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Children's understanding of quantitative and non-quantitative transformations of a set

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Children's understanding of the transformation of a set needed for a change of the number was examined with help of the transform-set task. Based on previous studies it was assumed that the subset knowers will be outperformed by the cardinality principle knowers in both quantitative and non-quantitative transformations when the number in question was large, but both groups will perform equally well when the number in question was small. The results showed that there was no difference between the groups on large number quantitative change, but there was for small number quantitative change. Qualitative analysis sheds light on children's understanding of the non-quantitative transformations of a set as well as on their understanding of reversibility of an operation. These findings might suggest a better approach to teaching children addition and subtraction.

Key words: quantitative transformation of a set, non-quantitative transformation of a set, counting, subset knowers, cardinality principle knowers

The child's concept of a number has long been the subject of psychological research (Piaget, 1952). Most recently researchers have been specifically interested in the development of children's counting principles (Ansari et al., 2003; Gelman & Gallistel, 1978; Gelman & Meck, 1983; Muldoon, Lewis, & Berridge, 2007; Wynn, 1990). The understanding of the cardinality principle, which states that the cardinality of a set is determined by the last number word used to count that set, has been researched most extensively. There is at least one year gap between the time children start to recite a counting list and the time they start to use counting to represent the number (Le Corre & Carey, 2007; Schaeffer, Eggleston, & Scott, 1974; Wynn, 1992). It has been found that before children master the cardinality principle they pass through phases of one-, two-, and three- and sometimes four- and five-knowers (Nikoloska, 2009; Sarnecka & Gelman, 2004; Wynn, 1990; Wynn, 1992). The one-, two-, three-, four-, and five-knowers are called *subset knowers* (Le Corre, Van de Walle, Brannon, & Carey, 2006) because they know the meaning of only a subset of the number words within their counting range. Once children learn the cardinality principle they go from naming the sets on the basis of associative connections between words and set sizes to making inferences about the cardinality of a set based on their knowledge of the cardinality principle (Barner, Libenson, Cheung, & Takasaki, 2009).

What is it that distinguishes subset knowers and cardinality principle knowers? Using a series of experiments, Sarnecka and Carey (2008) found that the only thing that distinguishes subset knowers and cardinality principle knowers is that the cardinality principle knowers are aware that going forward one step in the counting list means adding one item, whereas going backwards one step in the counting list means taking (subtracting) one item, that is, they know the exact unit of the change. For example, they put five toy frogs in a box and told the children the exact number of frogs they were putting in the box. Next, they added one or two more frogs and asked the children if there were six or seven (or "seven or six" in counterbalanced order) frogs in the box. The analysis showed that the cardinality principles knowers performed significantly better than the subset knowers. They concluded from these findings that the cardinality principle knowers have understood the successor function.

In another task, the direction task, Sarnecka and Carey (2008) tested whether cardinality principle knowers and

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subset knowers would know that adding items means going forward in the counting list and subtracting items means going backwards. In this task they were not testing if there is an understanding of the exact unit of numerical increase which happens when moving a particular step(s) on the number sequence. For example, the children were told "There are five bears here and five bears here. Now I'll move one." After the experimenter moved one bear from one pile of bears to another, in which case there were now four bears in one and six in the other, children were told that there was one pile with four and one with six and they were asked which one had either four or six. Four-knowers and cardinal principle knowers did not differ in their performance between each other but the lower subset knowers (one-, two-, and three-knowers) performed significantly worse than both four-knowers and cardinality principle knowers. Therefore, the four-knowers knew the direction of the change, but did not know the exact unit of the change. The exact unit of the change was known only by the cardinality principle knowers.

From these series of experiments several assumptions about cardinality principle knowers could be drawn. If cardinality principle knowers know the meaning of all the number words within their counting range and if they know the successor function, then they should know which transformations of a set affect discrete quantity. More specifically, they should know that only adding or subtracting items to a set will be accompanied by a change of the number, because they know the successor function and should know that change such as rearranging the items of a set is irrelevant for the successor function. But what can be said about the subset knowers? Do they know that only quantitative transformations are relevant for the number to change?

Another study might shed light on that question. Sarnecka and Gelman (2004) investigated which transformations children see as relevant for the change of the number word. They told the children in their study (Experiment 1) the exact number of items in a bowl and performed transformations. They either added or removed an item or shook or rotated the bowl. For example, they told the children "Here are five moons. Now watch," and they performed one of the transformations and asked "Now how many moons - is it five or six?"

They tested both cardinality principle knowers and subset knowers and found that both groups (in fact the subset knowers were further differentiated as Level I, II and III, depending on their knower level) of children were likely to repeat the same number word for sets that had been shaken or rotated but said a different number word for sets to which an item had been added or removed.

Lipton and Spelke (2006) were examining children's understanding that number words refer to exact cardinal values for numbers which are beyond children's counting range and children's understanding that when items are added or removed from a set, the number words change their application. In their study, they put one set of objects in a container and told the children the exact number of items in the container. Then, they performed the manipulations: stirring, removing one item from the container, or removing half of the objects and returning the half to restore the original numerosity. After the manipulations they asked the children "Are there N objects?" What they concluded from the results is that children see large number words as referring to specific cardinal values and that children knew that number word will change when items are added or removed from a set and will not when they are rearranged. In their study they used large number words (beyond children's counting range), and concluded that even before children can count to high numbers they understand what transformations are relevant for a number word to change.

In all these experiments children seem to know which transformations are relevant for the change of the number. However, Lipton and Spelke's participants were five years old and probably there weren't any subset knowers in their sample. Sarnecka and Gelman's participants were younger, but they were not tested with large numbers. There is a gap in knowledge about the performance of subset knowers on the trials with large numbers. Therefore, the current research was conducted to verify their findings and to expand them by testing subset knowers with numeric and non numeric transformation of a large set and by investigating whether, once children understand something about the small numbers, they generalize it to the large numbers or not. More specifically, this researched looked for an answer to the following questions: Is there a difference between subset knowers and cardinality principle knowers in their understanding that small number numeric transformation and large number numeric transformations are accompanied by change of the number, and that small number non numeric transformations as well as large number non numeric transformations are not accompanied by a change of the number? Will children within each group find the transformations with small numbers to be easier than those with large numbers?

We hypothesize that when small numbers (1 - 10) are in question, both cardinality principle knowers and subset knowers would be likely to know that a quantitative change results in a change of the number and non-quantitative change does not. This has already been shown to be so in other studies for numbers up to six, and we speculate that children transfer this knowledge by analogy to all the number words they frequently encounter, which are the first ten. However, when children are tested on trials with large numbers, we expect the cardinality principle knowers to perform better than the subset knowers when there is a non-quantitative transformation of a set, that is, to know that a non-quantitative change of a set is not accompanied by a change of the number, but also that when there is a quantitative change, it is accompanied by a change of the number. These expectations stem from the fact that the cardinality principle knowers know the successor function, and presumably can transfer the knowledge they have about the frequently encountered numbers to all numbers, where as subset knowers can not.

METHOD

Participants

An initial number of 68 children were tested. However, data for only 59 were used in the analysis because three children did not attend to the task and their attention was very difficult to obtain, one of the children had a communication difficulty and his answers were not intelligible, and five children failed at least two memory checks for the same question for at least three trials. These children were excluded from the analysis and were all one-knowers. The mean age for the final sample was 4;4 (years;months) (the range was 3;9-5;2). Out of those, 37 children were cardinality principle knowers (mean age 4;6, range 3;10-5;2), while 22 were subset knowers (mean age 4;4, range 3;9-5;1). The sample consisted of 23 boys and 36 girls. All children were native speakers of Macedonian and all children were attending state kindergartens.

Coding and data collection

The conversations with the children were audio tape recorded and later transcribed. For the quantitative part, the answer (correct or incorrect) was noted immediately in a previously prepared form. These recordings were later checked with the transcribed material and any discrepancies were corrected (actually there were no discrepancies, but on several occasions the experimenter missed to note down the answer of the child, so these gaps were filled after the transcription was over).

Materials

Materials included 15 yellow cubes, which were used for the give-a-number task. A plastic lion toy and a plastic monkey toy were used for the warm up trials and the lion was also used for the give-a-number task. A light blue plastic box with dimension of 22×13×6 cm was used for the warm up trials and for the transform-set task. Other material included: grey buttons with 1 cm in diameter, cream colored plastic balls with 3 cm in diameter, seashells of medium size, brown plastic stars 2 mm thick and approximately 4 cm wide, red straws 3 mm wide cut into pieces 3.5 cm long, little wooden clothes-pegs approximately 3 cm long, and hazelnuts. These materials were used for the transform-set task. During this task the materials would be put in the opaque box and covered with the lid, and then one of the operations would be carried out.

Procedure

A female experimenter tested each child individually in a separate room in their kindergartens. Each session lasted approximately 20 minutes.

The experimenter introduced herself and told the children that they would play a counting and number games with her. The children were asked to join her in another room. Upon arrival the child was given 10 yellow blocks arranged in a straight line approximately 1 cm apart and was asked to count them. The purpose of this task was to see whether the child could count to 10 and whether they used the standard counting sequence or not. If they did not manage to count to 10, they were given the counting task again at the end of the session to see whether they knew the counting sequence to 10 but failed to demonstrate that knowledge. Only four children did not count up to 10 on either occasion. All children used the standard counting sequence up to the number they could count reliably.

After this they were given the *give-a-number* task. In this task children were asked to give one item, then three items and further questioning depended on the answer of the child. If children were unsuccessful at a given number, they were asked for N-1. Each child was asked until he had two successes at a given number and two failures at a subsequent number. Fifteen yellow cubes were put in a pile in front of the children and a lion toy was introduced. The lion was put approximately 20 cm away from the pile and the children were asked to give one cube to the lion. They were told "Could you give one cube to the lion? Take one cube and put it in front of it." After they complied with the request, they were asked a follow up question "Is that N?" This procedure was repeated for the other numbers asked for. If children responded "No" to the follow up question, the initial request was repeated in the following way: "But the lion wanted N items. Could you put N items in front of it?" Children were given neutral feedback. For example, if after the follow up question children would answer "Yes", whether the number of cubes they had given was the number asked for or not, the experimenter would say "Okay, now let's put those back, and could you give N cubes to the lion. Take N cubes and put them in front of the lion." If after the request a child asked the experimenter "How much is N?" or "Is this N?", the experimenter replied "Just guess how much N is."

Children who had two successes at a given number and two failures (that is to say, they gave some other number when asked for N) at a subsequent number were classified according to the highest number that they could give (that is to say, two or more successes at three and two failures at four means that the child was classified as a three-knower). Because the experimenter was not interested in a specific performance of the one-, two-, three-, four-, and five-knowers, these levels were collapsed in a group called *subset knowers*. Children who could give six items were classified as cardinality principle knowers. Namely, Wynn (1990,

1992) has suggested that once children grasp the meaning of six and are able to produce sets of six items, they have mastered the cardinality principle and are able to produce sets for all the numbers within their counting range. Subset knowers, on the other hand, know the meaning of only a subset of the number words within their counting range and thus are able to create sets with the numbers they know, but not with the higher numbers (for example, a two-knower knows to form sets of one and two, but not three and higher number of items). The purpose of this task was to sort children into subgroups.

The next task administered to the children was the *transform-set* task. Before this task there were warm-up trails in order to introduce the children to the general demandings of the task. Children were told that the experimenter is going to put some things in the box and children were supposed to tell what was inside the box. The experimenter first put a plastic lion toy in an opaque box while telling the child: "Now I am going to put something in the box and your job is to tell me what is inside. Ready? OK, I am going to put in a lion. What is in the box?" All the children answered correctly that there was a lion inside, but two girls closed their eyes. After it was explained that in this game they need to watch what is being put in the box, they did not try closing their eyes anymore. Next, the children were told "Now I am going to put in a monkey." while putting plastic monkey toy inside the box and afterwards they were asked "What is inside the box?" All children got both of the practice trials correct. There were only two practice trials in total, once with lion toy and once with plastic monkey toy. In order to introduce them to the real task they were told "Now I will put inside *several* things and you need to tell me how many things are inside. OK. I am going to put two cubes. How many cubes are there?" The same yellow cubes from the give-a-number task were used for this task as well. If children did not answer correctly on this introductory trial (one child), they were told "Lets see. Oh no, there are two cubes. OK, let's try again. Now I will put *three* cubes. I always tell you the right number of things inside the box. How many cubes are inside?" This time, all the children got the answer right.

After this practice trial the transform-set task was immediately introduced. Children were told the exact number of items in the box as they watched the experimenter put the items in the box. Then the lid was put on the box and they were asked how many items there were, after which a transformation was performed. The transformations were either quantitative, such as adding or removing one item, or non-quantitative, such as shaking or rotating the box for 180 degrees. For example, children were told "Now I am going to put 37 buttons in the box. How many buttons?" If the child responded with a different number, the experimenter said "Oh no, I think there are *37* buttons (stressing the word 37). Let's try again. There are 37 buttons in the box. How many buttons are there?" If the answer they gave the first time was correct, the procedure continued in the following way: The experimenter said "Yes, there are 37. Now watch." and either took one button away from the box, added one button to the box, rotated the box 180 degrees, or shook the box. Then children were asked "Are there still 37, or is it a different number?" Half of the children were asked the reverse question "Is it a different number or there are still 37?" For a given child the format of the question was kept always the same. Children had eight trials in total, four trials per transformation, twice with small numbers, twice with large numbers. The small numbers were three, five, seven and nine. The large numbers were 37, 54, 68, and 72. The objects associated with the numbers were kept the same for every child, and they were always combined like this: three stars, five balls, seven circles, nine seashells, 37 buttons, 54 clothes-pegs, 68 straws, and 72 hazelnuts. The transformations performed with those numbers were randomized across children. The order of presentation of the trials was randomized across participants as well.

After the children gave their answer, no feedback was given, but they were asked why did they think that was so, and how could one make the buttons be 37 again (if they said it was a different number) or how could one make it be a different number (if they said there were still 37). If the child was willing to cooperate, a further discussion took part. Each conversation with the children was recorded and transcribed.

The scoring for this task was carried out in the following way. If the child gave a correct answer, such as, saying there were still X items after non-quantitative change was performed, or saying there was a different number after quantitative change was performed, they were given 1 point. If they gave an incorrect answer (saying there were still X items after quantitative change was performed, or saying there was a different number after non-quantitative change was performed), they received 0 points. So, for each condition they could have either 0 (both answers inaccurate), 1 (one correct answer and one wrong answer) or 2 (both answers accurate). There were four conditions in total: small number non-quantitative change (shaking or rotating box with small numbers), small number quantitative change (adding or removing one item from a box with small numbers), large number non-quantitative change (shaking or rotating a box with large numbers) and large number quantitative change (adding or removing one item from a box with large numbers). A composite score was also calculated by combining the results from the four conditions.

RESULTS

Almost all children, other than four, could successfully count to 10. The four children who could not were all subset knowers. Two of these children could count up to six and they were two-knowers. One of the children was an one-knower and he could count up to five. The other one was a five-knower and he could count to eight. Mann – Whitney U tests did not reveal significant differences between these four children and the rest of the subset knowers for any of the four conditions so they were included in the analysis (all $p > .05$).

Table 1
Means and standard deviations for cardinality principle (CP) knowers, subset knowers, and the whole group

Group		Small number numeric change	Large number numeric change	Small number non numeric change	Large number non numeric change
CP knower	Mean	1.89	1.68	1.22	1.24
	N	37	37	37	37
	Std. Deviation	0.458	0.709	0.886	0.955
Subset knower	Mean	1.68	1.59	0.73	0.73
	N	22	22	22	22
	Std. Deviation	0.477	0.734	0.883	0.883
Total	Mean	1.81	1.64	1.03	1.05
	N	59	59	59	59
	Std. Deviation	0.473	0.713	0.909	0.955

In order to see whether children were performing at chance binominal tests were computed (Gravetter & Wallnau, 1996) for each of the eight questions children were asked. First, this test was computed for the group as whole, then for each group separately. In all three cases the performance did not differ from chance for the small number non numeric and large number non numeric transformations (rotate and shake), but it was significantly different from chance for the small and large number numeric transformations (plus and minus). Since children performed at chance for small and large number non-quantitative change of a set, further analysis on that data will not be reported. Descriptive statistics for both groups and the group as a whole are presented in Table 1.

In order to test for a difference between the cardinality principle knowers and subset knowers a Mann-Whitney U test was done. The test revealed significant difference between the cardinality principle knowers and the subset knowers for the small number numeric change, $U = 306$, $N_1 = 37$, $N_2 = 22$, $p < .01$. There was no significant difference between the groups for the large number numeric change condition, $U = 377.5$, $N_1 = 37$, $N_2 = 22$, $p > .05$.

Because children performed at chance for the non numeric transformations, we wanted to see if these conditions were more difficult for them. In order to see this, Friedman test for the group as a whole was conducted. The test revealed a significant effect of condition, $\chi^2(3) = 42.682$, $p < .001$. Post hoc comparisons were performed to see which conditions differ in performance using Wilcoxon test but correcting for the number of tests (Field, 2009). This means that something will be accepted as significant only if it is less than α/number of comparisons, which is in the social sciences .05/number of comparisons (Field, 2009). In this case there are six comparisons. That makes .05/6 = .008 the critical level. Anything below .008 would be considered a significant difference.The results from the Wilcoxon Signed Ranks Test for the group as a whole are given in Table 2.

Table 2
Wilcoxon Signed Ranks Test of significance for the whole group, cardinality principle (CP) knowers, and subset knowers

Group		Small number non-quan. trans. - small number quan. transformation	Large number quan. transformation - small number quan. transformation	Large number non-quan. transformation - small number quan. transformation	Large number quan. transformation - small number non-quan. transformation	Large number non-quan. transformation - small number non-quan. transformation	Large number non-quan. transformation - large number quan. transformation
Whole group	Z	-4.347	-2.055	-4.262	-3.402	-0.232	-3.072
	Asymp. sig. (2-tailed)	.000*	.040	.000*	.001*	.817	.002*
CP knowers	Z	-2.986	-2.070	-2.913	-1.905	-3.02	-1.76
	Asymp. sig. (2-tailed)	.003*	.038	.004*	.057	.763	.078
Subset knowers	Z	-3.198	-0.632	-3.274	-2.985	0.000	-2.737
	Asymp. sig. (2-tailed)	.001*	.527	.001*	.003*	1.00	.006*

* $p < .008$

Separate comparisons were done for each group, looking for differences in performance in different conditions. For the subset knowers there was a difference between the same conditions as for the group as a whole. For the cardinality principle knowers there was a difference only between small number non numeric change and small number numeric change on one side and large number non numeric change and small number numeric change on the other side.

DISCUSSION

Contrary to the expectations, the cardinality principle knowers performed significantly better than the subset knowers for small number numeric transformations. This performance was the highest for the subset knowers compared with the performance on the other three conditions, but nevertheless they were outperformed by the cardinality principle knowers, who performed almost at ceiling. Ninety-four percent of the cardinality principle knowers answered both questions about small number numeric change correctly, and 6% (only two children) answered neither question correctly. No cardinality principle knower answered one right and one wrong, but 33% of the subset knowers did. The rest of the subset knowers answered both questions correctly. This means that the cardinality principle knowers have a better idea that quantitative changes of a small set are accompanied by a change of the number or at least they are more certain of it. The subset knowers on the other hand are less certain, as can be seen from the substantial number of children who gave one correct answer and one wrong answer for this condition. Further analysis showed that out of these seven (33%) children, five erred for the addition and two for subtraction, which might indicate that subset knowers are less certain that a number changes when items are added to a small set than when they are subtracted. Because the cardinality principle knowers' performance was almost at ceiling, and the subset knowers did perform the best within their group on this transformation, the difference between the two groups is probably due to the cardinality principle knowers performing almost perfectly.

Another interesting aspect of these findings is that there was difference for the small number numeric change and not for large number numeric change. Does this mean that tasks with large sets are easier for the subset knowers than the task with small sets, so they catch up with the cardinality principle knowers in their performance? The answer is no, because within each group there was no difference between the performances on these two conditions, so it is not the case that one was easier than the other. This difference probably reflects the fact that the small number numeric condition was an easy task. This task is especially easy for cardinality principle knowers because they have had a lot of practice with small sets and that is why the cardinality principle knowers performed better. For the large number numeric condition the cardinality principle knowers "fall down" and meet the subset knowers. In general, the scores for both small and large number numeric transformation are relatively high, which means that children knew that adding or subtracting an item would result in a change of the number.

These findings are also incongruent with the findings of Sarnecka and Gelman (2004) because in their transform-set task both groups performed well on the quantitative as well as non-quantitative trials. We expected to replicate those findings, and also expected to find that the trials with small numbers (regardless of transformation) would be easier than the trials with large numbers. However, we found no effect of number size but of transformation. This is probably due to the differences in the method. Their question "how many" probably gave some clue as to what the answer needs to be. Also, offering children concrete alternatives (five or six), as in Sarnecka and Gelman's (2004) study, might be easier for children to answer than asking whether it is same or different in undefined terms. It might be that in the first case children think concrete, while in the second case the question is more abstract and more difficult. (However, sometimes concrete knowledge is derived from abstract, for example see Simons & Keil, 1995.) Besides the difference in method, the discrepancy could be due to cultural differences. The sample in this study consisted of Macedonian children whereas in other studies the sample consisted of American children. Perhaps because more attention is paid to children's formal schooling from an early age in the US, those children have better conceptual understanding.

Within each group there was no difference between the same transformation of different number size (that is to say, between small and large number numeric change and between small and large number non numeric change). This might be so because once children learn something about several numbers in a given context (for example, adding items), they apply this knowledge to all numbers by analogy (Goswami, 2001). Although they have rare encounters with large number words, when they do hear them, they apply the same rules as if they are small numbers.

Children's performance at chance for the non-quantitative trials is also very interesting. It is possible that the question did not make sense to the children, or that these transformation are unusual and not encountered everyday, thus children have no experience to draw on. Because children performed at chance for the non-quantitative transformations, the quantitative analysis was not very informative. Therefore we present a qualitative analysis of children's answers about the non-quantitative transformations.

For the non-quantitative transformation the cardinality principle knowers were more certain in their responses if they answered right. Those who answered right (that it is the same number) were making allusion to quantity in their follow up answers, demonstrating that they know what transformations are needed for the number to change. Here is an excerpt from one of the conversations with a girl:

> Experimenter: Why do you think it is the same number? (silence) I shook the box, should not that change the number?
>
> Girl: No, you did not put one inside.
>
> Experimenter: How can I make it a different number?
>
> Girl: Put one.
>
> Experimenter: What if I take one, (taking one out), now is it a different number?
>
> Girl: Mh (affirmative sound).

The subset knowers, on the other hand, were less certain in their answers. For example, when one child answered correctly about the non-quantitative transformation, the experimenter tried to see whether the child believed in his answer firmly. Here is an excerpt from that conversation:

> Experimenter: Should not the number change when I shake the box?
>
> Boy: Yes, but you didn't shake it hard enough. You need to do it like this (the child shakes the box).
>
> Experimenter: Oh, I see. So now it is a different number?
>
> Boy: Yes. Like this.
>
> Experimenter: Do you know what number it is now?
>
> Boy: Aaaa seventeen (thinking for a while to come up with an answer).

With some children, several demonstrations were done after the end of the session with a same number to show that after shaking the box there would still be three stars inside. After several trials and errors children learned to answer correctly for three, but when asked for five, they were giving wrong answers again, thus not demonstrating that they have understood that non-quantitative transformation is not accompanied by a change of the number word. This might mean that training has no effect, but that this skill is dependent on maturation only. However, this cannot be claimed because the purpose of this study was not training, and thus these several indications might be misleading.

Finally, a comment about a methodological issue. It might be argued that the pronunciation of the large number words is more difficult and thus a confound to the design. However, the results seem not to agree. It turned out that the children had no trouble performing on the quantitative trials of the task regardless of the number size, but they had trouble with the non-quantitative trials, again regardless of number size. This seems to indicate that using large number words which are presumably more difficult to pronounce did not prove to be a threat to the design.

CONCLUSION

This study had a goal to examine cardinality principle knowers and subset knowers understanding of how quantitative and non-quantitative transformations of a set affect the number. Both groups performed at chance for the non-quantitative transformations, meaning that they were guessing when these transformations were in question. For the quantitative part both groups performed above chance and they did not differ in their performance, except for the small number quantitative transformation. The children's performance on the quantitative transformations was relatively high. Whether the number was small or large did not make any difference.

It was hypothesized that the cardinality principle knowers would perform better than the subset knowers on the transformations upon large numbers. The results showed that there is no effect regarding the size of the number, but rather whether the transformation is quantitative or non-quantitative.

It is obvious from this paper that children's concept of number is present in both cardinality principle knowers and subset knowers, but it is not refined. They were answering correctly for the quantitative transformations, but were unsure about the non-quantitative transformations. They need to refine their ideas, that is, they need to realize that a non-quantitative transformation does not affect number. They were not sure whether it affects the number or not. Experience probably plays a major role, until their knowledge becomes common sense.

Whether children realize that quantitative changes of a set are accompanied by a change of the number, but not the non-quantitative ones, has educational implications. When we teach children adding and subtracting, we demonstrate these operations with examples such as adding items to a set or taking items away from a set. However, it might be helpful for children if we contrast these transformations with transformations which do not affect number words and quantities, such as rearranging the items. This might help children to realize that only non-quantitative changes of a set are accompanied by a change of the number word and quantity.

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