	17 (24%)
	1–0	9 (24%)	6 (18%)	15 (21%)
	0–1	4 (11%)	2 (6%)	6 (8%)
	0–0	13 (34%)	20 (61%)	33 (46%)
Quantification/ Selection	1–1	15 (39%)	6 (18%)	21 (30%)
	1–0	16 (42%)	6 (18%)	22 (31%)
	0–1	1 (3%)	3 (9%)	4 (6%)
	0–0	6 (16%)	18 (55%)	24 (34%)
Use/Selection	1–1	12 (32%)	5 (15%)	17 (28%)
	1–0	9 (24%)	1 (3%)	10 (16%)
	0–1	4 (11%)	4 (12%)	8 (13%)
	0–0	13 (34%)	23 (70%)	26 (43%)

Note: 1–1 represents a successful performance on both tasks, 1–0 stands for cases where participants succeeded on the first task but failed on the second one, 0–1 stands for cases where participants failed on the first task but succeeded on the second one, and 0–0 represents cases where participants failed on both tasks.

information onto the path in order to advance the toy horse exactly three boxes (*use* task) or to keep this numerical information in mind to select the appropriate face of the die (three dots for the *selection* task). The first demand is akin to that of the *quantification* task, with the difference being that the child is not required to communicate the cardinal value of the set. It is no surprise, then, that most children who were able to use the information presented visually to them (*use* task) and who also succeeded in transferring the quantitative information of the path to the die (*selection* task) also succeeded with the *quantification* task. The intra-individual analysis confirms this trend when the *quantification* task is compared to the *use* and *selection* tasks. In both comparisons (see Table 3) very few children (six and four, respectively) failed in the *quantification* task and succeeded in the *use* or *selection* task (i.e. presented the success pattern 0–1 described above). Therefore, it seems that recognising the quantitative value of a collection represents a necessary (though not sufficient) prerequisite for transferring such information to a new situation (both from die to pathway and from pathway to die).

Our findings indicate that this numerical transfer process is rather complex for children at this age. Our results also show that both tasks (*use* and *selection*) present a similar degree of difficulty. DeLoache (1991, 1995) demonstrated that between the ages of two and three, children develop the ability to transfer information from visual representations, such as pictures, drawings, or scale models, to their actual referents. As posited by DeLoache, this ability reveals that children understand the dual nature of symbolic representations. However, dual representation depends not only on age but also on the characteristics of the objects: the more interesting an object is, the more difficult it is to conceive of the object as a representation of something else. A global comparison between DeLoache's results – based on the use of visual spatial information – and our own results – based on the use of visual quantitative information – suggests that transferring numerical information from the visual mode might be even more difficult than transferring spatial information from a similar visual mode. What might be the reasons behind this apparent greater difficulty in using numerical information than spatial information symbolically?

If we focus on objects' characteristics, three dots have probably less interest for children than an image or a model scale of a room. In this sense, if we take into account the dual representation hypothesis, understanding the symbolic nature of three dots should be easier than understanding the symbolic nature of images or model scales. However, in our study the three dots are on a die, an attractive object to play with. As Cavalcante and Rodríguez (2015) have observed, children from 24 and 36 months of age playing the same game needed considerable help to consider the dots as symbols. Other studies in mathematical teaching have also indicated children's difficulties considering concrete objects (manipulatives) symbolically (Uttal, Scudder, & DeLoache, 1997). Therefore, we need to consider the cognitive demands of both the *use* and *selection* tasks.

Both tasks differ in the goal of symbolically using visually presented information. While in the model/room paradigm children have to locate an object in a target space based on the visualisation of an object in space (model and room are isomorphic), children in the *use* and *selection* tasks used in the present study had to use the three dots on the upper side of the die as quantitative instructions for regulating the advancement of the toy horse along the path or appreciate the quantitative information of adjacent boxes of the pathway and then select the corresponding face of the die. In these two cases it is not enough to be aware that the numerical information in one situation can serve to solve the problem in the other situation. First, children have to quantify exactly the number of dots or the number of boxes in the path and, second, regulate the movement of the toy horse (exactly three steps) or choose the face of the die (the configuration with three dots). The numerical tasks seem more cognitive demanding than the spatial task. However, a systematic study of this gap in future investigations will require an intra-individual analysis that compares how children at different ages use spatial *versus* numerical information symbolically.

A second set of results deals with the influence of children's socioeconomic background on their early numerical performance. Children from families that are characterised by a middle-high SES outperformed their peers from a very low SES on the social number-related task (*expressing age*) and on the four numerical tasks. These results are striking because the tasks involve dealing with a very small quantity (three), which (1) both infants and children seem to discriminate easily when compared to slightly larger quantities (i.e. collections of four or more elements, Fischer, 1991; Huang et al., 2010; Starkey et al., 1990), and (2) pervades a broad spectrum of everyday exchanges. Note that even cross-linguistic studies reveal that the vast majority of current and defunct languages possess a word for this quantity (Hurford, 2001). However, and if we consider the four strictly numerical tasks (*reciting*, *quantification*, *use*, and *selection*), the same order of difficulty was observed across tasks in both populations at the overall performance and intra-individual levels of analysis. Enunciating the first three number words in the conventional series was the easiest task, followed by quantifying three dots, and finally using visually presented numerical information (in both tasks, *use* and *selection*). The *expressing age* task had the same success rate as the *quantification* task. The common trends and differences across SES groups indicate that managing the number three at a symbolic level is a slow developing ability that is sensitive to socioeconomic variation from an early age.

The huge difference across SES groups regarding the activity of quantifying three dots (82% *versus* 36% of correct responses, respectively) is particularly worrying, given that the ability to assess the cardinality of a set is widely considered to represent a landmark in early numerical development (Fuson, 1988; Gelman & Gallistel, 1978; Wynn, 1990). This difference indicates that to a large extent the ability to quantify small sets depends on factors that are related to the social environment in which children develop. Given that we coded both verbal and gestural expressions as correct responses, the above consideration applies to various ways of assessing the cardinality of a set, such as subitising, using fingers as *witness collections* (Brissiaud, 1991), or executing counting principles. In prior research on the preschool years, SES differences were mostly found for more complex tasks (Sarama & Clements, 2011; Saxe et al., 1987; Thomson et al., 2005; West et al., 2001). No differences were found for simpler tasks such as reciting number words or counting very small sets, neither found at age two nor at age four. By revealing SES differences at age three for a range of very simple numerical tasks, the results of the present study disconfirm the hypothesis that SES effects during preschool years are only confined to more difficult numerical tasks.

Presumably, the socioeconomic differences in children's performance on the five tasks that are included in the present study originate from a multitude of factors, and future studies will be required to pinpoint the precise way in which they operate. A more accurate account of these differences will require a combination of methodologies, including ethnographic studies that explore the family and school environments of the children by means of naturalistic observations, as well as extended interviews with parents and teachers (see, e.g. Young-Loveridge, 1989). Recent studies have focused on the relations between children's SES and the amount of number talk they are provided by teachers and parents. While the raw amount and the variety of teacher math-talk did not differ across classrooms serving different SES groups (Klibanoff et al., 2006), children's SES was significantly correlated with the amount of number talk provided by their parents (Gunderson & Levine, 2011). After successively sampling parent math-talk at 14, 18, 22, 26, and 30 months of age, Gunderson and Levine found that only math-talk about present objects reliably predicts success in the "point to x" task at 46 moths of age. More specifically, while number talk about present collections of one to three objects only predicted success in quantifying collections within the subitisable range, talk about larger collections of present objects was also predictive of success beyond the capabilities of the object tracking system, something that demands comprehension of the cardinal principle. In sum, recent data both provides plausible explanations about SES-related delays in mathematical development and points to possible avenues for alleviating them. With regards to the SES differences observed in our use and selection tasks, results from Ramani and Siegler (2008) on the related activity of playing linear board games showed that exposure to these games in the family environment was positively correlated with SES, and also that a brief intervention (one hour total) centred on having four-year-old children play these games produced stable gains in abilities such as counting and numerical magnitude comparison. By finding that three-year-olds' success in using presented quantitative information (a precondition for understanding board games) for a given set seems to require the ability to quantify such a set, the results of the present study add to those of Ramani and Siegler by way of suggesting a mutual bootstrapping between these activities, as well as by pointing to the basic quantification skills that should be mastered before this positive feedback system can be unleashed.

The data that we have presented demonstrate that achieving symbolic knowledge regarding the number three entails a progressive process that children experience in a variety of different settings. Different aspects of this symbolic knowledge become apparent in children's responses to different tasks and seem to depend largely on the socioeconomic environment in which children develop, even in tasks that are apparently simple. These results call into question the appropriateness of overly generalised descriptors for the main landmarks in numerical development, such as "three knowers" (Carey, 2009; Huang et al., 2010). Reifying "the knowledge of the number three" conveys the idea that at given points in development, children attain a global conception for this quantity. Such an approach may conceal a gamut of knowledge resources that come into play based on the particular demands of the task at hand, whose acquisition largely relies on a host of contextual factors that require further investigation.

In future research some limitations of the present study could be overcome. We have compared our results in *quantification* and symbolic use tasks with DeLoache's results but this comparison is indirect, as it involves different participants. It will be necessary to design a unique study where the same children participate in both numerical and spatial tasks to compare their performances. Another line of study that we are preparing is to compare how children deal with numbers 1–5 across this same set of tasks. Do tasks present the same order of difficulty when smaller numbers as one or two or larger numbers as four and five are involved? It is also necessary to explore with more detail children's responses (types of errors and semiotic modalities). For instance, do responses offering correct information through gesture and incorrect verbal information reveal fragile, emerging gains or is the correct component coincidental? These explorations would give us a more complete picture of children's early numerical development. We also think that in future studies the age variable could be more controlled reducing the age variation inside the two SES groups and also designing two age groups with a greater interval. It is possible that the absence of age effects on performance in our study was due to the narrow difference between age groups and the high standard deviations of this variable inside the groups. Finally, for a more accurate comparison between SES groups, future research has to identify with more details home and school practices with numbers that could explain the differences we have found in all the tasks.

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