THAT DOESN'T COUNT: THE INTERFERENCE OF LANGUAGE IN THE DEVELOPMENT OF COUNTING MECHANISMS IN ENGLISH-SPEAKING PRESCHOOLERS[1]

DANIEL FRIEL

SWARTHMORE COLLEGE

SENIOR THESIS, DEPARTMENT OF LINGUISTICS, FALL 2009

0. ABSTRACT

Phenomena in the development of counting principles alongside language acquisition in preschoolers provide insight into mechanisms for quantifying entities in English. In particular, research has sought to discover the relationship between language acquisition and two phenomena – the ability to distinguish between parts and wholes and the ability to use containers to quantify substances like sand – in quantification tasks. I sought to discover how mastery of measure words like "cup" (in *cup* of sand) and "piece" (in *piece* of a fork) improve a child's ability to correctly quantify substances and broken objects. Shipley and Shepperson (1990), Sophian and Kailihiwa (1998) and Melgoza, Pogue & Barner (2008) showed that preschoolers do not discriminate between parts and wholes in counting broken objects. Huntley-Fenner (2001) showed that preschoolers cannot use containers to help differentiate amounts of substance-mass nouns like "sand" in difficult ratios. Instead, preschoolers prefer to count each discrete physical object as a count-noun unit ("fork") regardless of its whole/piece status ("whole fork" or "piece of a fork"). These findings beg further questions. Does mastery of either measure words or counting principles foster the development of the other? And if so, which one comes first? I collected original data to compare preschooler responses in three tasks and show that mastery of measure words does not improve performance in quantification tasks. Some subjects failed at a language-based quantification task but were successful in a non-linguistic quantification task, which suggests language as a constraining factor in the ability to effectively communicate about number.

[1] Many thanks are extended to Peggy Li for mentoring me and throughout the development and execution of this research project, Susan Carey and the Harvard Laboratory for Developmental Studies for offering me the internship during which I conducted the research, Donna Jo Napoli for helping me acquire that internship, and Vera Lee-Schoenfeld, K. David Harrison, and Jenna McCreery for guiding me throughout the writing process. Special thanks go to Robyn Churchill and family for giving me a place to stay while I conducted my research.

1. LINGUISTIC DISTINCTIONS IN COUNTING

For adults, choosing the proper units when talking about quantities is easy. Just as we know that a fork isn't *broked* (it's *broken*), we know that even when a fork is snapped in half, it shouldn't be called *two forks*. It's still just one fork, only broken into two pieces. Similarly, it's easy for adults to quantify substance-nouns, like *sand* and *water*, using containers. We count *three cups* of sand and *four bowls* of water, not *three sands* or *four waters*.

These concepts are simple, and even the exceptions are easily understood. Sometimes the distinction between an English *count-noun*[2] (the kind that we can assign numbers to without measure words) and an English *mass-noun* (the kind that requires a measure word in order to receive a number) isn't so categorical. Let's consider some food words that pinpoint ambiguous assignments. What about *tomato*? Of course, we can ask for somebody to cut up *two tomatoes*. But we can also ask for somebody to pass the [bowl of] *tomato*, where the *tomato* in question is a bowl of diced tomatoes. Indeed, *tomato* is a flexible noun – a noun that works as either a count-noun or a mass-noun, depending on context. It's important to note, however, that quantification rules still hold. When acting as a mass-noun, a flexible noun still takes a measure word (two *bowls of tomato*), even if it can act as a count-noun in other contexts.

Aside from standard count- and mass-nouns are the object-mass nouns. These nouns, like *silverware* and *mail*, are used to refer to a collection of discrete objects that together form an instance of the noun in question. For example, three forks, two knives, and a spoon together are *some silverware*, while each individual utensil can be labeled as either a fork, a knife, or a spoon

[2] An appendix with a glossary for terms used throughout the paper is available following section 4.

– or equivalently as a *piece of silverware*. But what about a fork that is broken in half? Each of these pieces is a *piece of a fork* or a *piece of a piece of silverware.*

For adults, this isn't hard either. An important distinction here is that when looking for a *piece* of furniture, one is looking for an intact unit of furniture, but when one is looking for a *piece* of a chair, one is looking for a broken piece of a chair (a broken piece of a piece of furniture). While this isn't the most salient instance of the part/whole distinction, it's one that is easily recognized by adults, testable in children, and therefore worth looking into for the purposes of this project.

2. PREVIOUS RESEARCH

There are a few puzzles here. First, how are preschoolers able to use the part/whole distinction in quantifying broken objects together with wholes? Second, how are preschoolers able to use containers to quantify substances without count-nouns? And finally, how does the child's ability to talk about these kinds of quantities correlate with the ability to use the correct technique? Extensive research has already sought answers to these questions. In this section, I will review those papers that were especially influential in the motivation of my research.

2.1 SHIPLEY AND SHEPPERSON (1989)

Shipley and Shepperson explored the style preferences of 3-6 year-olds in a series of counting tasks involving both broken objects and whole objects. The goal of the study was to determine whether children prefer to count each discrete physical object (DPO) as a whole unit in the array, or whether children prefer to include only the whole objects in the final count.

In addition, Shipley and Shepperson sought to determine how the arrangement of stimuli affects the chosen counting method. In particular, they explored the effect of placing broken pieces very closely together in order to indicate membership to the same original unit on the child's likelihood at counting each whole unit rather than discrete physical objects. Furthermore, the authors studied the effect of the wording of the task instructions on the child's answer. Finally, Shipley and Shepperson sought to decide either that the DPO bias (the preference for counting discrete physical objects), if it exists, is a product of a learning process or that it is an innate cognitive function.

Shipley and Shepperson put forth two hypotheses to explain the DPO bias. It is possible that preschoolers adhere to the rules of the typical learned counting procedure, which requires that he points to each item as it is enumerated out loud, in order, until each item has been assigned a number. A second explanation, which would require further cross-linguistic research to verify, indicates a bias that has nothing to do with language or counting: the DPO bias is innate.

The experiment seeks to find one of two results. It is possible that a child's preferred counting technique is governed by an abstraction principle that results in a lack of discrimination between broken pieces and whole objects in a counting task. Under the governance of such a principle, the kind of unit is not important; if an entity is a salient physical object, it will receive its own count in the enumeration process. That is, it will be determined either that there is a bias toward counting discrete physical objects or that there is no such bias.

If indeed there is a bias for counting discrete physical objects and it is also the case that younger children use a DPO counting method more often than do older children, then the canonical countable entity for 3- and 4-year old children is the DPO – not the whole functional unit – and therefore the younger children do not make part-whole distinctions.

The study, comprised of eight tasks, was carried out as follows. In experiment 1, each subject was presented with a linear array of four whole objects and two broken objects. The detached parts of the broken object were arranged alternately separated or aligned. Shipley and Shepperson found that 73% of children preferred a DPO counting approach. However, older children were less likely to choose this technique than younger children. Heterogeneous-familiar stimuli (more than one kind of broken objects) were more likely to be counted separately than were homogenous-familiar stimuli (77% vs 68%), while broken pieces that were spatially separated were more likely to be counted separately when they were arranged separately than when they were aligned (89% vs 56%).

In experiment 2, the first task was replicated with the added designation of two broken pieces as a whole object in order to make sure that the child was aware that the broken pieces once formed a whole object. The percentage of count-all responses decreased from 67% to 38% after the object was explicitly identified as forming one labeled entity. However, the number of count-whole responses (in which the child ignored the broken parts entirely) also increased.

In experiment 3, the subjects were presented with an array of objects that contrasted either at the basic, sub-basic, or color level. That is, a set of two objects may have been identical except for color, members of two different classes of the same type of object, or two different objects altogether. The subjects were asked to respond to questions that sought to identify the number of classes of objects in the array. In this task, older children were better than younger children at providing the correct answer. Shipley and Shepperson indicated that the older children "indicated awareness of the classes."

Experiment 4, an identification of entities task, was a replication of experiment 3 with added prompts. When an incorrect answer was given, the objects were reorganized by class and the question was given again. If the answer was incorrect again, the reorganized groups were identified by class. However, the suggestions did not assist most children in arriving at the correct answers.

In experiment 5, further encouragement was provided. If the child answered incorrectly, the experimenter prompted the child by asking again how many classes were represented among the stimuli and demonstrated the correct count by counting the classes aloud. These suggestions were helpful for some children. The errors were identified in three patterns: early insight (the prompts in task 4 improved answers), late insight (the prompts in task 5 improved answers), and no insight (the prompts were not helpful at all). Notably, there were some children who were able to correctly identify classes but whose answers were still influenced by the DPO bias despite the demonstrations.

Experiment 6 was a replication of experiment 3, but it asked children to count classes represented in a list of objects read aloud, without physical stimuli. Children performed better in this task than they did in experiment 3, which suggests that the visual stimuli distract the children from making correct judgments and that language is less distracting than visual stimuli.

In experiment 7, the children were asked to identify the number of classes in an array of objects, which was the same as the number of objects (one exemplar per class). Even though some children first responded by naming the different objects in the array, they all ultimately answered correctly. Shipley and Shepperson noted an important interaction in that the numerosity of visible exemplars of a given class makes it more difficult for a child to count the number of classes in the array.

In experiment 8, children were asked to name the different classes in a set of objects. Shipley and Shepperson found that older children gave more class-name responses than the younger children. Meanwhile, younger children were more likely to name or describe individual objects. Since subjects had already participated in counting tasks, there may have been a bias toward processing of individual objects. It was concluded that the DPO bias is not a result of the learning-to-count process, but rather it is a pre-counting bias.

The results provide a comprehensive view of what principles govern counting and class-naming of objects by children aged three to five – results that allow important assumptions to be made during the creation of my project. Shipley and Shepperson ultimately report that the DPO bias is a pre-linguistic disposition in children, and it is found both in counting and non-counting tasks. The DPO bias and variations in arrangement override the effects of the wording of the question.

2.2 Sophian and Kailihiwa (1998)

A study by Sophian and Kailihiwa similar to the work of Shipley and Shepperson aims to find underlying principles that govern kind-based counting in English-speaking preschoolers. Sophian and Kailihiwa look to determine how children define counting units in quantification tasks based on instructions given. Broken objects and family-unit distinctions are key points of focus.

In the first task, subjects were asked to count either families or members of a family of objects. The subjects received training to ensure that it was clear what was to be counted. The results of this task ensure that the subject is comfortable with the correct sequence of numbers. Children always succeeded on the individual-count trials, but they varied in their responses to family-count trials. The 4-year-olds showed a stronger preference toward counting individual terms in the family-count tasks than the 5-year-olds.

In the second task, each subject was asked to count objects in an array. Some of the objects were whole, and some were broken. In one type of trial, the subject was prompted to count the number of whole objects in the array, and in the other trials, the subject was prompted to count the discrete "things" in the array. Seven counting patterns emerged from the study, depending on a child's preference to count only whole objects, to count only pieces, to count all discrete physical objects, to ignore intact items, or to ignore broken items. The delineation of the counting patterns was such that each subject was consistent in using one type of count. Again, counting of discrete items was more common among the 4-year-olds. Some of the older children adopted a count-whole technique, in which broken objects were completely ignored.

In the third task, the subjects were asked to count both the number of wholes and the number of pieces in an array of objects, of which some were whole and some were broken. Subjects in the third task were again consistent in choosing a counting pattern. Older children exhibited a greater ability to choose a new counting pattern between questions than did younger children, which indicates sensitivity to the semantics of the instructions. That is, their counts increased when asked to count all pieces rather than just wholes.

Sophian and Kailihiwa provide data that hints at underlying conceptual limitations that prevent young English-speaking children from being able to correctly interpret linguistic instructions to count objects in an array. Some subjects who were able to correctly identify the family of an individual were not able to count the number of families. That is, even young children who were clearly able to delineate different families did not take them into consideration when enumerating members of these families in the quantification tasks.

2.3 Melgoza, Pogue, and Barner (2008)

Melgoza, Pogue, and Barner developed a study to find out the extent of the DPO bias in broken object quantification. By using a quantity judgment task based on the work of Barner and Snedeker (2005), the study distracts subjects from defaulting to learned counting techniques by simply asking which of two arrays has *more* of a given stimuli. This way, if the preference for counting DPOs is due to interference of learned counting techniques, the subjects will be less likely to count DPOs in the quantity judgment task.

In each trial, two figurines – Farmer Brown and Captain Blue – were arranged on a table, each with his own array of objects. The two arrays were consistently comprised of two whole objects and three broken pieces of a single object, and the arrays were counterbalanced with the figurines across trials. Whole objects and broken pieces were always presented in a 2:3 ratio such that one figurine had two whole objects and the other figurine had three broken pieces of a single object of the same type.

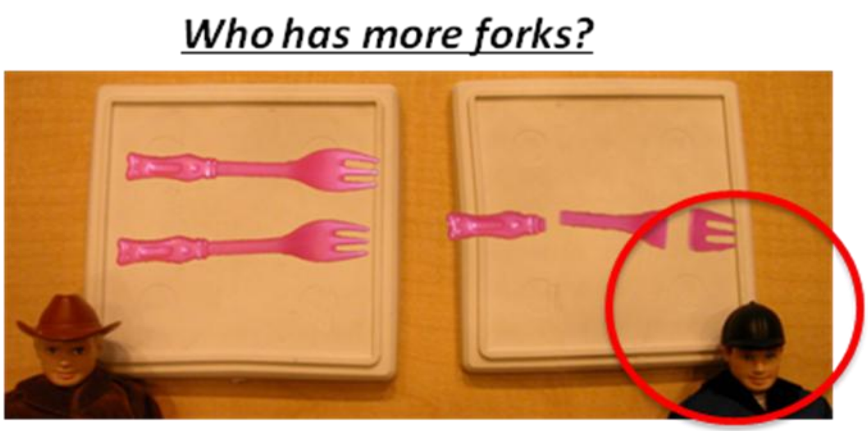

Figure 1: A typical choice governed by the preference to count discrete physical objects in a who-has-more task.

Melgoza, Pogue and Barner showed that the DPO bias exists not only in give-a-number tasks, but also in quantity judgment tasks, and furthermore, in simple naming tasks. This finding is critical in beginning to understand the interaction between language and counting in the acquisition period. If a child does not make distinctions between parts and wholes that correctly qualify an item as one or the other, it is to be expected that he falls victim to the DPO bias in quantity judgment tasks.

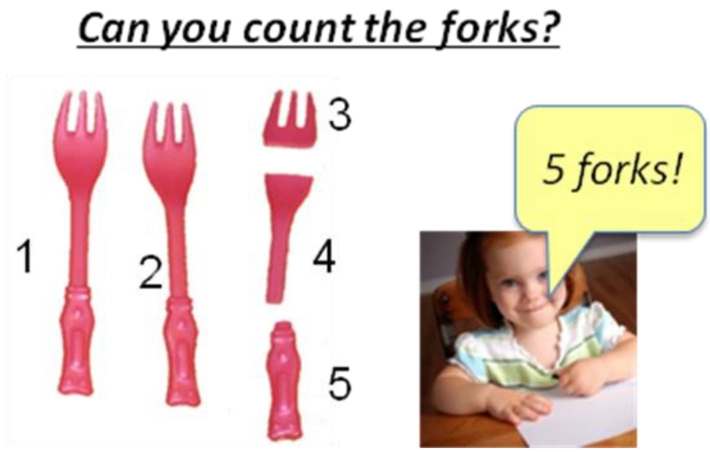

Figure 2: A typical response governed by the preference to count DPOs in a give-a-number task.

2.4 Huntley-Fenner (2001)

Huntley-Fenner showed that preschoolers are unable to quantify substances using containers. In a quantity judgment task that required a subject to choose which of two arrays had more of a given stimulus, he showed that in a 2:3 ratio (a difficult ratio to distinguish), preschoolers are unable to determine which of two piles of sand has more. More importantly, however, he showed that even when the sand is put into cups, preschoolers are still not able to correctly decide which array has more sand, even though they are able to correctly decide which has more cups.

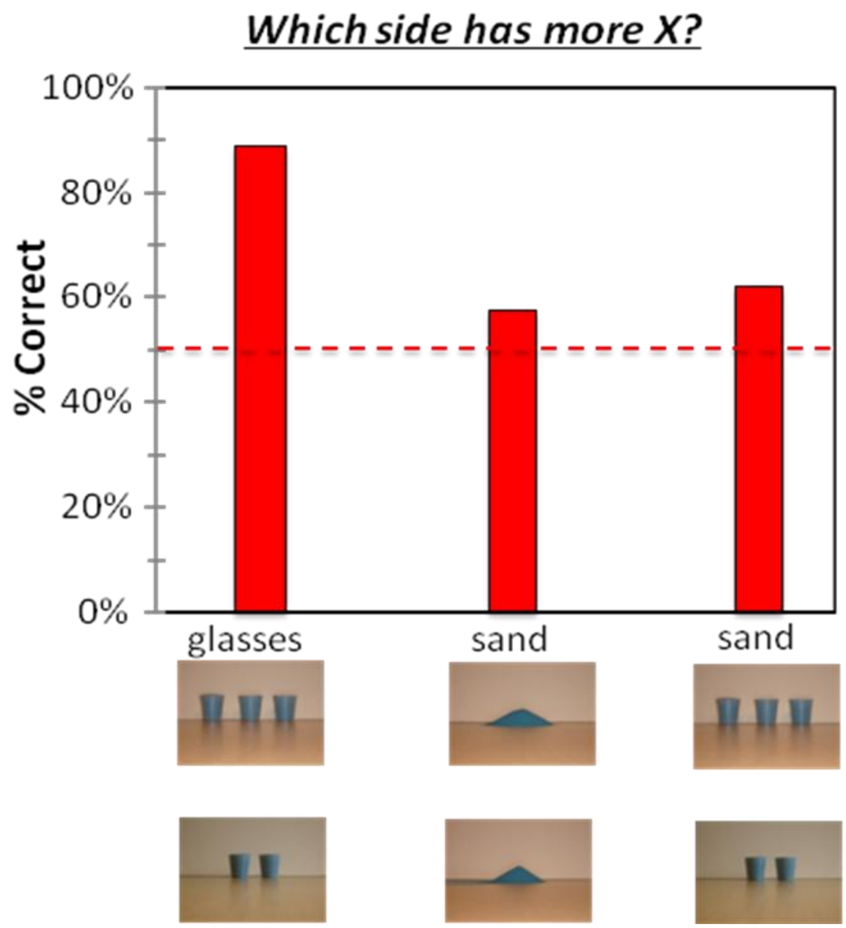

Figure 3: Results of Huntley-Fenner's who-has-more task.

3. Current research

What we have are two very different phenomena. There are inconsistencies in the counting strategies between preschoolers and adults in both quantifying broken objects and quantifying substances. Preschoolers, who are unable to apply techniques to correctly quantify substances or broken objects, ultimately emerge as adults competent in both language and counting. But which comes first?

I aimed to investigate the interaction between language acquisition and the acquisition of counting principles. Three tasks were developed as a part of a within-subjects design that would gauge each subject's ability to quantify both broken objects and substances together with a language assessment that would offer some insight into whether mastery of measure words like *cup*, *box*, *piece*, and *whole* correlates with high scores on the quantification tasks.

3.0 SUBJECT POOL

The 29 subjects ranged in age from 3;6 to 5;4. They were recruited from a standing database of over 7000 compiled by the Laboratory for Developmental Studies at Harvard University, from cold recruiting at the Boston Children's Museum, from cold recruiting at the Boston Museum of Science, and from regulated recruiting at local daycare facilities.

3.1 THE EXPERIMENT

3.1.1 TASK 1: QUANTITY JUDGMENT

Components of this task are attempts at replicating the data of Huntley-Fenner (2001), Shipley and Shepperson (1990), and Melgoza, Pogue and Barner (2008).

This task combined broken objects and substances in a "who has more?" design. The same figurines – Farmer Brown and Captain Blue – that were used by Melgoza, Pogue and Barner were used in the task, so that each array of entities was assigned to one of the two figurines for the purposes of comparison. Three types of trials were developed to assess ability.

The first type of trials gauged the subject's counting competency by using only whole objects. Stimuli included three types of plastic cups and one type of plastic cup filled with one of three colors of sand. Cups were assigned to the figurines in a 2:3 ratio so that in each trial, one had two cups, and the other had three cups. In these trials, the subject was asked which of the two figurines had more cups.

The second batch of trials placed broken objects alongside whole objects of the same type. Stimuli included plastic forks, foam balls, and plastic plates. Objects were assigned to the figurines in a 2:3 ratio – two wholes and three pieces of a single object – so that in each trial, one had two whole objects, and the other had three broken pieces of an object. In these trials, the subject was asked which of the two figurines had more forks, balls, or plates.

The third batch of trials explored the ability of the subject to compare quantities of sand. Quantities of sand in a 2:3 cups ratio were assigned to the figurines either in cups or in piles. So, in half of the trials, one figurine had a pile of sand that amounted to 3 cups, and the other had a pile of sand that amounted to 2 cups. In the other trials, the figurines had the same amounts of sand, but the sand was inside the cups. In these trials, the subject was asked which of the two figurines had more sand.

3.1.2 TASK 2: QUANTITY TRACKING

This task was developed to attempt to reproduce the environment in the quantity judgment task in the absence of linguistic interference.

A cardboard box was constructed such that flaps concealed the contents of the box, leaving a center area visible to the subject. The game was designed such that the subject was presented with an array of three objects. The three objects were placed inside the box, one at a time. Then, two or three of the objects were removed from the box. The task given was to determine whether the box was empty or whether there was still something inside after all transactions were complete. If the subject decided that there was still something inside, he was prompted to describe what was inside. If the subject was unable to quantify what was left, photographs of three plausible responses (including the correct response) were provided so that the subject could make a decision without the experimenter using linguistic cues. This allowed for the development of two scores: an objective score, which measured simply whether the subject was correct in judging the emptiness of the box, and a stringent score, which measured whether the subject was able to judge exactly what was inside the box (here, if the subject knew there was something left inside the box, but answered incorrectly as to how *much* was left inside, his answer was marked as incorrect).

Again, three types of trials were developed to assess ability. The first batch of trials gauged the subject's ability to track whole objects as they were taken in and out of the box. Stimuli included two kinds of plastic cups, and two trials were conducted for each type of cup. In all trials, three cups were presented in an array and then placed inside the box. In one trial, all three cups were subsequently removed. In the other trial, only two of the cups were removed, leaving one cup still inside the box.

The second batch of trials tested the subject's ability to use cups to help track quantities of sand. Stimuli included plastic cups filled with either blue sand or yellow sand. Two trials were conducted for each color of sand. In all trials, three cups filled with sand were presented in an array. The experimenter poured the sand into the box, one cup at a time, until there were three empty cups on the table and three cups' worth of sand inside the box. In one type of trial, two cups of sand were scooped out of the box, leaving one cup still empty. In another type of trial, three cups of sand were scooped out of the box, leaving no empty cups.

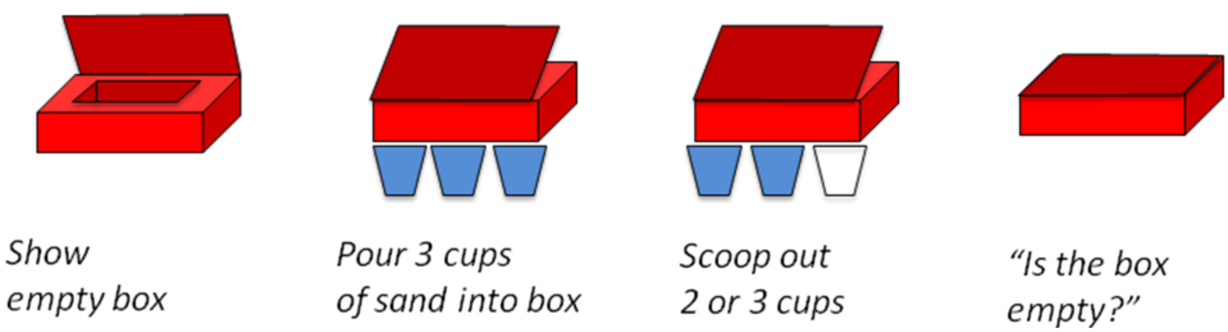

Figure 4: Study design in quantity tracking task.

The third batch of trials explored the subject's ability to track broken objects. Stimuli included two kinds of plastic cups. In all trials, three intact cups were presented to the subject in an array and then inserted into the box one at a time. The experiment used a pair of scissors to "cut" the cups inside the box, out of view of the subject. (Pre-cut cups were stored behind flaps in the box for ease of experimentation). The cups were cut horizontally, such that each cup was split into a top ring-like piece and a bottom piece that was a shorter cup. In one type of trial, four cup pieces were removed from the box – two tops and two bottoms, yielding two cups. In the other type of trial, all six cup pieces were removed from the box – three tops and three bottoms, yielding all three cups.

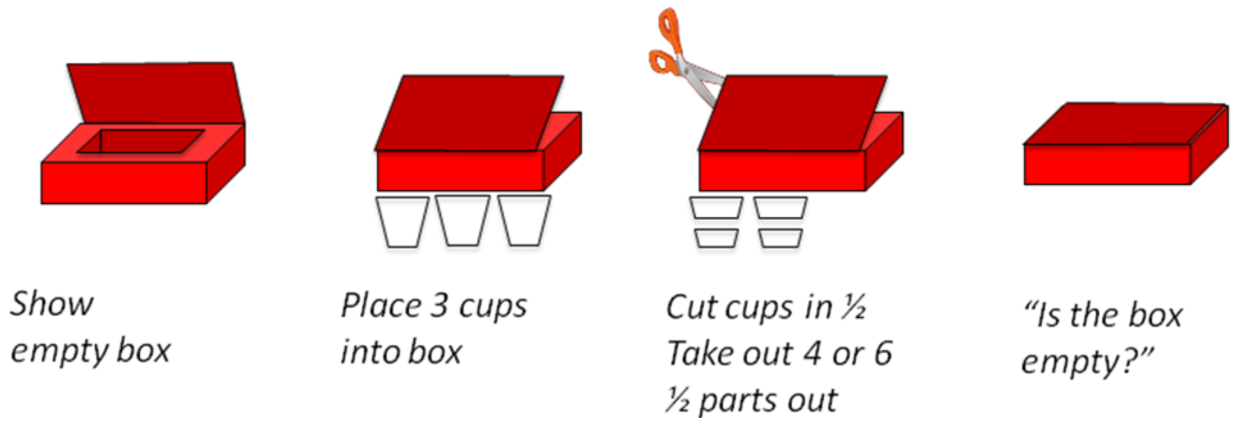

Figure 5: Study design in quantity tracking task.

3.1.3 TASK 3: LANGUAGE ASSESSMENT

This task was designed to test the subject's mastery of lexical distinctions between wholes, parts, groups of wholes, and groups of parts. A game was developed in which the subject was asked to help the experimenter select appropriate images to be used in a picture book that fit descriptions given by the experimenter. Fourteen stimuli were slotted into one of two groups: flexible nouns (8) and object-mass nouns (6). The subject was trained to ensure that he was familiar with the word corresponding to each stimulus. The fourteen stimuli were images of apples, bananas, eggs, cucumbers, pumpkins, potatoes, doughnuts, tomatoes, silverware, mail, furniture, clothing, footwear, and jewelry.

For each stimulus, the subject was asked to select which of four images would be appropriate to use for a given page. The four images corresponded to four syntactic constructions of the same noun X: one X, one piece of X, one box of X, and one box of Xs.

However, in each trial, the subject was only asked for one of the constructions. Thus, only one of the four images should have been selected in each trial.

	Individual	Collection of Individuals
Whole		
Part		

Figure 5: Four images of the flexible noun *apple*.

The primary focus in this task was on the eight flexible noun stimuli. The object-mass nouns present more difficult distinctions. Again, because these nouns refer to collections of DPOs, the construction *one piece of X* corresponds to an image of a whole item. For example, one piece of silverware only can be illustrated by an image of an intact fork (or spoon or knife), whereas a piece of a piece of silverware can be illustrated by a piece of a fork.

	Individual	Collection of Individuals
Whole		
Part		

Figure 6: Four images of the object-mass noun *jewelry*.

3.2 Results

All attempts to replicate existing findings were successful with the exception of Huntley-Fenner's quantity judgment data, in which he determined that preschoolers are unable to use containers to help quantify sand in a 2:3 ratio.

Huntley-Fenner reported that when asked which of two arrays has more cups, preschoolers have no trouble choosing three cups over two, regardless of whether the cups are full of sand. However, he also reported that when the cups were full of sand and the subject was asked which array had more sand, the children were no better at choosing the correct side than when the sand was presented in piles in the same ratio.

My findings (see figure 7) showed that preschoolers took very easily to using cups to help quantify sand in a 2:3 ratio. Subjects answered correctly in 100% of trials with empty cups and 98% of trials with cups full of sand. However, only about two thirds of the responses in the trials with sand in piles in a 2:3 ratio were correct, indicating that quantification in cups was helpful in determining which figurine had more sand. I also found that scores in the quantity judgment task did not significantly improve after a threshold of 4.5 years, as reported by Huntley-Fenner, which hints at a gradual increase in ability to correctly use counting techniques rather than a timely acquisition of the concept at a given age.

Percent correct	Sand Piles	Sand Cups	Broken Objects
3-4.5 years	63%	96%	42%
4.5+ years	77%	100%	47%

Table 1: Age effects in quantity judgment task.

I was able to accurately replicate the findings of Melgoza, Pogue and Barner (2008). About half of all responses corresponded with a DPO bias in the broken object trials. Some subjects used a count-whole technique in some trials but a count-DPO technique in other trials, which supports the finding put forth by Shipley and Shepperson that physical stimuli can be a distraction for preschoolers that ultimately disrupts their ability to count.

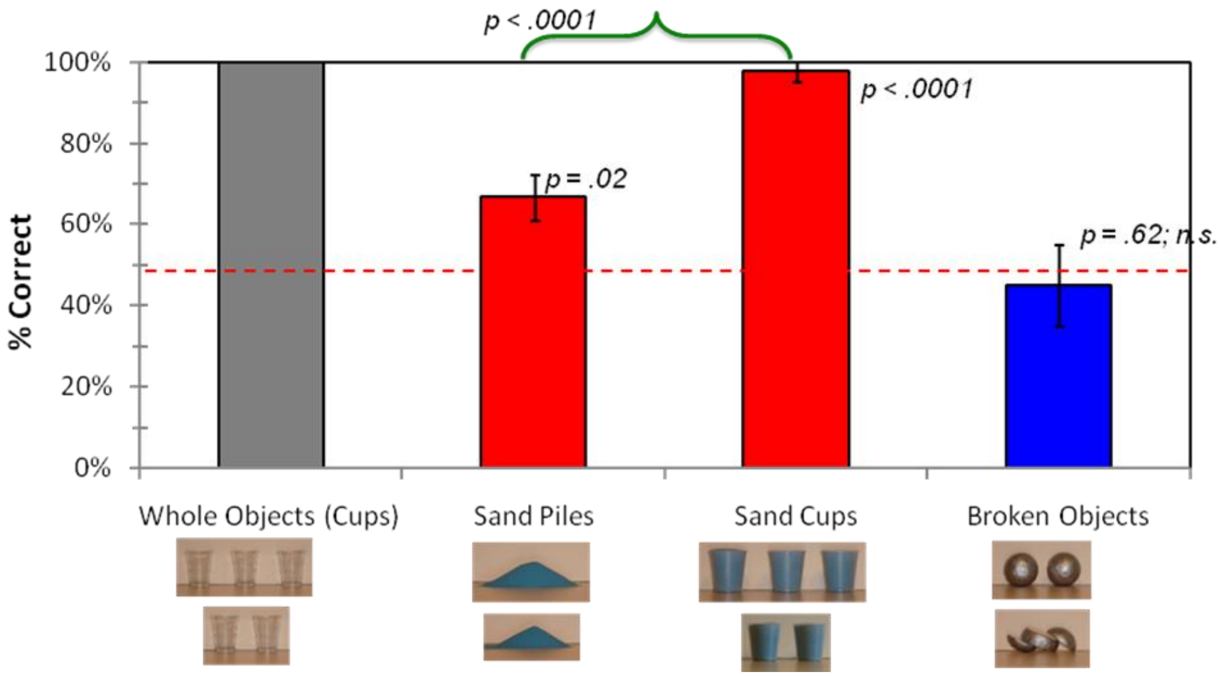

Figure 7: Results from the quantity judgment task.

In the quantity tracking study (see figure 8), 95% of the responses in whole object trials were correct, indicating that the added difficulty of memorizing the number of items placed inside the box was small. Trials involving cups of sand that were poured into and then scooped out of the box were also quite easy; 88% of responses were correct. Subjects had difficulty with broken object trials. In broken object trials in which the box was not empty, eight subjects responded that the box was indeed empty. This suggests that the subjects used a DPO preference in counting the cups. In these trials, three cups were put into the box, cut in half, and removed. Under a DPO bias, it makes sense to respond that the box is empty after four halves are removed. Because the number of items removed was not less than the number of items put into the box, it is assumed that the box is empty.

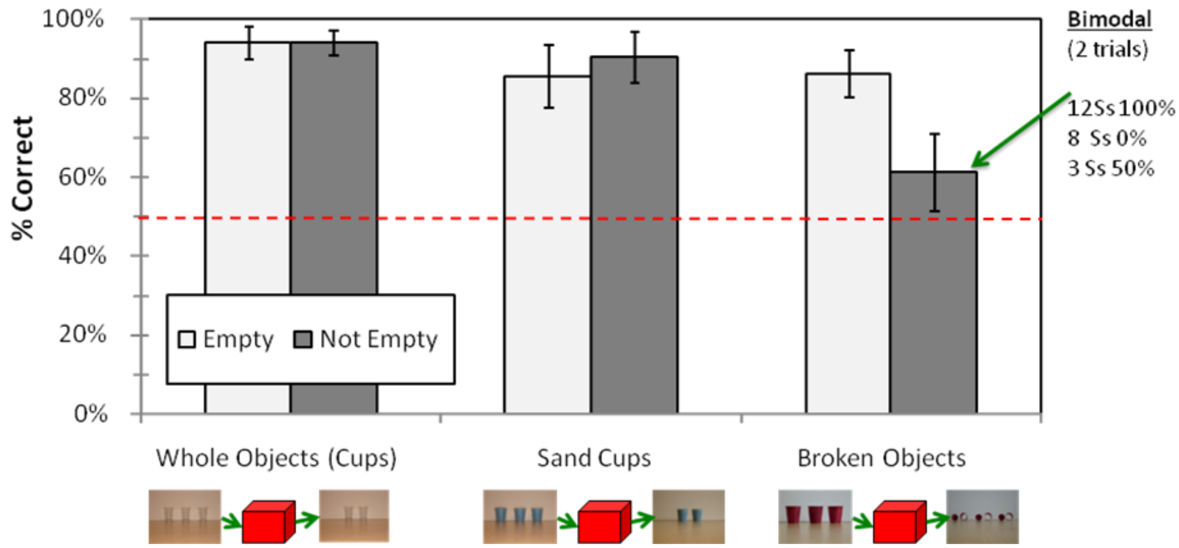

Figure 8: Results from quantity tracking task.

After eliminating language from the quantification task and creating the quantity tracking task, I searched for an improvement in scores, despite the added memorization component associated with the box design. Under the hypothesis that language is a constraining factor in the development of counting techniques, it was predicted that scores would improve once language was eliminated from the experimental task.

However, only in broken object trials were subjects more likely to succeed in quantity tracking than in quantity judgment (both tasks were easy across sand trials). There was no significant difference between performance in quantity judgment and quantity tracking in either whole object trials or sand trials.

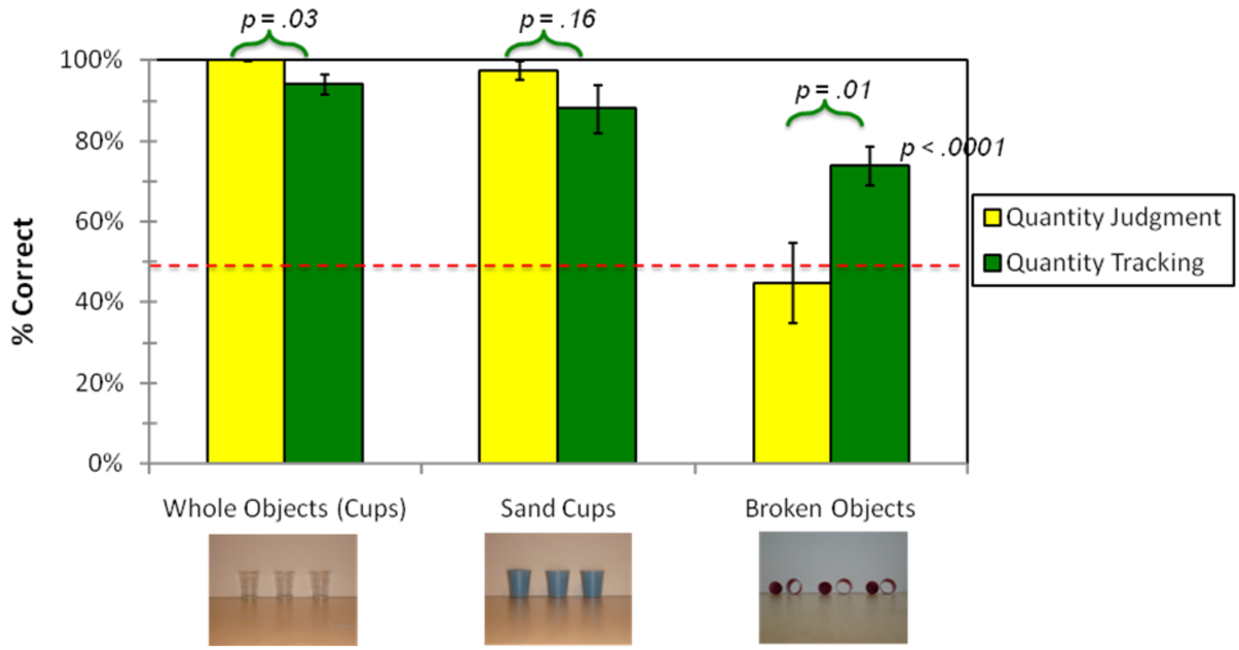

Figure 9: Results from quantity judgment and quantity tracking tasks, pointing out improvement in quantity tracking within broken object trials.

The language assessment task showed that preschoolers were sensitive to the distinction between wholes and parts, but not to the distinction between a box of wholes and a box of parts. Still, about half of the subjects only made distinctions between [+box] and [-box], and in fact, this was the only distinction made consistently in the subjects' answers in the object-mass noun trials. Some responses indicated no distinction between any variants of the stimuli.

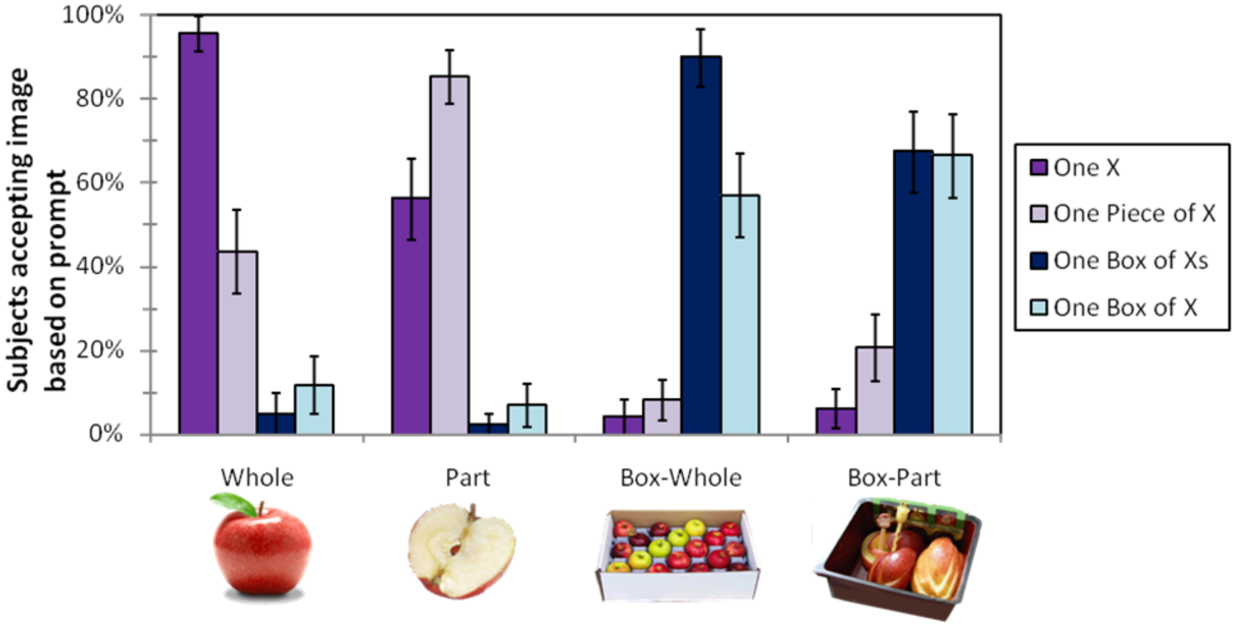

Figure 10: Results from the flexible noun trials in the language assessment task.

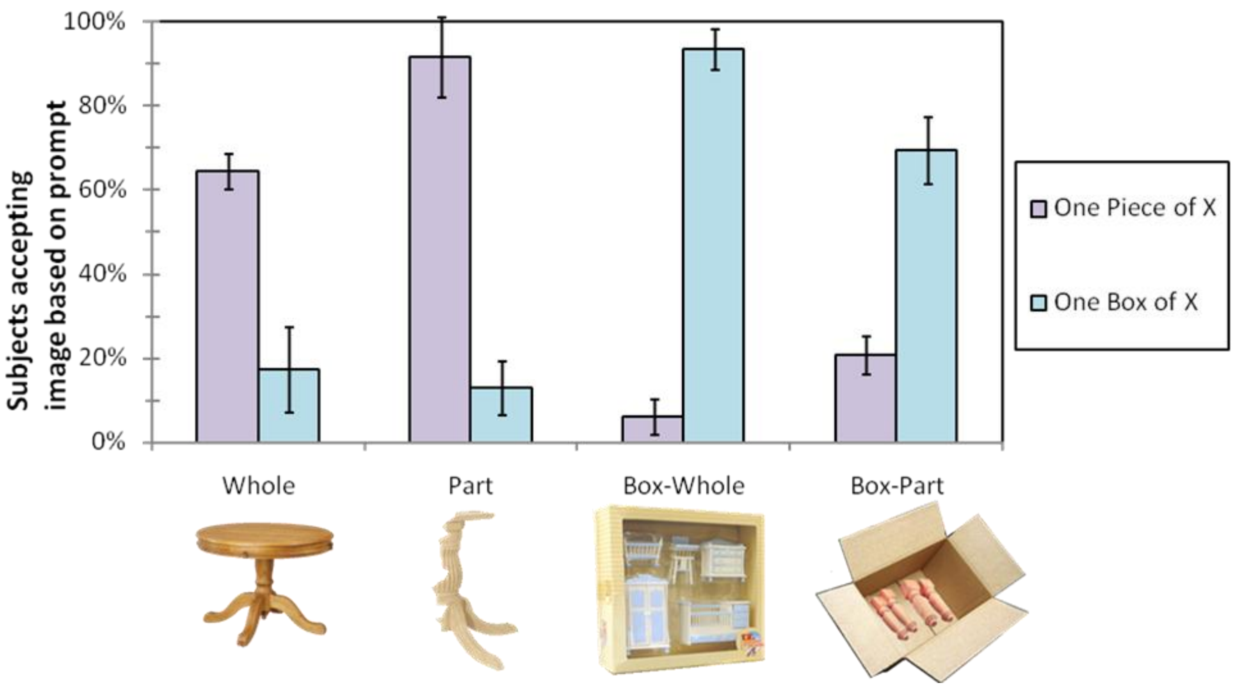

Figure 11: Results from the object-mass noun trials of the language assessment task.

Scores measuring the number of correct answers across all trials were calculated for each subject in each task in order to search for correlations between performance on quantity judgment, quantity tracking and language assessment. However, none of the scores were useful in predicting any of the other scores. Even age was insignificant in predicting scores in any of the tasks.

In particular, the ability to make linguistic distinctions between *one X* and *one piece of X* does not make a preschooler more likely to make part-whole distinctions in quantification tasks. That is, even among subjects who answered correctly for most or all of the language assessment prompts, there was no indication of increased ability to count in the quantification tasks. Indeed, some of the subjects scored above average in the quantification tasks and below average on the language assessment, while others were below average in the quantification tasks but scored well in the language assessment.

4. CONCLUSION AND RESIDUAL ISSUES

The results suggest that language acquisition and the acquisition of counting principles are at least somewhat disjoint, which of course, has been proposed by many theorists prior to the inception of my project and the motivators for my project. However, if neither language acquisition nor counting is a good predictor for the other, then why was it easier for subjects to quantify broken objects in the quantity tracking task than in the quantity judgment task, even with the added difficulty of the memorization component?

The effects of the ordering of the three tasks may have led to more conclusive findings. By presenting a further developed version of the language assessment task first, it may be possible to train the subjects to be sensitive to making part-whole distinctions. By giving feedback to language assessment responses, a subject may be inclined to formulate more educated answers in the quantification tasks, yielding better performance.

Similarly, perhaps physical manipulation of the stimuli could encourage different answers. Shipley and Shepperson showed that the presentation of stimuli has effect on answers in quantification tasks. It is possible that the DPO bias is preferred by virtue of some innateness. Perhaps then, children who haven't yet learned how to properly count need some other reason to answer contrary to the suggestion of the DPO bias. This could be done rather simply: arrange broken objects so that they are nearly touching – so that it's clear that they once formed a whole object. Future work could explore the effect of distance between broken objects as well as the effect of moving the pieces closer together until they touch, in the subject's view, in eliciting responses free of the DPO bias.

Meanwhile, though the subject pool was similar to those of the original studies in age, it was not representative of average preschoolers. A self-selecting group, many of the subjects were the children of professors and scored much higher than one would expect a subject of this age to score on one or more of the tasks.

A promising area of further research is bilingual acquisition. In particular, how does competency in classifier languages, which require a lexical entity to classify a noun based on its definition, influence the development of the linguistic part-whole distinction in English? If it hinders the development of this concept, we expect that children bilingual in, for example, Mandarin and English to perform more poorly than English monolinguals on these tasks.

APPENDIX: GLOSSARY

Count noun	A noun compatible with numbers without measure words. Example: book. Three books. Four books.
Discrete physical object (DPO)	An individual tangible item without regard its membership in a given noun class (i.e. count-nouns, mass-nouns)
Family-unit distinctions	Taxonomic distinctions made between members of classes, and classes within a family. Example: *Tiger* is a member of the class *cat*, which is a member of the family *animal*.
Kind-based strategy	A strategy of counting only whole functional units as accurate examples of a given noun. Judgments governed by this strategy do not count broken objects as examples of the object. Example: three broken pieces of a fork are not three forks.
Language assessment	A task that requires the subject to select pictures that would be appropriate to use for a given requirement for a page in a picture book
Object-mass noun	A noun that refers to a collection of whole discrete physical objects. Example: silverware.
Quantity judgment	"Who has more?" tasks that ask subjects to compare quantities in two arrays

Quantity tracking	A task that requires the subject to decide whether a box is devoid of stimuli after a series of transactions into and out of the box
Substance noun	A noun compatible with numbers with the requirement of a measure word. Example: sand. Three cups of sand. Four cups of sand. *Three sands. *Four sands.

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ADDENDUM

Following are slides that I developed for a research poster session and talk in the Department of Psychology at Harvard University on August 6, 2009.

I presented a modified version of this talk to Professor Lee-Schoenfeld, Professor Harrison, and the senior majors in the Department of Linguistics at Swarthmore College on October 2, 2009.

Credit is also due to Peggy Li for helping me streamline these slides.

Language and Quantification:

the relationship between mastery of measure words and counting techniques

Daniel Friel, Swarthmore College
Mentors: Peggy Li, Post-doctoral fellow, Harvard University
Professor Susan Carey, Harvard University

Counting & Measurement Units

Whenever you can, count.

-- Francis Galton

Smart
My dad gave me one dollar bill
'Cause I'm his smartest son,
And I swapped it for two shiny quarters
'Cause two is more than one!

And then I took the quarters
And traded them to Lou
For three dimes -- I guess he didn't know
That three is more than two!

Just then, along came old blind Bates
And just 'cause he can't see
He gave me four nickels for my three dimes,
And four is more than three!
…

-- Excerpt of Poem by Shel Silverstein

Mastery of the initial concept of the unit is the most important step in the formation of elementary arithmetic concepts (they are all built on the unit or presuppose it).

-- Gal'perin & Georgiev 1969, p. 197

Previous Research

Two Phenomena:

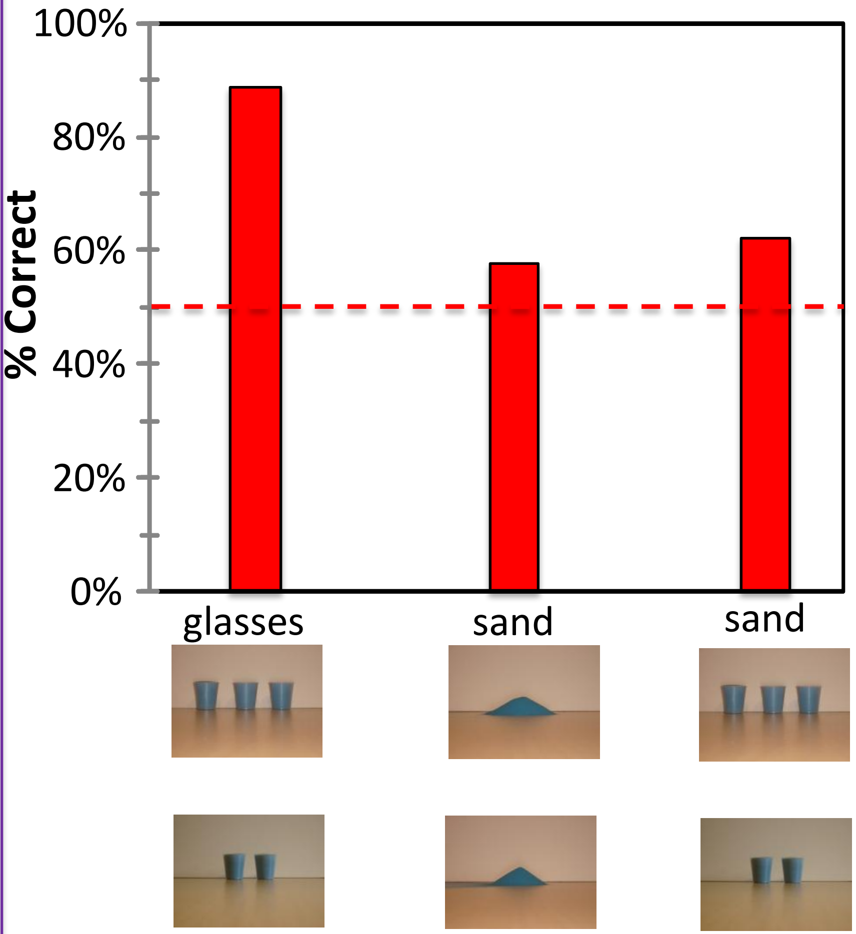
- Huntley-Fenner (2001)
  - Containers do not help preschoolers quantify substances
- Shipley & Shepperson (1990)

  (also Wagner & Carey, 2003; Sophian & Kailihiwa, 1998; Melgoza, Pogue, & Barner, 2008)
  - 4-year-olds do not prefer a kind-based strategy in counting broken objects
  - 4-year-olds are biased to count and quantify over spatio-temporally discrete individuals

Phenomenon #1

Huntley-Fenner (2001)'s data
of 3-4.5 yr-old children

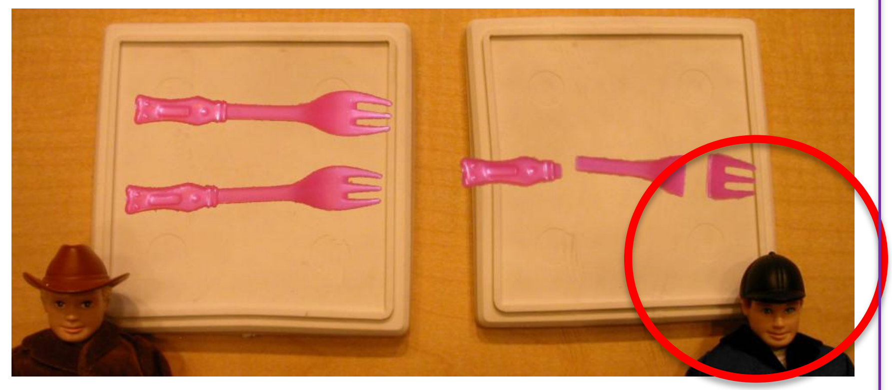
Which side has more X?



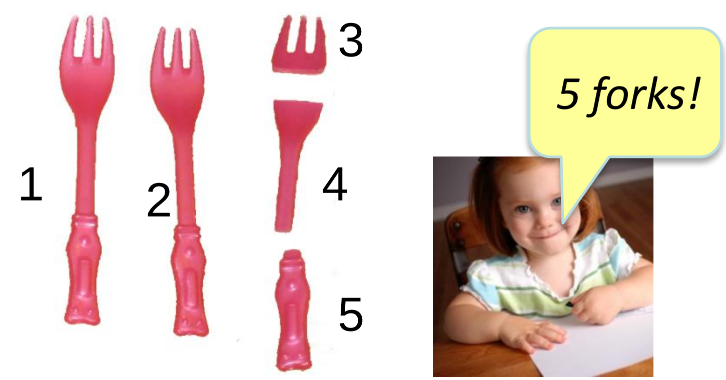
Phenomenon #2

Melgoza, Pogue, & Barner (2008)'s data

Who has more forks?



Can you count the forks?



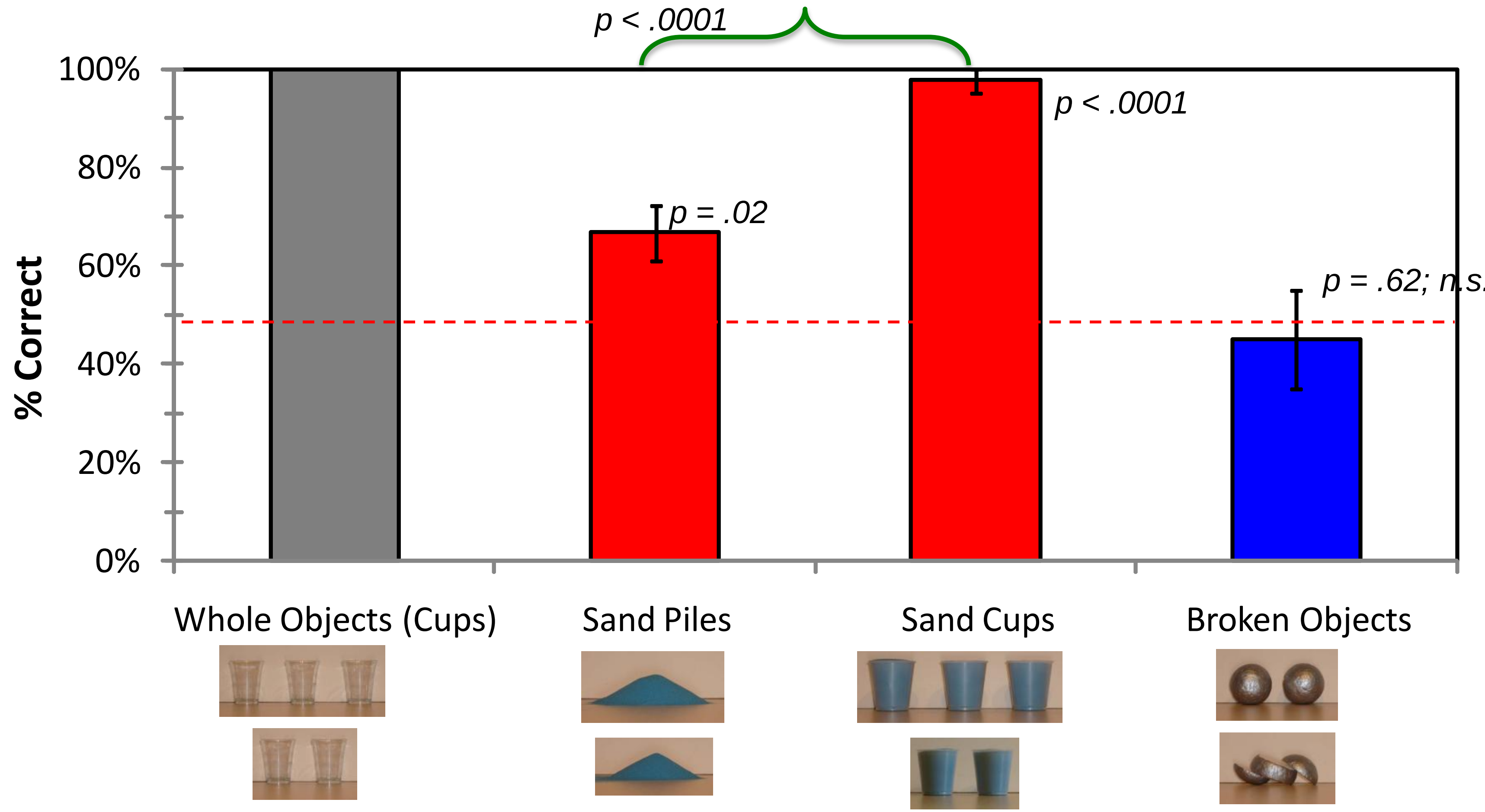
The Puzzle

- Sand Quantification:
  - Are children unable to use containers as units for quantifying substances?
- Broken Object Quantification:
  - Are children able to discriminate between a “whole” object and a “part”?
- Language Ability:
  - Does the mastery of measure words like “piece” and “box” improve performance on these two tasks?

Current Research

- Task1: Quantity Judgment (replication)
  - N=27, (Age range: 3.2-5.4 years. Mean age: 4.6 years)
- Task 2: Quantity Tracking (memory representation)
  - Can we observe the phenomena in other tasks?
  - N=27, (Age range: 3.2-5.4 years. Mean age: 4.6 years)
- Task 3: Language Assessment
  - How is language development related to performance on Tasks 1 & 2?
  - N=24, (Age range: 3.2-5.4 years. Mean age: 4.5 years)

Task 1 Results

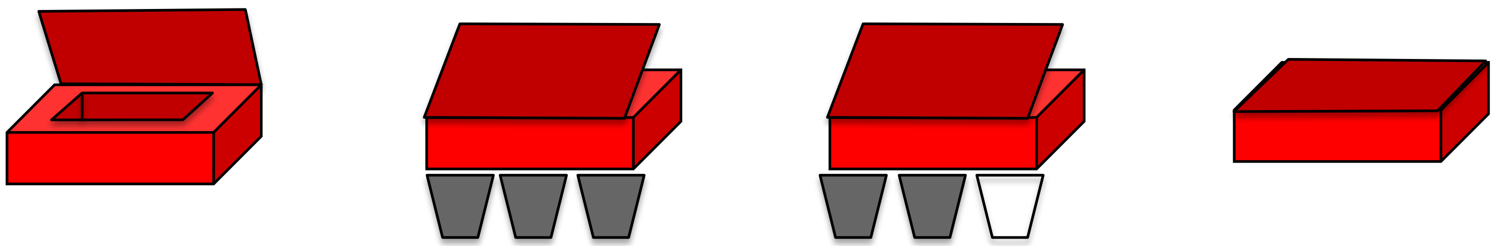


Stimulus type	Replication?
broken objects	✓
sand	✗

Percent correct	Sand Piles	Sand Cups	Broken Objects
3-4.5 years	63%	96%	42%
4.5+ years	77%	100%	47%

- **No significant statistical difference** between means of the each age group
- This hints at a gradual increase in ability rather than acquisition of concept at age 4.5 years

Quantity Tracking

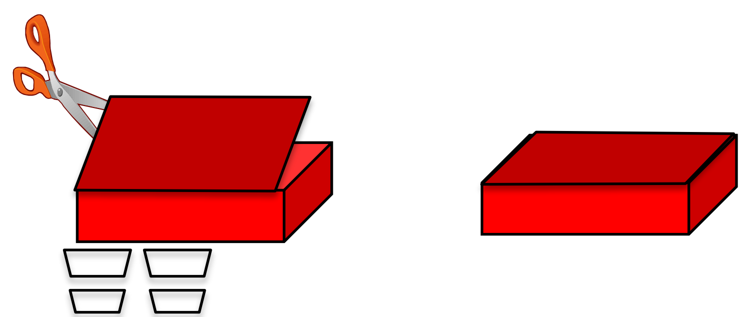


Show empty box

Pour 3 cups of sand into box

Scoop out 2 or 3 cups

"Is the box empty?"



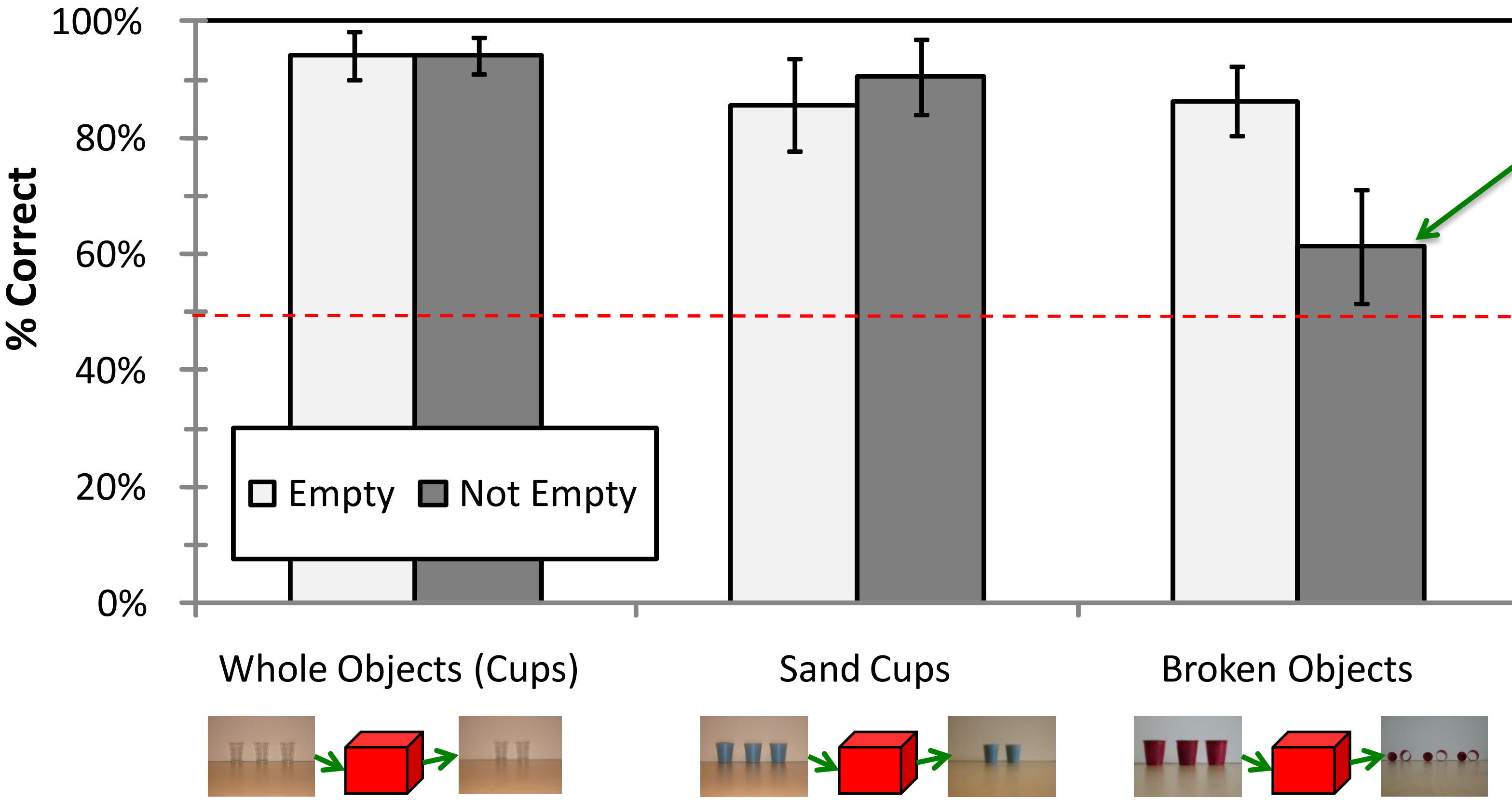
Show empty box

Place 3 cups into box

Cut cups in ½
Take out 4 or 6 ½ parts out

"Is the box empty?"

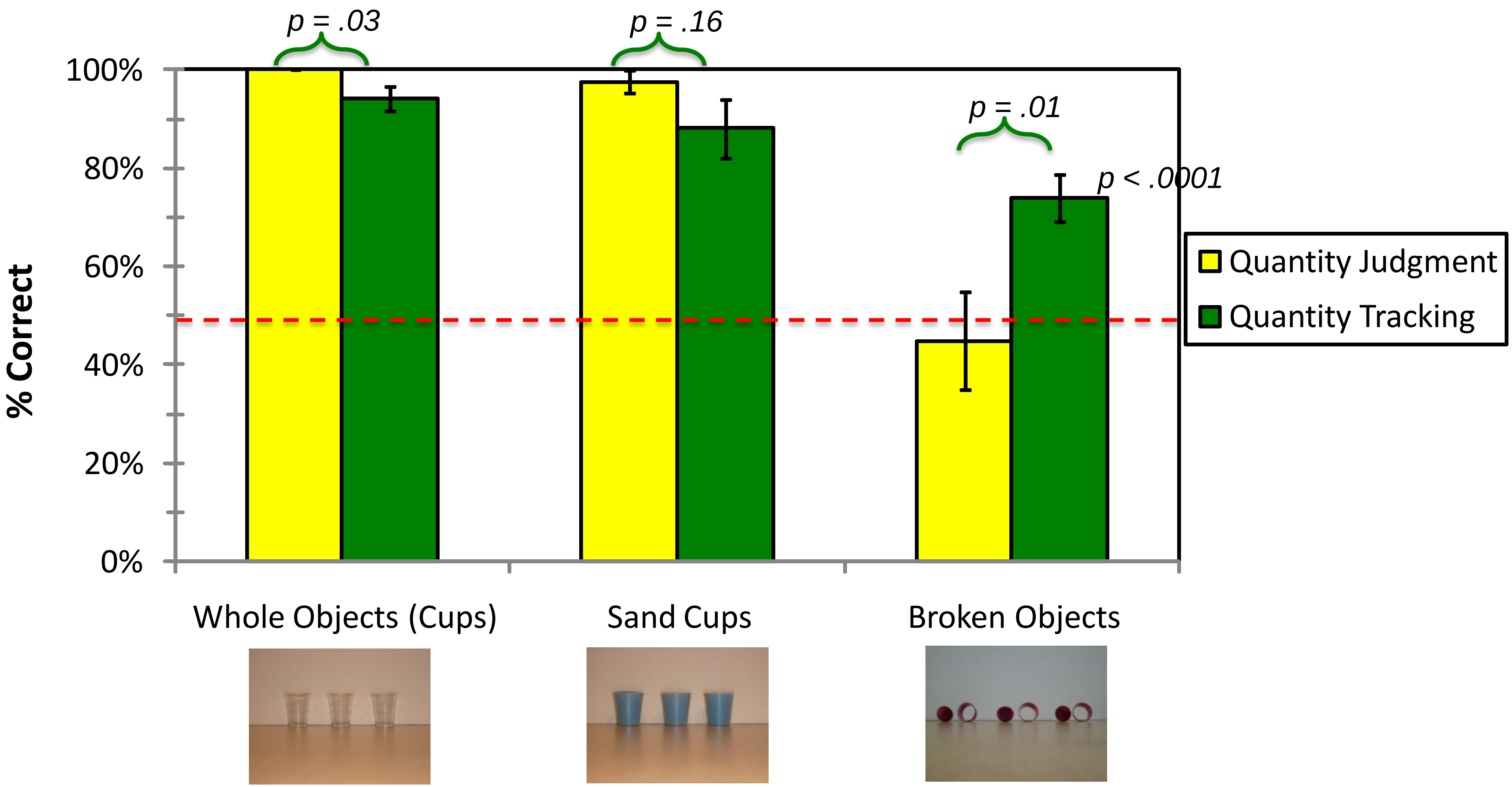
Task 2 Results



Bimodal
(2 trials)

12Ss 100%
8 Ss 0%
3 Ss 50%

Results: Task 1 vs. Task 2



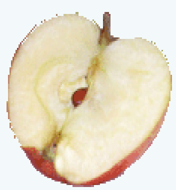
Findings: Tasks 1 and 2

- Task 1
  - Huntley-Fenner's results not replicable: children use containers to quantify substances
  - Some children prefer a kind-based counting technique
- Task 2
  - More difficult to track broken objects than sand
- Tasks 1 & 2
  - Tracking is easier than judgment for broken objects
  - Something in the quantity judgment task interferes!

Language assessment

Picture-book-making task.

“Can you help me find a picture of ________? Is this ________?”

	Individual	**Collection of Individuals**
Whole		
Part		

	Individual	**Collection of Individuals**
Whole		
Part		

Flexible Noun Questions

One Apple

One Piece of Apple

One Box of Apples

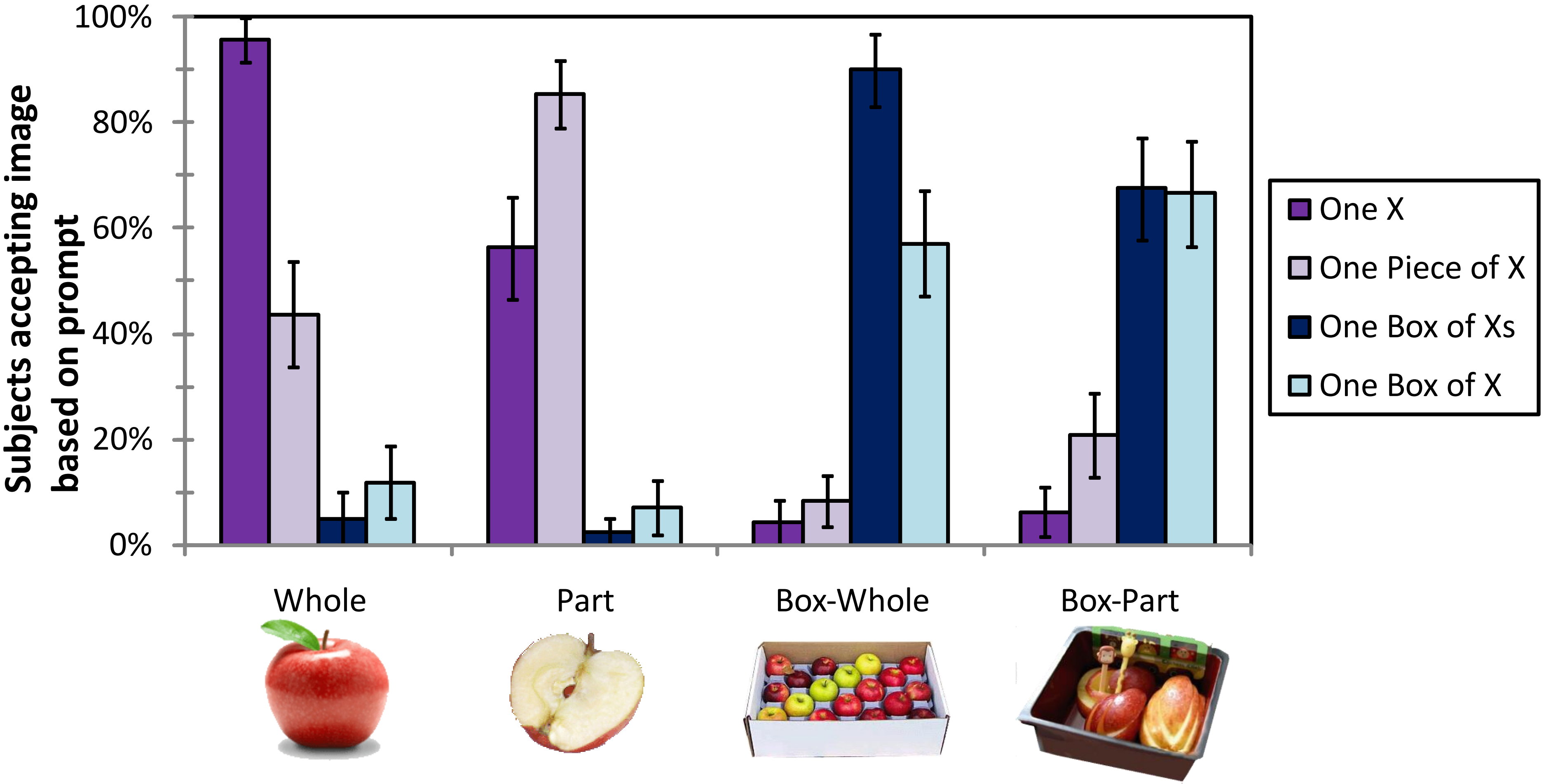
One Box of Apple

Object-Mass Noun Questions

One Piece of Jewelry

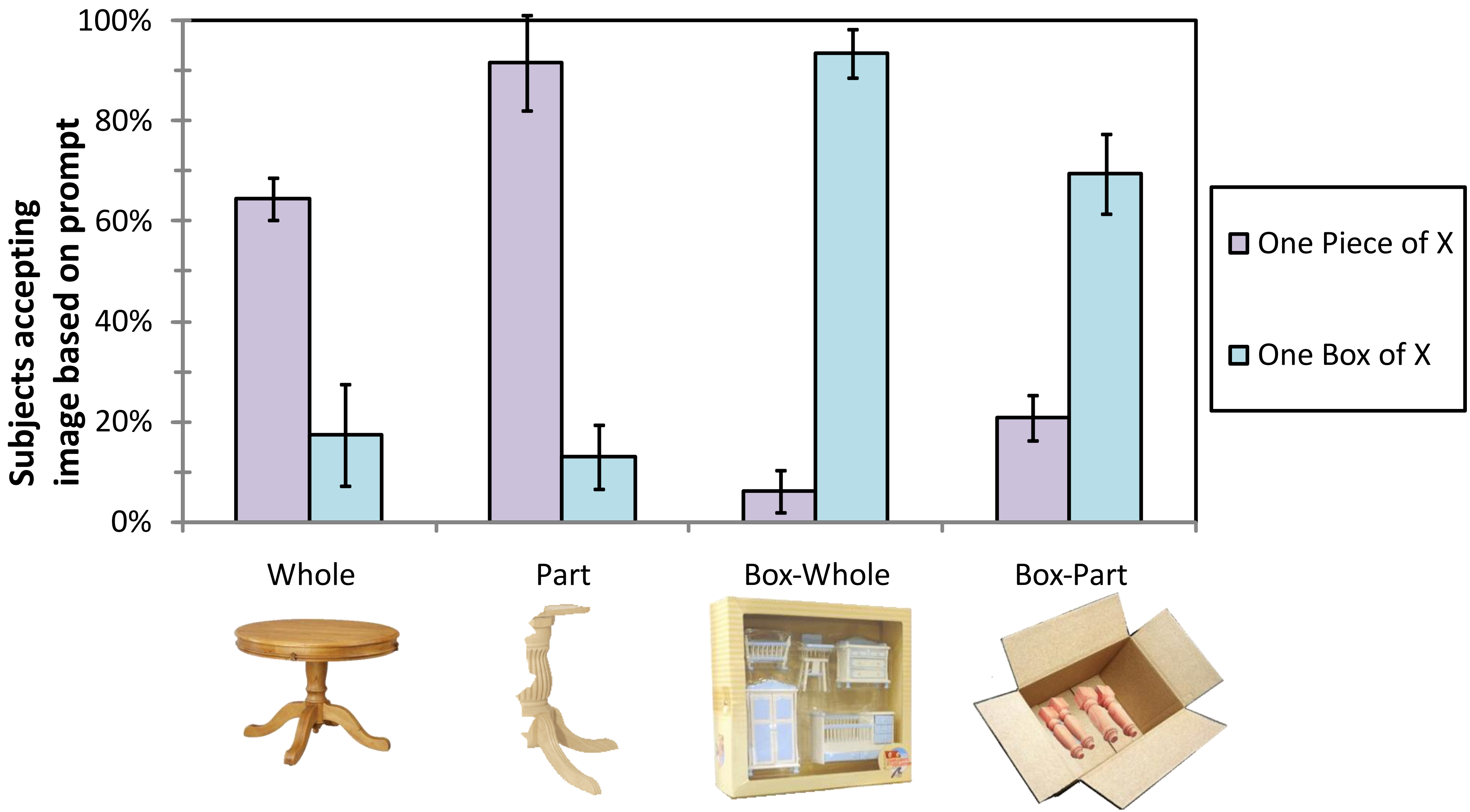
One Box of Jewelry

Results: Task 3 (Flexible Nouns)



- Preschoolers are sensitive to the distinction between "one X' vs. "one Piece of X"

Results: Task 3 (Object-Mass Nouns)



- Preschoolers know to select the box pictures when hearing "one box of X(s)"

Findings: Tasks 1, 2 & 3

- No correlation between subjects across tasks
  - Ability to distinguish between "one X" and "one piece of X" does not predict success in quantity judgment or quantity tracking
- Some preschoolers who understand counting concepts are still not able to use language to discuss quantities
  - Do children fail at tracking because they don't know language?
  - Or do they fail at language because they can't quantify broken objects and substances?

Questions for further research

- What is the link between the development of number concepts and the development of language?
- Can children be trained to make distinctions between parts and wholes?
  - Order effect: linguistic task first
- Bilinguals
  - Does knowing more than one system of noun classification improve scores on the language task?
  - Does it improve performance in tracking?
  - Does it make for conflicting responses in quantity judgment?