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WHAT DO PEOPLE COUNT?
PERCEPTUAL AND CONCEPTUAL INFLUENCES ON WHAT IS CONSIDERED A
COUNTABLE OBJECT

by

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ABSTRACT OF THE DISSERTATION

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The only a priori constraint on the kinds of entities that can be the members of a to-be-counted collection is that they can be treated as if they are separate from each other. Otherwise, the result would not be a natural number. But, there is nothing about counting itself that dictates the nature of the entities for a given count. As Gelman and Gallistel (1978) noted, any items that can be treated as discrete can be collected together for a count. The entities need not be objects; they can be spaces between telephone poles, the number of great Presidents, or even the number of good ideas one had in a given time period. This degree of permissiveness introduces a fundamental question: What sets the boundary conditions on what is actually contained in a to-be-counted collection? The studies presented here demonstrate that people use a variety of constraints. These constraints include some that are highly conceptual, some that involve simple perceptual groupings, and some that are invoked by verbal labels or conversational pragmatics. The common characteristic of these options is that they provide contexts that place items at a common level of interpretation or perception. It is shown that the same rectangle can

serve different framing effects depending on whether it is dubbed a mirror, a window, or a picture frame. It is also shown that the numerosity of a given number of circles is interpreted differently, depending on whether the circles are arranged concentrically, whether some of the circles are positioned inside others, or whether none of the circles are so bounded.

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DEDICATION

For Grandma

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CHAPTER ONE

INTRODUCTION

Counting yields a representation of the cardinality of a collection of discrete items. As long as the person doing the counting perceives or conceives of the to-be-counted items as discrete, it does not matter what the items are (Gelman & Gallistel, 1978). This raises a key question: Are there principled constraints on what kinds of items can be collected together for a count? The problem of set identification may seem of little interest at first glance but, as is the case for many activities that humans find simple, it rapidly becomes clear that the issue is more complex than might be first assumed. For example: consider the following display (Figure 1.1). I assume that most people will say there are three items. If so, they have focused on the fact that the display has three identical symbols with even spaces between them.

Figure 1.1: A set of items

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But, there are other possible answers. For example, a reply of ‘two’ may indicate that one has counted the spaces between the symbols, much as some children count the spaces between lamp posts. There also is nothing to prohibit a decision to count the number of strokes on the page, and so on. This illustrates the fact that, in many cases, what defines the current countable set is up to the person who is going to do the counting. Even so, one’s system of perceptual organization is likely to bias one to treat the spaces as a reason to separate out the three identical complexes that are made up of four strokes. But how alike do these items need to be? It probably does not matter if each item varies

in color and orientation, but it might matter if one item is moved to the edge of the page, as in Figure 1.2.

Figure 1.2: A transformed set of items

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In this dissertation, I show that the phenomenon of agreement in set choice is not a matter of random happenstance. Rather, people tend to converge on a very limited range of what constitutes the countable set in a given context. This is not just a matter of sharing a common language, as suggested by Wagner and Carey (2003). There is a rapidly increasing body of work (e.g., Cordes & Brannon, 2009; Xu & Arriaga, 2007; Xu & Spelke, 2000) showing that preverbal infants are capable of evaluating numerosity. Such results could not be obtained unless infants in these studies were consistently identifying and enumerating the same set of items as do adults when shown same displays.

A. People must have biases on the kinds of sets they count

1) It is important to know what kind of sets people count

When one thinks about counting, it is important to keep in mind that people do not count a random collection of things; they bring together a conceptually or perceptually selected set of things. Cardinality is not a property of any single entity. Rather, cardinality is a property of a set as a whole. In other words, numerosity is a property of a collection of items rather than a property of the individual members therein. Given a set of five white sheep, all of the sheep are white, but none of the sheep are five. As a consequence, what counts (cardinalities) a person produces is inexorably linked to

what sets a person counts (enumerates).

In order for a set of items to be counted, two things must occur. First, the entities in the set in question must be individuated. If they cannot be individuated, then they cannot be included in a count. One cannot count the number of trees in a forest without having a way to keep separate all of the trees. Secondly, the counter must correctly identify the items in question as members of the set to be counted. If such entities are not correctly identified as being members of the to-be-counted set, then it will not be possible to accurately assess the cardinality of the set.

The question of *what* people count has tended to be subsumed by the question of how well people count. Those who test adult counting knowledge and skill tend to assume that adults' counting ability is at ceiling. When adults are asked to make numerosity judgments, the stimuli they are presented with are nearly always clearly specified sets. Counting ability is gauged primarily by reaction time and only secondarily by error rates. Mistakes in normal adults' counts are judged to be simply performance errors or the result of insufficient processing time, rather than the result of pervasive deficits in either their counting competence or in their understanding of the conditions of set enumeration. (See: Mandler & Shebo, 1982; Trick & Pylyshyn, 1990). Studies that focus on children's counting ability also tend to concentrate on error rates to conclude that children have a restricted idea of what can be in a countable set. But, it could be that there is a communication lapse, one where the children do not read the experimenter's intention regarding item kinds. This could be why they count whole as opposed to broken objects or do "better" when they are given a verbal description of objects to count. (Shipley & Shepperson, 1990; Sophian & Kailihiwa, 1998; Wagner & Carey, 2003).

Both adult and developmental studies tend to invoke issues related to individuation (see: Shipley & Shepperson, 1990; Trick & Pylyshyn, 1990). When looking at the relationship between counting and individuation as presented in the literature, I am reminded of the ouroboros, the mythological snake that eats its own tail. How many things are entailed? If one does count an item, then it serves as evidence that said item has been individuated. However, as counting serves to find the cardinality of a certain set, one cannot know a priori if the reason a person did not include a specific item in a count was because they had not individuated it, or, instead, because they had not considered that item to be a member of the to-be-counted set. This issue provides a challenge both to the literature on individuation and to research on counting. One way to mitigate this problem is to make very clear and unambiguous which items the subjects are to count. If one asks an adult to count all of the letters on a screen, all of the circles, or all of the Xs, one does not expect the subject to count the corners of the screen.

2) People must share biases on what kinds of sets they count

It is not always possible to use language to specify the to-be-counted set in developmental research and it is never possible to do so for research involving non-human animals. One cannot instruct an infant to count all of the circles on a screen. Rather, one must simply assume that they will do so spontaneously. One might assume that they would enumerate the circles, but it would be just that, an assumption. It is not impossible that infants would instead enumerate the sides of the display, for example. As stimuli come to involve more complex shapes, the variety of sets that infants might enumerate increases exponentially. Beyond individual shapes, they might instead enumerate the various angles, curves, inflection points, and indentations. They may even

enumerate the kinds of items, angles, curves, and other such visual features they have observed. One might even speculate that they may enumerate the line segments that can be formed between individual items, the number of unique polygons those line segments can form, or the shape categories those polygons could collectively fall into. Such speculation is not entirely without merit. It has been shown that infants as young as five months can and do spontaneously enumerate subgroups of items moving in coordination with each other (Wynn, Bloom, & Chiang, 2002). Given this rapid expansion of set possibilities, it is a wonder that studies are ever able to find evidence of counting ability in infants or animals. And yet we are able to do so.

Infants as young as six months distinguish between sets of dots with numerosity ratios of 2/1 (Xu & Spelke, 2000). This ratio changes to 3/2 by ten months of age (Xu & Arriaga, 2007). Infants preferentially look at sets of two or three dots after hearing two or three drumbeats (Starkey, Spelke, & Gelman, 1983). Monkeys preferentially look at sets of two or three faces after hearing two or three voices (Jordan, Brannon, Logothetis, & Ghazanfar, 2005). Given the vast range of possible countable sets, these results beg the question of just how it is that infants manage to spontaneously count just the kind of sets the experimenters intend for them to count. Conversely, one might also ask how it is that the experimenters managed to select stimuli that include just the kinds of items that infants will almost always spontaneously count, without first going through decades of arduous piloting.

As one speculates on the range of possible sets, it becomes clearer that infants, children, adults, and quite possibly animals must share many biases about the kinds of sets that can be enumerated. Thus, adult experimenters are able to use their own judgment

of what they think is the obvious countable entity in a display as a useful proxy of what their infant subjects will enumerate. These biases can also serve as common ground between conversational partners. Eye tracking studies have demonstrated that people are particularly sensitive as to what information is shared between individuals (Brown-Schmidt, Gunlogson, and Tanenhaus, 2008). As would be expected by the Gricean maxim of Quantity (Grice, 1975), people do not tend to provide information they believe the other parties already have (Brown-Schmidt et al., 2008). Listeners do not expect to have received more information than necessary when resolving ambiguities regarding what a speaker has focused on (Tanenhaus, Spivey-Knowlton, Eberhard, Sedivy, 1995). It is simply expected that when one says “boing boing boing boing boing,” and asks “How many?,” the answer produced will be “five,” barring performance errors due to memory limits or, possibly, hearing difficulties. It is obvious to both the questioner and the respondent that the default countable set is the five ‘boings’. Thus, the question “How many?” is sufficiently unambiguous without further qualification (Gelman & Meck, 1992). Again, the questioner is able to use their own judgment of what is the obvious countable set as a proxy of what the respondent will think to count.

So what exactly are our biases on what sets we determine should be counted in a given situation? This becomes a deeply interesting question. Again, we come back to the issue that in order for items to be counted they must first be individuated. By extension, one may well predict that the easier it is for one to individuate an item, the easier it is to count that item. Ease of individuation would seem to tie directly to perception. This connection brings us to the subitizing literature.

B. Some biases on what kinds of sets people count seem perceptually based

1) People can count non-verbally

Many of the studies of adult counting involve non-verbal counting tasks of one kind or another. Non-verbal counting is how we can estimate how many items there are in a given set of entities. Although this process honors the count principles, and therefore proceeds in an incremental fashion, it does not involve the use of external symbols. Instead, the items are successively accumulated so as to generate an amount that represents the cardinality of the set (Cordes, Gelman, & Gallistel, 2001). Since the discrete non-verbal counting procedure generates a quantity, the output is bound to be variable – as are all quantities. In the case of counting, there is a typical signature, scalar variability, which means that as set size increases so does the mean and variance (Cordes et al., 2001). In addition to individuals' ability to non-verbally enumerate sequentially presented items (Cordes et al., 2001), people can also nonverbally enumerate items presented in simultaneously presented sets (Revkin, Piazza, Izard, Cohen, & Dehaene, 2008).

2) Subitizing is likely a form of parallel non-verbal enumeration

When subjects are asked to count displays of simultaneously presented items as quickly as possible, they typically produce what is known as the subitizing curve. They respond very quickly and accurately to sets of very low numerosity (from one to three or four), then begin to show a steeper linear increase in response time thereafter as set size increases (Mandler & Shebo, 1982). While it has been suggested that the shift to a steeper linear response rate at around four is not a sharp shift from one pattern to another but rather a smooth change in inflection along a continuous curve (Cordes et al., 2001), there

can be a change in the slope of reaction times between low and high numbers under some conditions. It has been suggested that this subitizing pattern is the result of subjects being able to use canonical patterns (Mandler & Shebo), FINSTs (Trick & Pylyshyn, 1994), or parallel non-verbal counting (Cordes et al.) to very quickly and accurately ascertain the numerosity of very small sets. However, past about three or four items, a more standard counting procedure is used - either because no other possibility is available or to preserve accuracy.

3) Subitizing seems to require parallel individuation

One thing all these explanations for subitizing have in common is that the items must be individuated at very nearly the same time. One cannot find a canonical pattern of four dots unless one can keep all four dots in mind simultaneously. Lana Trick and her colleagues have run a number of studies on adults' ability to subitize subsets of items presented simultaneously on a screen. (See: Trick & Enns, 1997a; Trick & Enns, 1997b; Trick & Pylyshyn, 1994). They found that people only produce subitizing curves when asked to count items that they are able to pre-attentively individuate. Trick and her colleagues have consistently found that subjects can subitize items that produce a pop-out effect. Items are said to pop-out of a given set if people are able to search the set for them in parallel, and thus locate those items in constant time, rather than showing a linear increase in reaction time as set size increases. People are able to subitize the number of Os in a field of Xs and Os, but they are not able to subitize the number of Os in a field of Qs and Os. Os will pop out of a field of Xs, but not Qs, presumably, because of the overlap in the shape of the Os and Qs (Trick & Pylyshyn, 1993). Also, people cannot subitize items defined by conjunctions, such as vertical white lines in a field of horizontal

and vertical black and white lines (Trick & Pylyshyn, 1993). Additionally, people are unable to subitize the number of items appearing on the same line, when determine that items are collinear requires focal attention. (Trick & Pylyshyn, 1993) In general, subjects fail to subitize items that it is known people cannot individuate in parallel. Further, Trick and Enns (1997a) found that people are able to subitize clusters of items, and thus they determined that it must be the case that visual clusters are pre-attentively individuated.

4) Individuation influences what people count

The above results suggest that people are biased to count what is most easily individuated. This is consistent with the fact that the nonverbal counting procedure for ascertaining numerosity values requires individuation. This conclusion is further supported by a pair of infant studies performed by Karen Wynn (1996). Wynn found that infants are able to enumerate sets of actions, such as a puppet jumping. She habituated infants to a puppet performing a fixed number of jumps (two or three). Once the infants habituated (as defined by a fifty percent drop in their looking times), she changed the number of jumps the puppet was performing and recorded whether the infants dishabituated (looked longer) at the new jump sequence. Infants dishabituated both in conditions where there were pauses between jumps and in conditions where the action was continuous. However, the dishabituation was stronger when there were pauses between jumps. Presumably, these pause conditions are also the conditions in which the jumps are more easily individuated from one another.

5) Individuation is influenced by perception

The above studies show a clear link between perceptual processes and what items are easily counted. Since items must first be individuated before they are counted, it

makes sense that there would be a bias for people to count items that are most easily individuated by the perceptual system. This may partially explain how it is that studies have been successful in finding that infants are sensitive to the numerosity of sets. The basic perceptual systems of both adults and infants are quite similar to each other (Pylyshyn, 2007). It is to be expected that experimenters will use stimuli that are likely to support the behavior that they are studying. Researchers are able to use their own judgment of whether a set seems likely to be counted in a given situation as an effective metric to determine whether or not an infant will automatically enumerate that set. Given this supposition, one would expect there to be a correlation between the kinds of items studies have shown that adults count easily (and especially subitize) and the kinds of items that developmental studies have shown that infants are able to enumerate. A review of the literature seems to yield such a relationship.

Adults are able to subitize separated shapes which are projected on a screen (Trick & Pylyshyn, 1993). Infants are able to enumerate such separated items (Xu & Spelke, 2000). Adults are able to subitize visual groups of items (Trick & Enns 1997a). Infants are able to enumerate such groups (Wynn, Bloom, & Chiang, 2002). Adults are able to separately subitize different kinds of items that 'pop out' of a given mixed set (Trick, & Enns 1997b). Infants are sensitive to the ratio between different kinds of items in a given mixed set, which indicates that they are extracting some numerical information about both kinds of items simultaneously. (McCrink & Wynn, 2007) Adults have been shown to be able to nonverbally count a series of sounds (Cordes et al., 2001). Studies have also shown that infants are also sensitive to the numerosities of sets of sounds (Starkey, Spelke, & Gelman, 1983).

6) Prediction: Visual nesting should influence counting

Surely, the more readily one can perceptually individuate items in a collection, the more likely it is that the number of items in that collection will be counted – at least nonverbally. Studies by Trick and Pylyshyn (1994) have found that adults do not show a subitizing curve when asked to enumerate sets of nested items (concentric squares). According to Trick and Enns (1997a), this implies that adults are unable to pre-attentively individuate such nested items. Pylyshyn (2007) links this to Intriligator and Cavanagh's (2001) finding that items in the visual field must be sufficiently separated (a minimum separation of one degree of visual angle, increasing outward from the fovea) before they can be individuated from each other without focal attention on the basis of location. Items that are nested inside each other are necessarily not separated. Importantly, it is the relative positions of the items that are at issue, rather than the distance between the items' edges. Trick and Pylyshyn (1994) found that subjects are able to subitize right angles and parallel lines placed at distances equivalent to the separation of the sides and corners of their concentric square stimuli.

Prior research also indicates that in some circumstances the perceptual features of visual sets can influence people's perception of the numerosity of those sets. People are quicker to identify the numerosity of small sets when they are in canonical arrangements (Allen & McGeorge, 2008). People's estimation of the numerosity of the identical set of items can be influenced by their arrangement (Vos, von Oeffelen, Tibsch, & Allik, 1988). Also, Von Oeffelen and Vos (1982) suggest that the total perceived area of gestalt groups created by various arrangements of items influences numerical estimation, though Simon and Vaishnavi (1996) find evidence that overt attention is a prerequisite of such effects.

Furthermore, Alston and Humphreys (2003) report that item movement, area size, and item spacing can influence reaction time on counting and subsidizing tasks.

It follows that one should be able to show that adults are less facile at non-verbally counting sets made up of nested items. In addition, adults should prefer counting non-nested items relative to nested ones. Further, the failure of pre-attentive individuation implicates difficulties in *simultaneously* individuating items in nested configurations. Thus, non-verbal estimates of the numerosity of sets including nested items will tend to be less than those of fully un-nested sets of equal cardinality. Rather than take the time and effort to enumerate all contained and containing items, subjects may simply fail to include all the contained and containing items in their counts.

C. Some biases on what kinds of sets people count seem conceptually based

1) Conceptual factors influence counting

Returning to the fact that it is possible to count any discrete collection of separable items, even ones that are not in the here and now, it makes sense to assume that a person's knowledge and language status will influence what he or she will count. For example, if one is asked to count all of the blickets in the room, it does not matter how perceptually salient the blickets are if one does not know what a blicket is. For this reason, skill on counting tasks that involve the deployment of knowledge and the ability to "read" what the experimenter expects should have a major influence on what kinds of items are included in a to-be-counted collection.

One is even less likely to locate and correctly enumerate the set of, for example, five blickets if one does not speak English and is unaware of being asked to count any set

of items. In order for such an interaction to take place, both the questioner and the counter must have a concept of natural number, must share the concept ‘blicket’, and must have a sufficiently robust shared communication system so that the request can be both made and understood in as unambiguous a way as possible. This last requirement adds an extra confound to any counting study: Even if both the experimenter and subject share a set of biases as to what kinds of sets are most countable, it is still possible that they will differ as to what they believe should be counted. This can happen when there is ambiguity regarding what *could* be counted. These factors may lead the subject to settle on counting a set that does not dovetail with the one that the experimenter intended. However, it would not follow that that interpretation of the countable set is the only one open to the subject or that the subject has limited counting skills. Rather, the subject may have resolved the ambiguity as to what is the countable set differently than the experimenter intended.

Given that the nature of the countable set may be ambiguous, it follows that the way a request is stated can influence how a subject interprets his or her counting goal. The Gricean maxims of quantity, relation, and manner (Grice, 1975) lead one to expect that any question will contain exactly enough information to determine what set the questioner is referring to, no more and no less. Thus, variations in how a question is worded may be used to determine which of the possible countable sets should be enumerated.

2) *It is important to know what people count*

To review, a common theme emerges when one looks at the studies so far discussed: They tend not to look at *what* people count, but rather at *how well* people

count. The experimenters construct various sets of items to be counted and explicitly tell their subjects to count those sets and only those sets. Ability at counting is recorded by the error rate (i.e., arriving at different numerosities than those of the experimenters' predefined sets) and/or reaction times. Very few studies look at what people will count given a more open question. One series of studies that does focus on this issue was run by Shipley and Shepperson (1990).

3) People become more likely to combine broken parts in their counts as they age

Shipley and Shepperson (1990) looked at how likely children and adults are to keep separate or mentally put together both halves of a split object (e.g., a fork) in a to-be-counted array. They also varied whether objects were heterogeneous & familiar, homogeneous & familiar, homogenous & unfamiliar, as well as varying the question asked ("Can you count [*these things/the X's?*]"). Adults were much more likely than children to treat both parts of the split object as a single item in their counts. Also, adults were much less likely to combine parts when asked to count "things", but children were not strongly influenced by question type. Conversely, children were slightly more likely to combine parts in their counts when dealing with homogenous & familiar sets, but this effect was not seen for adults. Further, children were more likely to combine parts when the parts were aligned than when they were separated.

4) These results are not explainable by a discrete physical object bias

Shipley and Shepperson (1990) concluded that young children have a discrete physical object bias and as a result these are the kinds of items that children are more prone to count. However, Wagner and Carey (2003) were able to replicate the finding that younger children are less likely to combine when they used clip art on a computer

screen rather than any actual physical objects. Further, studies have shown that infants are able to respond to the numerosity of groups (Wynn, Bloom, & Chiang, 2002), sounds (Starkey et al. 1983), and events (Wynn, 1996). Children can also count holes as readily as whole objects when directed to do so (Giralt & Bloom, 2000).

In a study by Giralt and Bloom (2000), researchers looked at how good children were at enumerating different kinds of objects and non-objects. In these studies, three-year-old children were shown sets of two to four objects, which were dubbed “toys” by the experimenter. These objects were foam blocks that had between zero and two obvious holes in them, and also between zero and two obvious extensions off of the main body of the block. These limbs were dubbed “handles” by the experimenter. The range of holes in and handles on the toys allowed the experimenter to vary the number of toys, holes, and handles in the stimulus set independently from each other. Sets of these objects were placed before the children who were then asked to count either toys, holes, or handles (“How many ___ are here? Can you count the ___?”) The children’s performance was above chance for all of the item types, but they had more errors in their counts of handles than their counts of holes or toys. Children were actually slightly better at counting holes rather than toys, being correct 89% of the time for holes, 80% for toys, and 65% for their counts of handles. Though this difference is not significant, that children were as good, if not better, at counting the non-objects (holes) as the whole objects (toys), clearly demonstrates that very young children are capable of counting items other than discrete physical objects in some situations. A discrete physical object bias alone cannot serve to explain these phenomena. It is therefore prudent to develop a framework in which all these abilities can be explained parsimoniously.

5) *Reconstructed items are not as real as whole items*

A rather complex thought process is necessary to combine broken pieces that are not currently one whole item but which might typically constitute a whole. The counter must ignore the real parts in favor of the imagined whole they symbolize. Therefore, the ability to achieve a dual-representation of the items is required. It is well known (DeLoache, Miller, & Rosengren, 1997) that young children have difficulties operating at multiple levels of representation simultaneously. Yet, that is exactly what this sort of abstraction entails.

a) Young Children have difficulty using items to represent others

DeLoache and her colleagues (1997) provide evidence to support their theory that dual-representation influences how children are able to deal with symbols (that is, items that are intended to stand for other items). In one study, 2 ½-year-olds were shown a scale model of a room. Each child saw a small model of a toy hidden in the scale model. The child was then told that a large version of the toy is in the same spot in the big room. The 2 ½-year-olds did not perform well on this task. Though they would eventually find the toy, they only rarely (20% of the time) went directly to the spot the experimenter indicated in the model. Three-year-old children, however, show much greater ability in this task and are typically able to retrieve the toy on their first try (DeLoache, 1987). The difficulty lies not with the 2 ½-year-olds' memory of the hiding location, but in their ability to understand and make use of the fact that the model is intended to symbolize the larger room. This is clearly demonstrated by the results of DeLoache et al.'s (1997) "Credible shrinking" room task.

In this study, DeLoache et al., (1997) convinced their 2 ½-year-old subjects that

they were in possession of a functioning shrinking machine. They did so by showing the children a large toy and placing it in front of a box they had dubbed a shrinking machine. Children were then led out of the room briefly, hearing a noise through the door. They returned to find that standing in the place of the large toy was a much smaller version of the same toy. Parents reported that their children found this demonstration quite convincing. The researchers then showed the children a tent like room and hid a large toy in it. Children were then led out of the room again while the machine ‘shrank’ the tent. They returned to find that where the tent had stood there was now a scale model in its place. Over eighty percent of the children were able to locate the small toy hidden in this model on the first try.

The striking thing about these two studies (DeLoache, 1987; DeLoache et al., 1997) is that both use essentially the same stimuli and both required their 2 ½-year-old subjects to make mental mapping between the locations in the large and small versions of the room. Both require the children to remember relative locations and, in later trials, to ignore memories as to where they had found the toy in any previous trials. And yet, while they were quite capable of completing the task when it invoked the rather fantastical shrinking machine, 2 ½-year-olds’ performance was quite dismal on the original model task (DeLoache, 1987). According to DeLoache and colleagues (1997), the reason for this seeming paradox is that the original model tasks require the children to maintain a dual-representation, while the shrinking machine task does not.

When one uses symbols, one first has to understand that a specific item is intended to represent something else (an important pragmatic consideration in its own right) and then maintain in one’s mind a representation both of the item itself and what it

is intended to symbolize. In the original model task (DeLoache, 1987), young children have to form this dual-representation to succeed, and keep in mind the larger room, the model, and the relevance of their symbolic connection to each other. In the shrinking task (DeLoache et al., 1997), no dual-representation is required. Since - as far as the children are concerned - the model and the room are the same object, there is no need to maintain a dual-representation. Children find the small toy was in the same place in the small room as the large toy was in the large room because they believe it is the same toy in the same place in the same room.

b) The more prominent the mental representation of items that act as symbols are, the harder it is to treat those items as representative of what they symbolize

The nature of representational symbols influences children's ability to utilize them successfully. As the items that symbolize other items are made increasingly more salient as items in their own right, children become less and less able to utilize them as the stand-ins for the items that they symbolize. For example, if three-year-olds are allowed to first play with a model before they are asked to use it as a representation of a larger room, their success on the task drops dramatically (DeLoache, 2000). Further, if children are allowed to view the model only through a glass window and are not allowed it interact with it directly, then even 2½-year-olds are able to retrieve the toy immediately on the majority of trials (DeLoache, 2000). Additionally, when photographs (DeLoache & Burns, 1994) and videos (Troseth & DeLoache, 1998) are used instead of the three-dimensional miniature model in similar retrieval tasks, 2½-year-olds are generally successful at immediately locating the toy in the large room. In summary, the more salient an item is to a child, the more difficult it is for them to use that item as

representative of something else. People mentally represent symbols both as themselves and as what they symbolize. As the items that act as symbols become more and more prominent, so does the mental representation of those items as themselves. Subsequently, it becomes more difficult it becomes to access the mental representation of the symbols as stand-ins for the items they are intended to symbolize.

c) Re-represented symbols are intentional

It is very important to the construction and maintenance of a dual-representation that people understand that one item is *intended* to represent another. The location of a small item in a model and a large item in a room are only connected because the experimenter intends for it to be so, and in fact, makes it so. Children who are successful at using models are very aware of this connection. Children who see a small toy placed in a model and then see the miniature “accidentally” jostled out of place will still look for the large toy in the large room *where the experimenter put it* rather than in the location corresponding to where they had last seen the small toy in the model (DeLoache, 2002).

d) Young children’s difficulty in combining parts in their counts can be attributed to difficulty with dual-representation

The age effect found by Shipley and Shepperson (1990), with adults and older children more readily combining parts in their counts than younger children, may be attributed to the continuing development of children’s ability to form and use dual-representations. Adults and older children would tend to have the higher level of re-representational ability needed to treat the real and present broken parts as a stand-in for a not-currently-extant whole object. Difficulties with dual-representation can also explain other answering patterns in Shipley and Shepperson’s (1990) study. Children more

readily combined pieces when they were aligned, a perceptual configuration that emphasized that the pieces come from the same object. Also, subjects were more likely to combine items when the sets were made up of homogenous items, whose shared features emphasized the pieces *could* be combined. Children's rates of combined counting also increased when these homogeneous sets were of familiar rather than unfamiliar items, a condition which would further serve to increase the likelihood that children would notice that the broken pieces could be combined into a single item. All these conditions emphasize the fact that the broken pieces can represent a whole object, and thus that the experimenter may intend for them to be treated as one object. Recall, symbols require intention.

Further, when the children in Shipley and Shepperson's (1990) study who did not spontaneously combine the parts in their counts were explicitly shown that the parts could be put together to form a single object, the rate at which subjects combined parts in their counts more than doubled. Following from the Gricean maxim of relation (Grice, 1975), demonstrating that the parts could be combined would be considered relevant to the current exchange and thus serve as a strong hint to the subjects that the experimenter intended for them to combine the items in their counts. Thus, a general pattern can be seen: As it becomes more obvious that broken parts can and should be combined, children are more likely to combine them. Older children, like adults, would tend to be more likely to independently realize that broken items can symbolize a whole item.

6) Young Children show a bias for counting real-world items

In this same series of experiments, Shipley and Shepperson (1990) also looked at children's ability to count things that are not individual objects, but are instead kinds.

They presented three- through six-year-old children with sets of objects made up of two to three homogeneous exemplars *each* of two to four different kinds. These kinds differed either at the basic level (e.g., airplanes and cars) or at the sub-basic level (e.g., red ducks and green ducks). Children were then asked to enumerate the different kinds present (e.g., “Here are some planes and cars. How many different kinds of toys do I have here?”).

In considering the results of these studies, one should keep in mind that kinds are not real. That is to say, while extensions of a concept, like “car”, have physical existence, intentional concepts are not instantiated in the real world. What the experimenters (Shipley and Shepperson, 1990) are asking children to do in these tasks is to consider various subsets of the items before them to be symbolic of particular intentional concepts, and then ignore the physically real items in front of them and instead count the various intentional concepts of which the items are extensions. Thus, as in the previous study, dual-representation is needed to perform this task. It is unsurprising, therefore, that three- and four-year-olds typically counted the real, present, items, while five- and six-year-olds typically counted the kinds represented by the groups of items.

In a follow up, Shipley and Shepperson (1990) found that if the experimenter separated the items into groups by kind and then labeled them for subjects who did not count the kinds in the initial trial, children’s performance improved. In another follow up, they found that if they also demonstrated counting the kinds for the children, these children’s rates of kind counting tended to improve on subsequent trials. Again, following from the Gricean maxim of relation (Grice, 1975), these conditions emphasize that the experimenters intend for the groups of items to represent kinds. Thus, as before, children in these follow-ups became more likely to count the groups of real items as the

kinds they symbolized.

7) Older children's counts are more strongly influenced by context

Sophian and Kailihiwa (1998) also looked at children's counting of parts and wholes. However, instead of breaking items into parts, their stimuli consisted of toys specifically made of two interlocking pieces, such as plastic Easter eggs. Their subjects were first explicitly shown that the toys were composed of two interlocking pieces and then asked to count either whole items or parts of items. The children were first told "This time we are going to count (whole/pieces of) [eggs] like these." Then they were shown a display consisting both of some intact toys and of some toys spilt into their component pieces. Component pieces were aligned in the display. Then they were asked, "How many (whole [eggs]/pieces) can we get from all these things?"

As in Shipley and Shepperson's (1990) study, Sophian and Kailihiwa (1998) found that in the count-whole conditions older children were more likely over all to combine parts than younger children. Furthermore, older children were more likely to separately count parts of items when asked to count parts. However, Sophian and Kailihiwa also found an interaction between age and question: older children's (five-year-olds' & seven-year-olds') response patterns differed depending on what they had been told to count, whereas younger children's (four-year-olds') response patterns did not differ based on the question asked.

In a follow up experiment, the questions were altered such that the children were asked either "How many whole [eggs] can we get from all these things" or "How many pieces can we get from all these things." In this case, Sophian and Kailihiwa (1998) found that overall rates of combining parts in the count-whole condition and counting

both halves of the intact items in the count-pieces condition increased. Also, while they still had the lowest overall rate of correctly combining or separating parts, the youngest children in this task *did* show a change in their answering patterns based on which question was asked. Further, the younger children had the highest overall rate of including only discrete physical objects in their counts. That is, they had the highest rate of producing counts that included both all the unattached parts and all whole objects.

8) People are very consistent within counts as to what kinds of items are enumerated

As Sophian and Kailihiwa (1998) note, the children were quite consistent within each set as to what kinds of items they counted. They did not combine one pair of pieces and count separately another pair in the same display, nor did they divide one whole egg into its component pieces while counting the other whole. Neither did they ever fail to count one whole item while counting another whole or one unattached part while counting another unattached part. In fact, there was only one inconsistent count ever seen in any of the trials and that was from one of the youngest children in the study.

9) Older children are better at using context to determine what to count

Sophian and Kailihiwa (1998) concluded that as children develop their ability to match which items they intend to count to which items they do count increases. They attribute this increase in matching ability to children acquiring the cardinality principle, and claim that, as children age, they come to understand that they have to count the kinds of items they want to enumerate in order to find the correct cardinality. As previously mentioned, Wagner and Carey (2003) also performed a partial replication of Shipley and Shepperson's (1990) study, asking three-, four-, and five-year-old-children and adults to count sets including split items. Wagner and Carey concluded that children have an

innate bias towards counting spatio-temporally separated items and also that children's ability to count other kinds of items develops as their linguistic ability grows sophisticated enough to allow them to represent things other than spatio-temporally separated entities.

I disagree with these conclusions. In Sophian and Kailihiwa's (1998) study, the variety of counts the children produced did not vary by age; rather it was the distribution of these counts across question conditions that differed between age groups. Children in all age groups produced counts that only included wholes, counts that only included parts, and counts of all discrete physical objects items, among other variations. It is possible the children's ability to make use of the pragmatics of the questioning contexts to match what they counted to the set that the experimenter intended for them to count increased with age. When Sophian and Kailihiwa simplified the question, the ability of all children to fit their responses to the question increased. This is not commensurate with either Shipley and Shepperson's (1990) conclusion that young children's behavior was simply the result of a discrete physical objects bias or with Wagner and Carey's (2003) conclusion that children have a spatiotemporal object bias that they overcome by learning new category concepts via language. If this was the case, Sophian and Kailihiwa should have found that different age groups produced different kinds of counts, rather than that they merely distributed those counts differently across question types.

Further, children in Sophian and Kailihiwa's (1998) study were almost always consistent as to what kinds of items they counted within a given trial. This is not commensurate with Sophian and Kailihiwa's conclusion that young children do not understand that in order to count correctly they have to count the items they intend to

enumerate. If that were the case, then one would expect that children would have shown inconsistencies in what items were counted *within* a given count rather than solely between what they counted and what the experimenter intended for them to count. Any remaining tendency of older children to be more likely to count broken parts as a single whole (and vice versa) than younger can be attributed to issues of dual-representation. The mentally reconstructed wholes are represented by broken parts and the mentally separated parts are represented by seamless wholes. Both require children to ignore real items and give preference to that which they symbolize. This is inherently difficult (DeLoache, 2000).

10) Prediction: 'realness' should influence counting

It is my contention that rather than having a bias to count discrete physical objects, as suggested by Shipley and Shepperson (1990), or spatiotemporally separated objects, as suggested by Wagner and Carey (2003), children have a bias to count real objects. Further, I believe that this bias continues to be present through adulthood. The effects of age seen on counting in these studies are the result of older persons being better equipped to overcome this bias, rather than a result of older persons not having this bias. Therefore, it should be the case that a preference for counting items that are conceived as being more 'real' should be seen in adults.

D. Context may influence what people count

If one considers the issue, it is very difficult to think of a natural condition in which the broken pieces of an item could be combined and counted as one whole object. For the purposes of a picnic, having three whole forks and the broken pieces of a fourth fork is functionally equivalent to having three forks. Lacking scotch tape, the pieces

cannot be combined. Further, in order for broken pieces to be combined at all, it is vital that they be pieces that fit together. In no context can the top halves of two forks be considered one fork, nor can the front half of a Ford Explorer and the rear half of a Toyota Prius be considered one car. It is only when segments might be physically combined to form a single object that it is legitimate to combine them for the purposes of counting. Otherwise, one must decide if an individual piece of an item qualifies as a member of the to-be-counted set. An important item of note is that the conditions in which the children in Shipley and Shepperson's (1990) study were more likely to combine parts were also those conditions that might serve to emphasize that the broken pieces *could* be combined into a single item. These conditions may have established the pragmatics of the situation such that subjects were more likely to determine the experimenter wanted parts to be combined in their counts.

1) Conversational Pragmatics and Language influence counting

It is known that the language one uses in number tasks can have a significant effect on children's apparent numerical ability. This is particularly seen in Piaget's (1965) classic number conservation task. In Piaget's task, he would place two rows of items in one-to-one correspondence and ask a child to judge if the rows had the same number of items (no counting allowed). After the children responded, he would move the items (spreading them out or moving them together) and ask the child if they still thought that there were the same number of items in each row. Young children (less than seven) would typically indicate that they believed the rows were no longer equal. Piaget attributed this result to perceptual information overriding the children's as-yet-undeveloped conceptual knowledge of number.

Gelman (1972) postulated that Piaget's movement of the items in front of the children and subsequent re-requesting the numerosity information influenced the pragmatics of the communicative situation. Following from the Gricean maxim of relation, (Grice, 1975) the children in Piaget's (1965) study may have expected that the move was relevant to the discussion, and consequently thought the shift must have somehow altered the cardinality of the set or that their first response was inaccurate. Thus, they changed their answers. Ellen Markman (1979) was able to construct a situation where young children were able to show conservation in Piagetian like tasks. In her study, children were introduced to sets of items either via a class noun (i.e., trees, soldiers) or a collective noun (forest, army). For example, "These are your soldiers and these are my soldiers." The children were then asked questions of the kind "What are more: my soldiers, your soldiers, or are they both the same?" Then the sets were rearranged so as to change the available perceptual information (area, density, etc.), and the question was asked again. Children who had heard the collective nouns conserved while children who had heard the class noun did not. Markman concluded that the use of the collective noun emphasized the existence of the group as a collection, whereas the use of the count noun emphasized the concept of the items as individuals and thus obscured the concept of the group as a set. As previously noted, sets have numerosity, individuals do not.

2) Word choice can influence counting

Giralt and Bloom (2000) also found an effect of language on counting. As previously stated, they found that children were less likely to count handles correctly than either whole items or holes in those items. However, there was some concern that this

might have been due to children being unfamiliar with the term “handles” as applied to the extensions on the block-like toys. One of the most basic ways in which conceptual information might affect a person’s counting ability follows from whether a counter understands the word the questioner uses for the kind of item in the to-be-counted set. In order to see if a simple lack of understanding of the word “handles” might have influenced the children’s performance on the task, Giralt and Bloom (2000) ran a follow up study in which the toys were changed from simple blocks to animal like items with a varying numbers of holes and legs. The procedure was the same as in their first study, except that they replaced the word “toys” with “animals” and the dubious term “handles” with the more familiar “feet”.

Again, the children showed great facility in counting the whole objects (“animals”, 94% correct), and non-objects (“holes”, 90% correct). Children’s accuracy in counting parts increased greatly with the shift to more familiar terminology (“feet”, 94% correct). These data again show that children are quite capable of counting parts and non-objects as well as they can count discrete physical objects, at least in some situations. Further, this is a clear instance in which children’s conceptual knowledge influences their counting ability. Children were better at counting parts that were “feet” rather than parts that were “handles.” It is unclear from the results whether this was due to the more familiar term making it clearer to the subjects what items the experimenter wanted them to count, or if instead subjects were better able to construct sets of items for which they possessed a clearer mental concept. However, in either case, children’s conceptual understanding of “feet” versus “handles” had a strong effect on their counting ability. (Giralt & Bloom, 2000)

3) *Some supposed age effects may have been a result of contextual differences*

Evidence suggests that the context of the trials influenced the results of the Shipley and Shepperson (1990) study. It is important to note that in the trials given to children, the type of set used varied not only within subjects but also but within each block. For adults, however, set type only varied between subjects, and there were only two types of sets used. It is quite possible that the reason the children, and not the adults, varied their responses when shown different set types was because this variation brought set type more to the children's attention. Also, for children, question type (that is, asking people to count either specific kinds of items or to count things) was only varied *between* blocks, while for adults it was varied *within* their one block of trials. It is possible that the reason adults and children diverged here is that this context systematically changed the relevance of the variables.

People will default to using the basic level terms (e.g., 'fork') and will only begin to use a super-ordinate or subordinate level terms (e.g., 'cutlery', 'salad fork') if it is particularly necessary for clarity (Brennan & Clark, 1996). Further, it has been found that once a term has been established in conversation, it will continue to be used despite being more specific than strictly necessary, unless a change is needed to clear up a newly introduced ambiguity (Brennan & Clark). It follows that the switch between specific and general question type will be seen as relevant by Shipley and Shepperson's (1990) subjects. In most situations, and particularly in interview-like situations such as these, adults follow the presumption of interpretability: "Each question means what it is obvious to me here and now that it means," (Clark & Schober, 1992). Listeners can assume "If a word seems vague, ambiguous, or strange, it isn't really vague, ambiguous, or strange,

because the surveyor is confident the respondent can figure out what it means." (Clark & Schober) Thus respondents assume the question means whatever it is most obvious to them that it should mean. Otherwise, they would have no other choice than to believe the experimenter was violating the Gricean maxim of quantity (i.e. there is a shift to the specific term for no purpose) and/or manner (i.e. the general term is overly ambiguous) (Grice, 1975). It is polite to give the speaker the benefit of the doubt.

Further relevant evidence comes from work by Wagner and Carey (2003). They also looked at people's rates of combining broken items in their counts, but ran both their child and adult subjects under the same set of conditions. They found a small effect of question type across both child and adult responses, though the variable did not reach significance within any particular age group. This is markedly different from the large effect on adults' responses and the complete lack of effect on children's responses as seen by Shipley and Shepperson (1990). It seems likely, therefore, that these differences between adult and child answering patterns in response to the specific or general word choice were a product of the different ways in which the subjects were run.

4) Prediction: Question context should influence counting

I propose that the difference in question context between adult and child subjects in Shipley and Shepperson's (1990) study artificially enhanced the different response patterns seen for child and adult subjects in response to the question. If this is the case, then adults' answering patterns should differ as a function of whether use of a specific or general object term is contrasted in the question set. One should find that effects of such a specific-general question variation will be stronger when it is varied within rather than between adult subjects.

E. Investigation

1) General Predictions

The literature reviewed above leads me to the conclusion that people must share biases on what kinds of items they count. Thus, when different adults are asked to count items in the same displays, their answers will converge on a limited range of countable sets. I also expect that some of the biases that are present in young children persist through adulthood. I expect adults, just like children, will show a bias toward counting real items. Also, adults, just like children, will be very consistent within their counts as to what kinds of items they enumerate. Furthermore, as demonstrated by the opening example (see: figures 1 and 2), the perceptual variables are bound to influence counting success. It will be shown that visual boundaries and the placement of items within and around these boundaries are among the perceptual factors that can bias counting. To test this, I ran studies designed to assess whether visual boundaries and the placement of items within and around those boundaries are among the perceptual factors that can bias what and how well adults count. I also will show that, although verbal cues are indeed important in determining what sets are counted, there are important pragmatic factors beyond word choice that influence what adults will decide to count in a given situation.

2) Research outline

The following studies set out to investigate these predictions. They can be divided into four units.

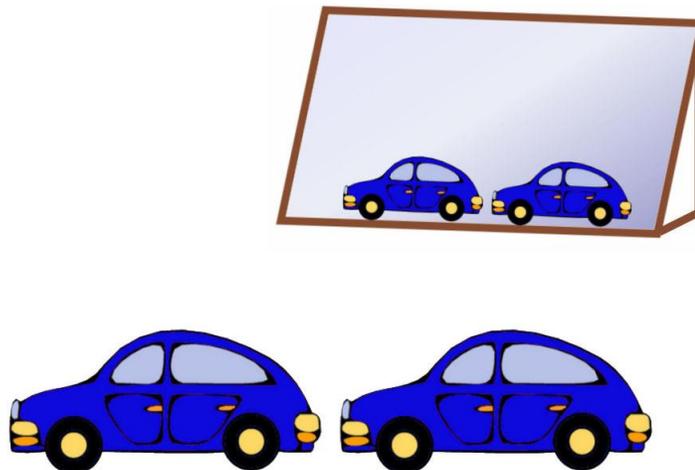
a) Chapter Two: Interview studies, between subjects

Chapter Two presents three studies that used an interview procedure wherein volunteers were asked their opinion as to how many items were present in an illustration.

Both the question and the picture varied between participants. These studies had three main goals:

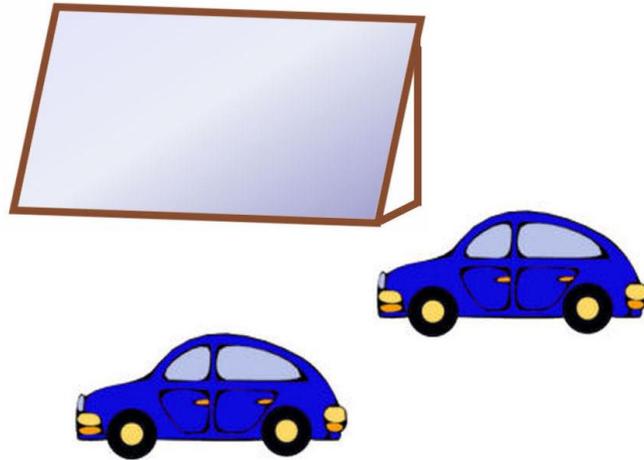
- i) To assess whether people will indeed converge on a narrow range of countable sets, even when asked ambiguous questions such as “How many things?”
- ii) To assess whether adults demonstrate a preference for counting items that are more conceptually real. The realness of items is manipulated by having some of the items in the stimuli contained within a visual frame (see: example below). The frame is sometimes identified as a mirror, a picture frame, or a window. These different containers entail different representational status - and thus different levels of conceptual realness - to the items they contain.

Figure 1.3: Mirror with cars



- iii) To assess whether adults demonstrate a preference for counting items that are spatially separated from others over items that act as containers. This was investigated by comparing the frequency with which people counted the visual frame in conditions where it acted as a container (see: example above) to conditions where it instead stood alone (see: example below).

Figure 1.4: Mirror with two cars



b) Chapter Three: Repeated measures studies

Chapter Three presents two studies that used a repeated measures procedure.

While the questions and stimuli were similar to those used in the interview studies, subjects were asked multiple “How many?” questions about multiple illustrations. The three main goals of these studies were:

- i) To assess whether pragmatic context, beyond word choice, influences what people count. Contrasting stimuli and verbal question formats within a single adult subject should magnify the effects of those variables relative to those seen in the interview studies. Also, variables that were not seen to have a strong influence on count behavior in the interview studies might yield an effect with the addition of the contrastive context created by the within-subjects design.
- ii) To determine whether the behavior of subjects in these studies is comparable to that of the adult subjects in Shipley and Shepperson’s (1990) studies. Shipley and Shepperson’s split-object study on adult subjects was partially replicated, with similar results.

iii) To assess whether the reason adults in the interview studies reported in Chapter Two so often failed to include the frame in their counts was because they had not considered counting the frame, rather than because they had consciously rejected the notion that the frame might be counted. When given more chances to count the frame, adults should be more likely to hit upon the idea that the frame might be countable. Thus, the overall frequency with which subjects count the visual frames which act as containers should be higher in these repeated measures studies than in the interview studies where people were only given one opportunity to count the frame.

c) Chapter Four: Visual contrast study

Chapter Four presents a study which, like the studies in Chapter Three, used a repeated measures procedure in which subjects were asked multiple questions about multiple stimuli. However, unlike earlier studies, the items contained by the visual frame were not of the same kind as the items in the foreground, as illustrated in the following example.

Figure 1.5: Window with trees inside the frame and cars in the foreground

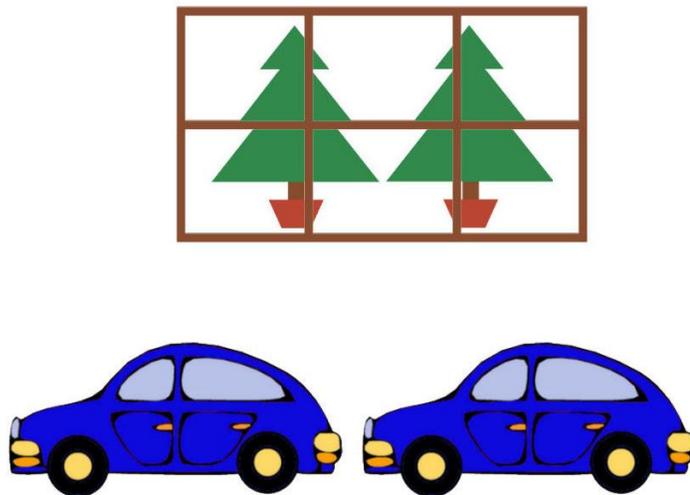
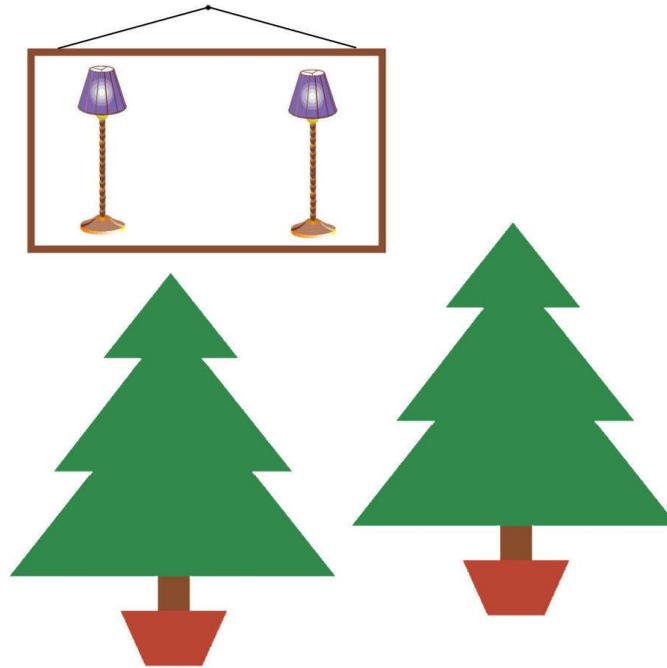


Figure 1.6: Picture frame with lamps inside the frame and trees in the foreground



There were two main goals for this study:

- i) To assess whether adults are less willing to count items when doing so would require them to cross the perceptual boundary. Adults should count items that appear in windows less often in conditions where they could also be expected to count the foreground items.
- ii) To assess whether the frequency with which adults count items that are less conceptually real is influenced by contrast. Items that appear in mirrors or picture frames are subsequently interpreted as reflections or drawings, thus lowering their realness status. Adults should count such items more often in situations where it would not be felicitous to also count the more real foreground objects than in situations where also counting the un-framed items would be expected, particularly as compared to any similar variation seen for items contained by windows.

d) Chapter Five: Reaction time study

Chapter Five presents a reaction time study where displays of circles in various perceptual configurations were rapidly presented at a rate meant to suppress verbal counting. Some displays included circles that were nested inside of others, some showed the circles separated from each other. Individuals were asked to indicate, as quickly as possible, if the cardinality of the circles set was greater than or less than a given digit value. There were two main goals of this study:

- i) To assess whether the perceptual feature of containment influences non-verbal counting. Subjects were expected to be slower and/or less accurate in their numerosity judgments of circle sets in nested configurations as opposed to non-nested ones.
- ii) To assess whether there is an inverse relationship between non-verbal numerosity judgments and the amount of perceptual nesting in visual stimuli. If arranging items in nested configurations makes it more difficult to individuate items, then when time is controlled for, fewer of those items should be successfully accumulated as compared to non-nested sets of equivalent cardinality. Thus, as nesting increases, reaction time should increase and numerosity judgments should decrease. Such an outcome would parallel adults' increased likelihood of including visual frames in their counts when the frames are not acting as containers.

CHAPTER TWO

Interview Studies

STUDY 1

How Many: Between Subjects

A. Purpose

As a reminder, the goals of this study are twofold. The first is to demonstrate that adults do indeed have biases on what kinds of objects they prefer to count. Adults in this study were shown drawings (see: Appendix A) and asked a question of the form “How many cars?”, “How many things?”, “How many real cars?”, or “How many real things?”. Rather than count a wide diversity of different sets, adults in an open ended (“things”) counting task should focus on a narrow range of possible countable sets. Clark and Schober’s (1992) principle of interpretability is specifically invoked for this task. Adults assume that the question refers to an obvious set and they consequently default to the set that seems most obvious to them.

Second, this narrow range of sets produced by adults should reflect the same sort of counting biases as did children in the studies by Shipley and Shepperson (1990), Sophian and Kailihiwa (1998), and Wagner and Carey (2003). Specifically, adults in this study should show a preference to count visually discrete items rather than attached parts or kinds. Further, they should prefer to count items that are more conceptually real. In this study, the conceptual realness of items in the stimuli was manipulated by varying the identity of a visual frame that contained two other items. This frame was identified as either a mirror, a picture frame, or a window. The items viewed through windows are

conceptually more real than those that are reflections. Thus adults in this study should count items shown as contained within windows more frequently than items contained by mirrors, which could be reflections. These results could contribute to the conclusion that there is continuity between the counting preferences of children and adults.

B. Method

1) Design:

This study used a 3 x 2 x 2 x 2 between subjects design with thirty subjects in each cell. The variables were:

a) Frame identity

The participants were told the frame represented a mirror, a picture frame, or a window.

b) Frame appearance

The frame was either visually interpretable or was a plain rectangle (see: examples below and Appendix A).

Figure 2.1: Visually interpretable mirror



Figure 2.2: Visually interpretable picture frame

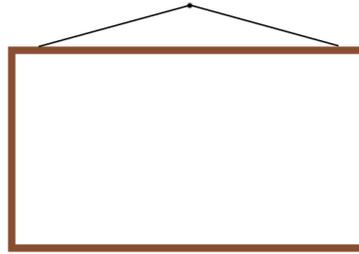


Figure 2.3: Visually interpretable window

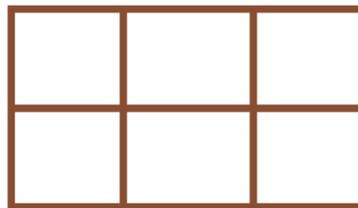


Figure 2.4: Plain rectangle



c) Standard-real question type

Participants were asked “How many?” questions that sometimes included the qualifier “real.” For example:

Standard: “How many cars?”

Real: “How many real cars?”

d) Specific-general question type

Participants were asked “How many?” questions that sometimes specified that certain kinds of items be counted. For example:

Specific: “How many cars?”

General: “How many things?”

2) *Participants:*

The participants were seven hundred and twenty people at Rutgers University, New Brunswick. Three hundred and eighty-one were female and three hundred and thirty-nine were male. Sixty-six were observed to have a non-native-English accent. The investigator approached participants individually in areas around the campus.

3) *Stimuli:*

There were a total of eight illustrations (see: examples below and Appendix A). Four were a visually interpretable drawing of a mirror, a visually interpretable drawing of a picture frame, a visually interpretable drawing of a window, and a plain rectangle. Each was depicted alone on an otherwise blank page. Four others depicted a pair of cars in the foreground and a smaller but otherwise identical pair of cars shown within one of these frames. The illustrations were printed by a color computer printer onto white paper, put into plastic page protectors, and placed in a three-ring binder.

Figure 2.5: Visually interpretable window with cars

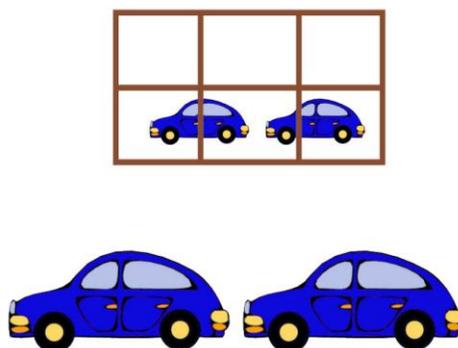
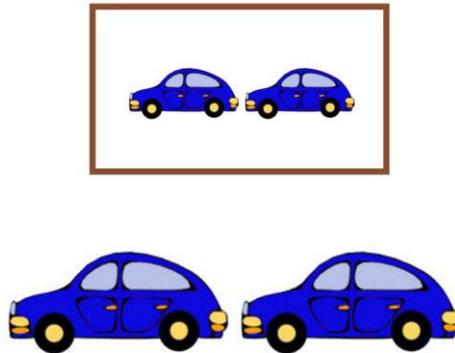


Figure 2.6: Plain rectangle with cars



4) *Procedure:*

a) Identification

Participants were first shown one of the illustrations of the solitary frames. Half the participants (360 participants total, 120 participants per frame) were shown one of the visually interpretable frames, while the other half (360) were shown the rectangle. They were then told that the depicted frame was a mirror, a picture-frame, or a window, via the following speech:

“First of all, let me apologize for the quality of the artwork. I drew it myself and I have no talent. *[There was typically a break here, during which the participant laughed or assured the experimenter that the drawing was not, in fact, that bad.]* Just so you know, this is supposed to be a (mirror/picture frame/window)”

Participants that had been shown a visually interpretable frame were given a matching description, while each description was told to one third (120) of the 360 participants that had been shown the rectangle.

b) Presentation

The investigator proceeded to show the participants the illustration that depicted the frame they had previously been shown, with the two cars inside of it and two cars in the foreground.

c) Question

Participants were then asked one of four “How many (HM)_____?” questions. These were either specific or general (e.g., “HM cars?” vs. “HM things?”). Also, half the trials used this standard question format, and in the other half of the trials it was specified that ‘real’ items be counted (e.g., “HM cars?” vs. “HM real cars?”). Thus, the full question set was “HM cars?”, “HM things?”, “HM real cars?”, and “HM real things?”. Each participant was asked exactly one of the above questions for exactly one of the stimuli. One quarter of the participants in each of the six previously described groups were asked each question, yielding thirty participants per cell in the resulting 3 x 2 x 2 x 2 design.

d) Follow up

Participants were then asked to explain their response. The investigator recorded the participants’ responses as well as their apparent gender and if the participants seemed to speak with an accent. Care was taken that participants did not see any illustrations other than their own stimuli before and during testing.

C. Analysis and Results

Responses were coded to indicate when all the cars (cars both in the foreground and within the visual frame) were included in the participants’ counts and also when the frame itself was included in their counts. For example, a response of three would indicate

that a participant had counted the frame, but not all of the cars, while a response of four would indicate that they had counted all of the cars but not the frame. (See: Table 2.1)

These codings were confirmed by the participant's explanations of their answers in the follow up.

Table 2.1: Coding rules for counting all paired items and counting the frame

Response	Counted All Paired Items	Counted the Frame
0 / 1 / 2	No	No
3	No	Yes
4	Yes	No
5	Yes	Yes

1) Did the participants count all the cars?

A 3 x 2 x 2 x 2 ANOVA was run on the frequency with which participants included all of the cars in their counts. There were 30 participants in each cell.

a) Frame

The extent to which individuals counted the cars varied as a function of the frame identity conditions. The percentage of individuals counting all cars in the window, picture frame, and mirror groups were 70%, 60%, and 22%, respectively ($F(2/696) = 82.512, p < .0005$). Of particular interest is the fact that simply telling people that a rectangle was a window, picture-frame, or mirror had a robust effect on whether all the cars were counted. Frame appearance also had an effect. Participants were significantly ($F(1/696) = 12.109, p < .005$) less likely to count all of the cars when the frame was visually interpretable (162 of 360, 45%) than when it was a plain rectangle (202 of 360, 56%).

b) Question

Further, participants were less likely to count all the cars when instructed to count ‘real’ items ($F(1/696) = 78.736, p < .0005$). In the standard question condition, 228 out of 360 participants (63%) counted all the cars, but only 136 of 360 (38%) did so in the real question condition. There was no main effect for specific-general (“HM cars” vs. “HM things”) question type ($F(1/696) = 0$). Exactly 182 of the 360 subjects (51%) in each of these conditions counted all of the cars.

c) Interactions

The only significant interaction found was between frame identity and standard-real question type ($F(2/696) = 4.927, p < .01$). There was a larger difference in car counting rates between the standard and real question types in the picture frame condition (50 fewer participants counted all the cars when the question included the qualifier “real”) than in the mirror condition (31 fewer participants counted all the cars when the question included the qualifier “real”). Also, there was a larger difference given the standard-real question for the mirror condition than the window condition, for which only nine fewer participants counted all the cars when the question included the qualifier “real.”

d) Explanations

Participants in the window condition were asked why they did not count all of the paired items. Forty-five participants articulated a response other than “no reason,” “I don’t know,” or “I didn’t think about it.” Thirty-seven members of this group indicated that they did not do so because two of the cars were inside of a frame. In the window condition five participants indicated that the framed objects were “outside” and therefore

“didn’t count.” Additionally, sixteen participants in the window condition suggested that items framed by the window were “reflections off the glass”. In the mirror condition, three participants also spontaneously stated that they were not counting the framed items because they were reflections. Further, in the picture condition, another two participants spontaneously indicated that the framed items were reflections, and three claimed that the framed items were “just pictures”. This “just pictures” response was similar to the justification spontaneously given by two of the few participants who answered the ‘how many?’ questions with “none.”

Figure 2.7: Proportion of participants counting all cars when the frame was visually interpretable in Study 1 (N = 360)

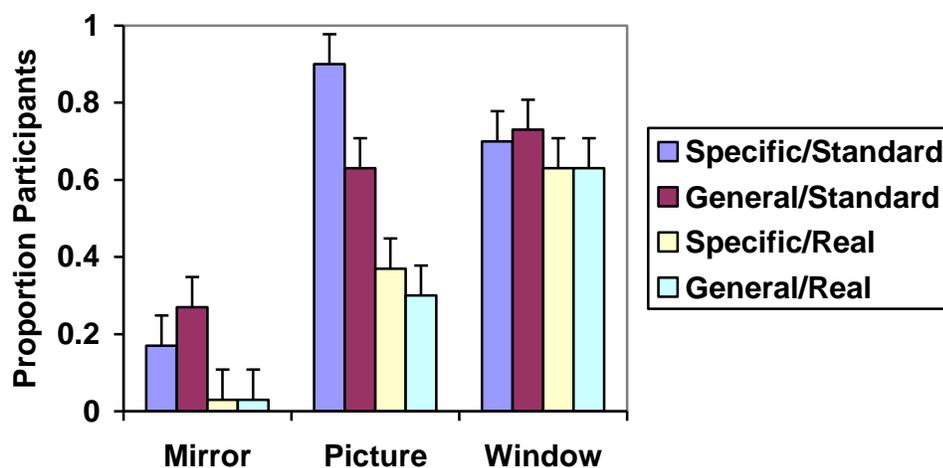
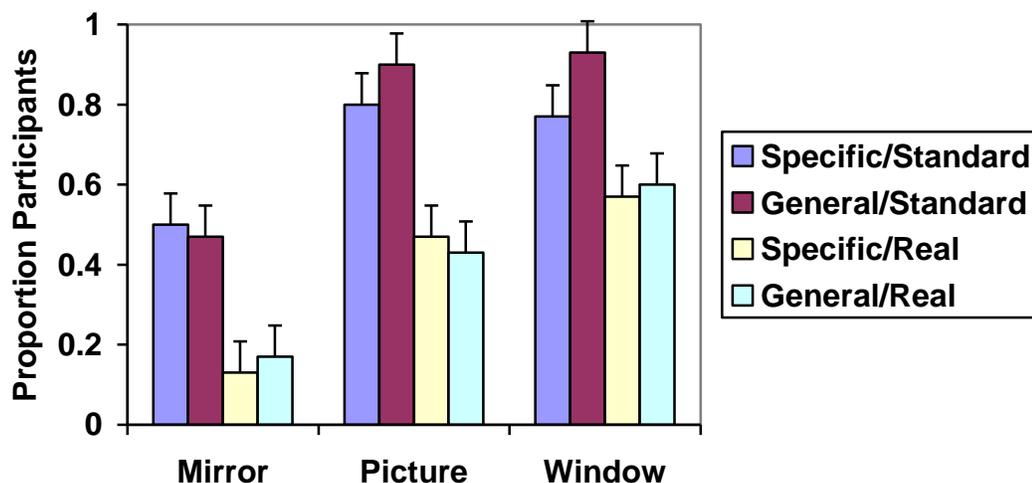


Figure 2.8: Proportion of participants counting all cars in the rectangle condition in Study 1 (N = 360)



2) *Did the participants count the frame?*

A 3 x 2 x 2 ANOVA was also run on the frequency with which participants included the frame in their counts when asked “HM things?” or “HM real things?” The participants in the “HM cars?” and “HM real cars?” conditions were not included in this analysis, as it was assumed that people would not include the frame in their counts when specifically asked to count cars (though one participant did, in fact, include the frame regardless). There were thirty participants in each cell. A binomial test showed that significantly less than half the participants (132 out of 360, $p < .0005$) included the frame in their counts.

a) Frame

Items identified as mirrors were counted less often than windows, which were in turn counted less often than picture frames ($F(2/348) = 26.534$, $p < .0005$). Sixteen out of one hundred and twenty participants (13%) counted the frame in the mirror condition, forty-nine (41%) in the window condition, and sixty-four (53%) in the picture frame

condition. Visually interpretable frames are more likely to be counted than rectangles ($F(1/348) = 8.164, p < .005$). Seventy-eight participants (43%) counted the frame in the visually interpretable and fifty-four participants (30%) counted them in the rectangle condition.

b) Question

Participants were less likely to count frames when real items had been specified ($F(1/348) = 9.582, p < .005$). Seventy-nine participants (44%) counted the frame in the standard condition and fifty-three (30%) in the real condition.

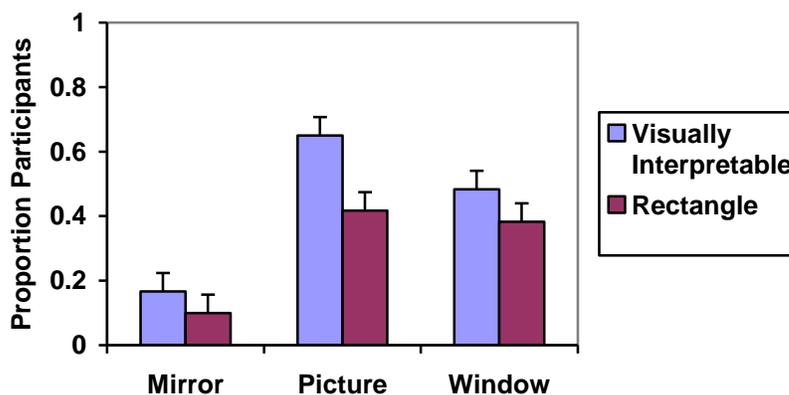
c) Interactions

No significant interactions were found.

d) Explanations

When participants were asked why they did not count the frame, the most common responses were on the order of “no reason”, “I didn’t think about it,” “I don’t know,” and occasionally, “I forgot about the frame” (103 participants total). Further, thirteen participants spontaneously indicated that, in retrospect, they believed the frame should have been counted.

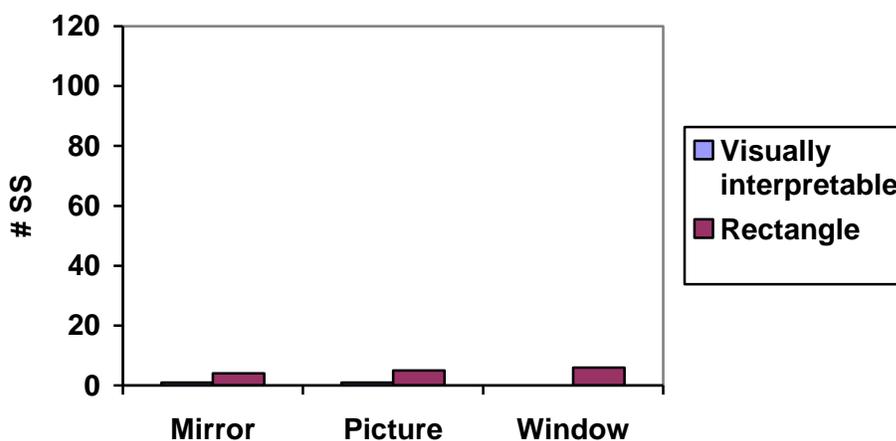
Figure 2.9: Proportion of participants counting the frame in Study 1, collapsed across question conditions (N = 360)



3) Did the participants produce unusual counts?

There were seventeen participants responding “none” or “zero” when asked “How many?” All were in the real question condition. Fifteen of these participants (4.2% of the 360 total participants in the real question condition) were in the rectangle condition. Two of the ‘zero’ responders (0.6% of 360) were in the visually interpretable frame condition, a significant difference. There was no significant difference in frequency of ‘zero’ replies between the mirror, picture frame, and window conditions, with respectively five, six, and six participants answering “none” or “zero” in those conditions. There was no significant difference due to specific-general question type, with seven participants responding ‘none’ in the specific condition and ten participants in the general condition.

Figure 2.10: Number of participants replying “none” or “zero” in Study 1 (N = 720, 120 per group)



D. Discussion

1) Conceptual ‘Realness’ influenced counting rate

It appears that the different intended interpretations of the framed objects were shared by many subjects. The different ways of framing objects influenced what objects

people considered to be countable. People were less likely to count items portrayed as reflections (as in the mirror condition) or mere drawings (as in the picture frame condition) than those that held equal status to the foreground items (as in the window condition). It is also of interest that many of these effects occurred even when the frames looked exactly the same and the only cue to differentiate them was the words the investigator used to describe them. Participants' responses differed solely due to the verbal label.

It is also clear that how a question is worded can have an impact on what is considered to be countable. Beyond the most basic level, wherein participants limited themselves to counting car-like items when cars were specified, people also appeared to be willing to include fewer cars when 'real' was specified. People seemed to apply different levels of 'realness' to identical images, differing only in size and whether or not they were located within a visual frame. It seems participants' conceptual interpretation of what the pictures represent biased what they considered to be countable entities.

2) People are disinclined to count the visual frames

Perhaps the most interesting result is that so few participants included the frame in their counts. This is particularly odd when one takes into consideration the fact that, upon questioning, some of these same participants indicated that the frame should have been included. Add to this that the experimenter began each trial by describing the frame to the participants and that the participants commonly indicated they had "forgotten" the frame, and this lack of counting becomes even more surprising. This supports the idea that perceptual variables, such as containment and visual boundaries, can have a strong impact on what is counted.

STUDY 2

How Many: No Introduction

A. Purpose

It might be argued that the peculiar lack of frame counting seen in Study 1 was merely a product of familiarity. Participants were first shown the frame and then shown a page with four cars and that frame and asked either “How many things?” or “How many real things?” It is possible that the participants could have assumed that the question pertained only to the newly introduced cars, and not to the frame they had just been shown. Study 2 was run to see if this might in fact have been the case.

B. Method

1) Design

This study used a 5 x 2 x 2 between subjects design with fifteen subjects in each cell. The variables were:

a) Visual Frame

As in Study 1, the illustrations included a visually interpretable mirror, a visually interpretable picture frame, a visually interpretable window, or a plain rectangle. Unlike Study 1, there was also an illustration with no frame present.

b) Standard-real question type

As in Study 1, participants were asked “How many?” questions that sometimes included the qualifier “real.” For example:

Standard: “How many cars?”

Real: “How many real cars?”

c) Specific-general question type

As in Study 1, Participants were asked “How many?” questions that sometimes specified that certain kinds of items be counted. For example:

Specific: “How many cars?”

General: “How many things?”

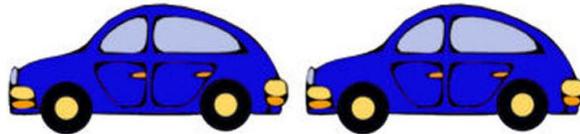
2) *Participants:*

The participants were three hundred people at Rutgers University, New Brunswick. One hundred and forty-seven were female and one hundred and fifty-three were male. Twenty were observed to have a non-native English accent. The investigator approached individuals in areas around the campus.

3) *Stimuli:*

There were a total of five illustrations. Four depicted a pair of cars in the foreground and a smaller but otherwise identical pair of cars shown within a frame. These four frames were: a visually interpretable drawing of a mirror, a visually interpretable drawing of a picture frame, a visually interpretable drawing of a window, and a plain rectangle. These were identical to the equivalent stimuli used in Study 1 (see: Appendix A). There was also one picture of two small and two large cars without a frame (see: example below and Appendix B). The illustrations were printed by a color computer printer onto white paper, put into plastic page protectors, and placed in a three-ring binder.

Figure 2.11: Cars without a frame



4) Procedure:

a) Presentation

The investigator first showed the participants one of the illustrations described above. Each illustration was shown to one fifth (60) of the participants. In contrast to Study 1, the frame was *not* identified prior to or during the presentation of this illustration.

b) Question

Participants were then asked one of four “How many (HM)_____?” questions. As in Study 1, these were either specific or general (e.g., “HM cars?” vs. “HM things?”), and in half the cases it was specified that ‘real’ items be counted (e.g., “HM cars?” vs. “HM real cars?”). Thus, the full question set was “HM cars?”, “HM things?”, “HM real cars?”, and “HM real things?”. One quarter of the participants were asked each question in each of the five previously described groups, yielding fifteen participants per cell in the resulting 5 x 2 x 2 design. Each participant was asked exactly one of the above questions for exactly one of the stimuli.

c) Follow up

As in Study 1, participants were next asked to explain their responses. The investigator recorded the participants' responses as well as their apparent gender and if the participants seemed to speak with an accent. Care was taken that participants did not see any illustrations other than their own stimuli before and during testing.

C. Analysis and Results

As in Study 1, responses were coded to indicate when all the cars (cars both in the foreground and within the visual frame) were included in the participants' counts and also to indicate when the frame itself was included in their counts. These codings were confirmed by the participants' explanations of their answers.

1) Did the participants count all the cars?

A 5 x 2 x 2 ANOVA was run on the frequency with which participants counted all of the cars. There were fifteen participants in each cell.

a) Frame

The visual frame condition had a significant effect on the frequency with which subjects counted all of the cars ($F(4, 280) = 11.144, p < .0005$). The overall rates at which the participants counted all of the cars in the visually interpretable frame conditions were 32 of 60 participants (53%) in the mirror condition, 34 of 60 (57%) in the picture frame condition, and 41 of 60 (68%) in the window condition. While these are not particularly different from each other, it should be noted that they rank order in the same manner as those in Study 1. Over all these were significantly (binomial test, $p < .005$) lower than the frequencies in the rectangle and no frame condition (51 of 60

participants (85%) and 53 of 60 (88%) respectively) which, in turn, were not significantly different from each other.

b) Question

Significantly more participants ($F(1,280) = 96.469, p < .0005$) counted all of the cars when the question was “How many?” (137 of 150 subjects, 91%) vs. “How many real?” (74 of 150, 49%). However, there was no main effect of the specific-general question type on car counting rates ($F(1,280) = .219$). One hundred and seven of 150 (71%) participants in the specific conditions included all the cars in their counts, as did 104 (70%) in the general conditions.

c) Interactions

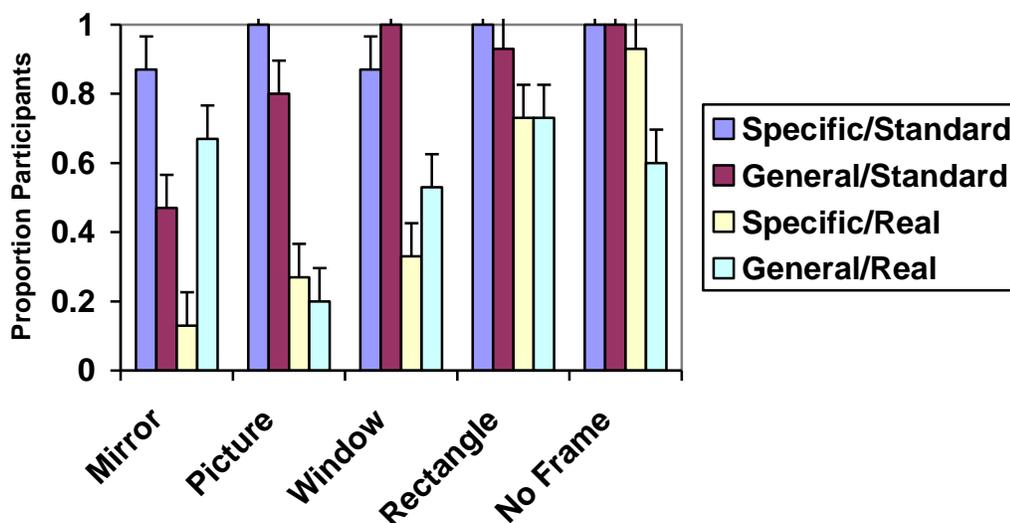
There was a significant interaction between visual frame type and standard-real question type ($F(4,280) = 3.804, p < .005$). It should be noted that the difference between the standard-real question conditions is much larger when the frame is of a visually interpretable kind than when it is a plain rectangle or when there is no frame at all. The drop is fourteen participants in the mirror condition, twenty in the picture frame condition, and fifteen in the window condition, but only seven in the rectangle condition and seven in the no frame condition. There is also a small but significant three way interaction between visual frame type, standard-real question type, and specific-general question type ($F(4,280) = 2.589, p < .05$).

d) Explanations

When asked why they did not count all of the cars, fifteen of the participants who were able to explain their reasoning indicated that it had something to do with the fact that some of the cars were contained inside a frame and others were not. There was an

exception in the no frame condition, where the one participant who was able to explain his response said it was because two of the cars were smaller. In all cases, there was a reliable tendency to leave the smaller rather than larger cars out of the count.

Figure 2.12: Proportion of participants counting all of the cars in Study 2 (N=300)



2) Did the participants count the frame?

Participants left the frame out of their counts significantly more than half the time (49 of 120 participants, 41%, binomial test, $p < .05$). A 4 x 2 ANOVA was run on the frequency with which participants counted the frame. As in Study 1, the participants in the “HM cars?” and “HM real cars?” conditions were not included in this analysis, as it was assumed that people would not include the frame in their counts when specifically asked to count cars. Subjects in the no frame condition were also excluded.

a) Frame

Visual frame had a significant effect ($F(3, 112) = 6.572, p < .0005$) The rank orderings of frame counting rates follow those of Study 1, with twenty-one participants

(70%) including frames in their counts in the picture frame condition, thirteen (43%) in the window condition, and ten (33%) in the mirror condition. The fewest number of participants (five, 17%) included the frame in their count in the rectangle only condition.

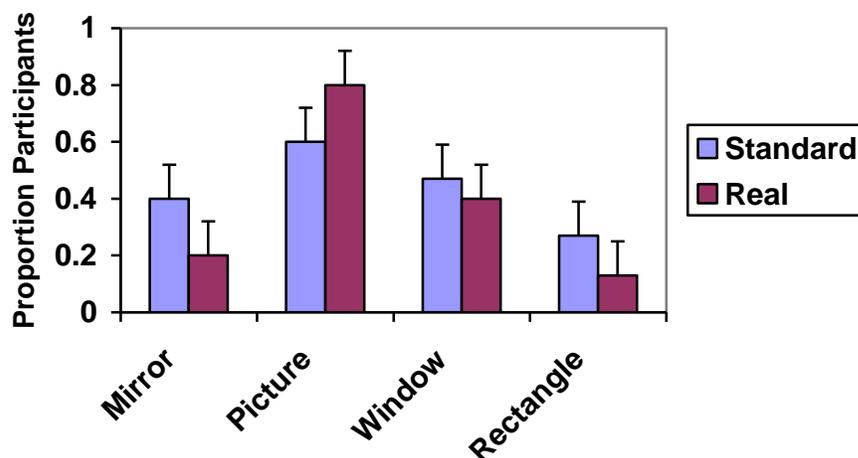
b) Question

There was no significant effect of the standard-real question condition, with the frame being counted by twenty-six participants (43%) asked “How many things”, and twenty-three (38%) asked “How many real things”, though the rank ordering was also the same as in Study 1.

c) Explanation

As was the case in Study 1, the most common response when participants were asked why they did not count the frame was “I don’t know” or “no reason” (twenty participants). Eleven participants indicated they assumed the question referred to the cars, and another five said they did not count the frame because “it was different.”

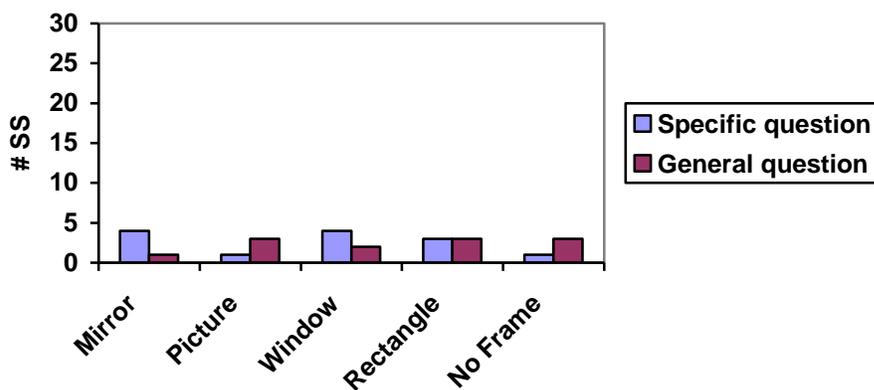
Figure 2.13: Proportion of participants including the frame in their counts in Study 2 (N=120)



3) Did the participants produce unusual counts?

A total of twenty-five of the participants did not count any of the items, replying “zero” or “none”. As in Study 1, all of these participants were in the ‘real’ question condition. Otherwise, there were no significant effects.

Figure 2.14: Number of participants replying “none” or “zero” in Study 2 (N = 300, 30 per group)



D. Discussion

1) Frame identity influences counting of contained items

The results of Study 2 were very similar to those of Study 1. Once again it appears to be the case that what people counted was influenced by both the visual frame and the questions asked. Also, as before, including the qualifier ‘real’ in the question influenced what was counted.

Of particular interest is how the subjects’ rates of counting all of the cars differed between the rectangle frame condition and the other frame conditions. The rate also was different from the rectangle conditions in Study 1. It appears that being able to apply a label to a frame, whether via visual properties or verbal identification, can influence the countability of items placed in relation to that frame. Further, it is the label - not the visual properties of the frame - that has the larger effect. This is clearly shown by the fact

that, for Study 2, the car counting rates in the rectangle condition are more similar to those in the no frame condition than to the interpretable frame conditions. A frame may group items, but that does not in and of itself seem to influence whether the groups are counted. Perceptual groups created by similarity and proximity can influence counting in the same manner as a literal boundary.

2) Familiarity does not explain the tendency to leave frames out of a count

Participants in Study 2 included the frame in their counts at nearly the same rate as those in Study 1 (Study 1, 37%; Study 2, 41%). This would seem to indicate that the general lack of frame counting seen in Study 1 was not due to a familiarity effect brought on by introducing the participants to the frames before testing. Rather, there must be some other factor that inhibits the counting of these frames.

STUDY 3

How Many: Empty Frames

A. Purpose

It is possible that the frames were less likely to be included in people's counts in Studies 1 and 2 because of the very fact that the frames functioned to contain other items. Objects that contain others are more difficult to count (Trick & Pylyshyn, 1994). If this hypothesis is correct, it follows that when individuals are run in conditions where items do not appear inside the frames, the frequency of frame counting should increase. A second hypothesis is that participants are not counting the frame because the number of cars greatly outnumbers the frames (four to one). This might be considered a salience manipulation that leads the participants to focus on counting like objects. If so, when the ratio of cars to frames varies, so should the tendency for participants to count the frame. In particular, participants should count frames more frequently in the low car-to-frame ratio conditions than in the high car-to-frame ratio conditions. These two possibilities were investigated in Study 3.

B. Method

1) Design:

This study used a 3 x 2 x 2 x 2 between subjects design with six subjects in each cell. The variables were:

a) Frame identity

As in Study 1, the subjects were told the frame represented a mirror, a picture frame, or a window.

b) Frame appearance

As in Study 1, the frame was either a plain rectangle or was visually interpretable.

c) Number of cars

Unlike Study 1, there were either two or four cars in the display.

d) Standard-real question type

As in Study 1, the participants were asked “How many?” questions that sometimes included the qualifier “real.” For example:

Standard: “How many things?”

Real: “How many real things?”

2) *Participants:*

The participants were one hundred and forty-four people at Rutgers University, New Brunswick. Seventy-six were female and sixty-eight were male. Twenty-seven were observed to have a non-native English accent. People were approached individually by the investigator in areas around the campus.

3) *Stimuli:*

There was a total of twelve illustrations. As in Study 1, four depicted one of the different frames on an otherwise blank page. These four frames were drawings of a mirror, a picture frame, window, and a plain rectangle. The frames did not contain any cars. Each frame kind was shown in the same display as four cars-- two large and two small but otherwise identical (See: examples below and Appendix C) The illustrations were printed by a color computer printer onto white paper, put into plastic page protectors, and placed in a three ring binder.

Figure 2.15: Window with two cars

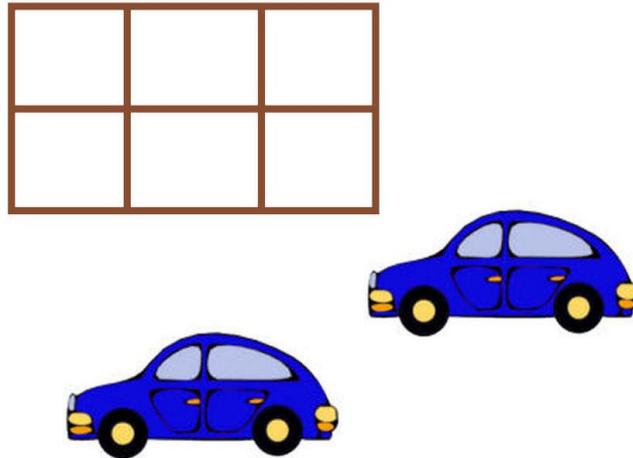
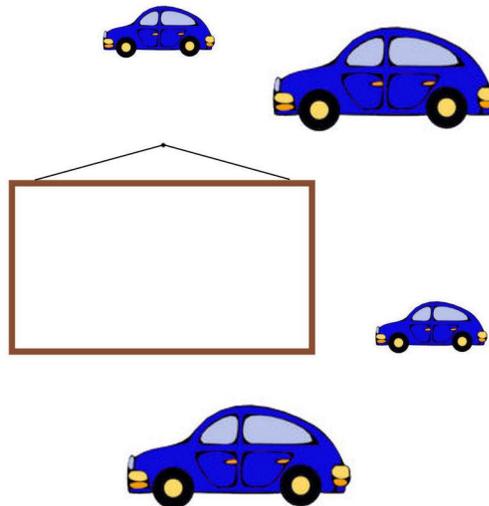


Figure 2.16: Picture frame with four cars



4) Procedure:

a) Identification

As in Study 1, participants were asked exactly one question about exactly one of the displays. They were first shown one of the illustrations containing only a frame. Half the participants (seventy-two) were shown one of the visually interpretable frames.

Twenty-four saw the drawing of the mirror, twenty-four saw the drawing of the picture

frame, and Twenty-four saw the drawing of the window. The other half (seventy-two participants) were shown the drawing of the rectangle. Also as in Study 1, all participants were then told that the frame represented a mirror, a picture-frame, or a window.

Participants that had been shown a visually interpretable frame were given a matching description. However, one third (twenty-four) of the seventy-two participants that had been shown the rectangle was told it represented a mirror, one third was told it represented a picture frame, one third was told it represented a window.

b) Presentation

The investigator then showed half (twelve) of the participants in each of these six groups the illustration that depicted two cars and the frame they had been shown. The other half was shown the illustration depicting four cars and the frame they had been shown. All of the cars were outside of the frame and the frame was otherwise empty. Participants were shown exactly one of these displays.

c) Question

As in Study 1, participants were asked exactly one question about this display. There were two questions used in this study: “HM things?” and “HM real things?” Half of the participants in each of the twelve previously described groups were asked each question, yielding six participants per cell in the resulting 3 x 2 x 2 x 2 design. Each participant was asked exactly one of the questions for exactly one of the stimuli.

d) Follow up

Again, participants were then asked to explain their response. The investigator recorded the participants’ responses as well as their apparent gender and if the subject

seemed to speak with an accent. Care was taken that participants did not see any illustrations other than their own stimuli before and during testing.

C. Analysis and Results

Responses were coded to indicate when the frame itself was included in their counts. This coding was confirmed by the subjects' explanations of their answers.

1) Did the participants count the frame?

A significant (binomial test, $p < .0005$) majority of the participants included the frame in their counts (100 out of 144, 69.4%). A $3 \times 2 \times 2 \times 2$ ANOVA was run of the frequency with which subjects counted the frame. There were 6 participants in each cell.

a) Frame

There was a small but reliable main effect of frame identity ($F(2,120) = 3.1, p < .05$). The rank ordering of the counting frequencies was picture frame, window, and mirror. Respectively, 81%, 67%, and 60% of participants counted frames given those labels.

There was no difference in the tendency for individuals in the rectangle versus the visually interpretable frame conditions to include the frame in their counts. The observed respective percents were 71% and 67%.

b) Question

No effect of question type was detected, with 51 of 72 participants (71%) including the frame in their counts in the standard question condition and 49 of 72 (68%) in the real question condition.

c) Number of cars

Fifty-four participants (75%) counted the frame in the two-car condition while forty-six (64%) did so in the four-car condition. This difference is not significant.

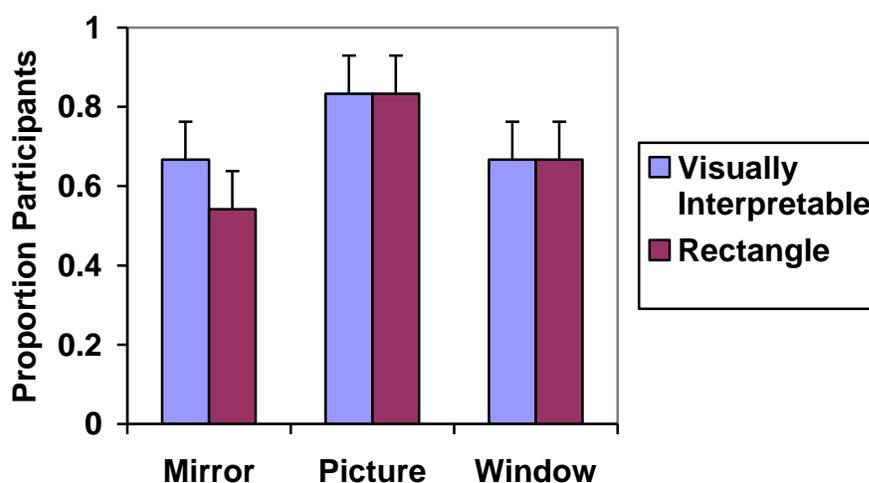
d) Interactions

No interactions were seen.

e) Explanation

When asked to explain why they did not include the frame in their count, the majority (23 out of 43) of the participants were able to give an answer, usually that the frame looked odd or that they were focusing on the cars.

Figure 2.17: Proportion of participants counting the frame in Study 3 (N=144)



2) *Did the participants produce unusual counts?*

It should be noted that eleven of the participants did not count all of the cars. For six participants, this was because they answered “none” or “zero”. As in Studies 1 and 2, all of the participants answering “none” or “zero” were in the real question condition. Of the remaining five participants, three were in the mirror condition while one each was in the window and picture frame conditions. Also, more than one of the participants in the

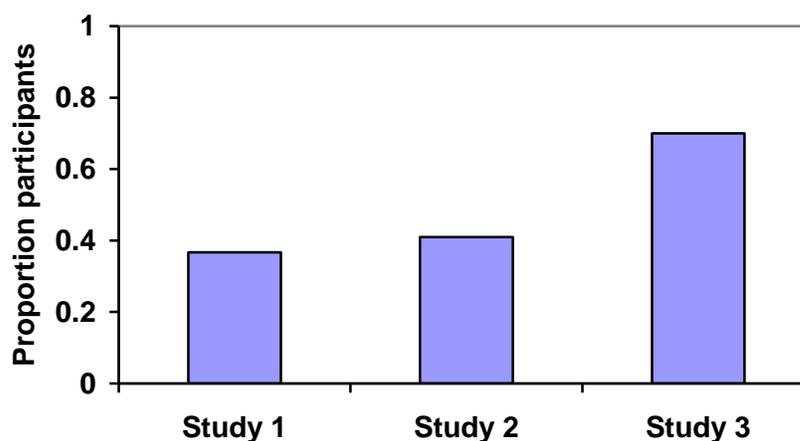
mirror condition who did not count all of the cars claimed that this was because the others were reflections, despite the fact that no cars were presented inside of the mirror.

D. Discussion

1) Frames were counted infrequently in Studies 1 & 2 because they contained other items

The supposition that participants were not counting the frame due to the relatively higher salience of cars is not supported. In both the two car condition and the four car condition in Study 3, more than half the participants counted the frame. While participants did include the frame in their counts at a slightly higher rate in the two car condition (75%) than in the four car condition (64%), the difference is not significant and any possible influence the number of cars may have had is clearly overshadowed by the effect of one item containing another. The results of Study 3 support the conclusion that items which frame others are less likely themselves to be counted. Significantly more than half the participants in Study 3 (70%) counted the frame, as opposed to significantly less than half of the participants in Studies 1 and 2 (37% and 41% respectively).

Figure 2.18: Proportion of participants counting the frame in the interview studies



CHAPTER THREE

Repeated Measures Studies

STUDY 4

How Many: Within Subjects

A. Purpose

It appears to be the case that a person's conceptual interpretation of a counting task influences what they will consider to be countable. The more 'real' an object is, the more likely it is to be counted. Also, the way a question is worded can influence what is counted. Further, these effects were seen even when all of the 'objects' were merely two-dimensional drawings on a page. The people's higher order knowledge of what the pictures represent appears to influence what kinds of items they consider to be countable entities. However, the studies presented in Chapter Two only asked a single question of their participants, about a single display. It is possible that if an adult hears multiple questions and sees multiple displays, the contrastive context will influence what items they count. Further, it is possible that the reason adults in the interview studies counted the frame infrequently was because they had not considered counting the frame, rather than because they rejected the idea that the frame might be counted. Adults should count the frame more often when given more chances to do so, as they would have more opportunities to come to realize that the frame might be countable.

B. Method

1) Design:

This study used a 5 x 2 x 2 within subjects design. The variables were:

a) Split object conditions and frame identity

Each subject saw five different kinds of displays. Three of these display types were like the visually interpretable frame conditions in Study 1. The subjects were told the frames represented a mirror, a picture frame, or a window.

For the two remaining display types, subjects were shown homogeneous sets of three items, one of which had been split in half. The two halves were either *adjacent* to each other but with a gap or *separate* with whole objects between them.

b) Standard-real question type

Subjects were asked “How many?” questions that sometimes included the qualifier “real.” For example:

Standard: “How many cars?”

Real: “How many real cars?”

c) Specific-general question type

Subjects were asked “How many?” questions that sometimes specified that certain kinds of items be counted. For example:

Specific: “How many cars?”

General: “How many things?”

2) *Subjects:*

The subjects were 63 undergraduate psychology students at Rutgers University, New Brunswick. Two (1 male, 1 female) of these subjects’ results were excluded due to experimenter error. Of the remaining 61 subjects, 38 were male and 23 were female.

3) *Stimuli:*

The stimuli consisted of twenty-one unique pictures. They were composed of one

of four different kinds of items (chairs, lamps, trees, or cars) displayed in one of five manners (one picture per item, per manner). Two of these manners shall henceforth be referred to as *split-object* conditions, and the other three as *frame* conditions. All the illustrations were generated on a computer using clipart and Paintshop Pro©. They were printed in color on white paper, and inserted into plastic sheet covers. These were then placed in a three ring binder. The picture containing all three frames was placed in the cover of this binder.

a) Split-object conditions

The eight different stimuli were used in the split-object conditions. These were composed of both halves of a broken (or ‘split’) item and two whole items of the same kind. These items were arrayed horizontally. The commensurate sides of the two halves always faced each other. In one condition, the separate condition, the two halves were separated by the two whole objects. In the other condition, the adjacent condition, the two whole items were on the left side of the page and the two halves were on the right. (See: examples below and Appendix D)

Figure 3.1: Separate

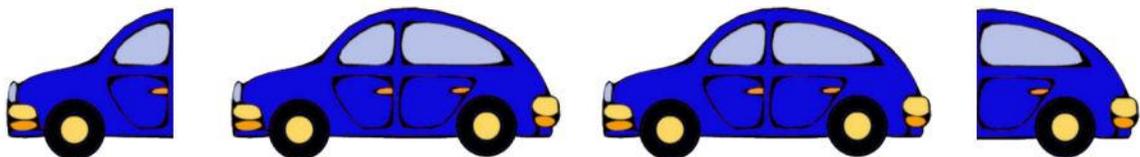


Figure 3.2: Adjacent



b) Frame conditions

There were twelve different stimuli used in the frame conditions. These were similar in form to those used in Study 1. Two objects (two chairs, two trees, two lamps, or two cars) appeared in the foreground of the picture. Above this pair was a frame, containing an identical pair of objects, reduced to thirty percent of the size of the foreground pair in both dimensions. The frame was a visually interpretable representation of a mirror, picture frame, or window. In the mirror condition, care was taken with the relative orientation of the foreground and background objects such that the objects in the mirror might reasonably be interpreted as reflections of the foreground objects. (See: examples below and Appendix D)

Figure 3.3: Mirror with chairs

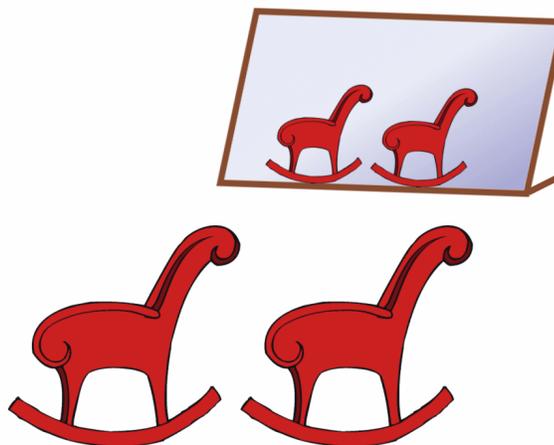
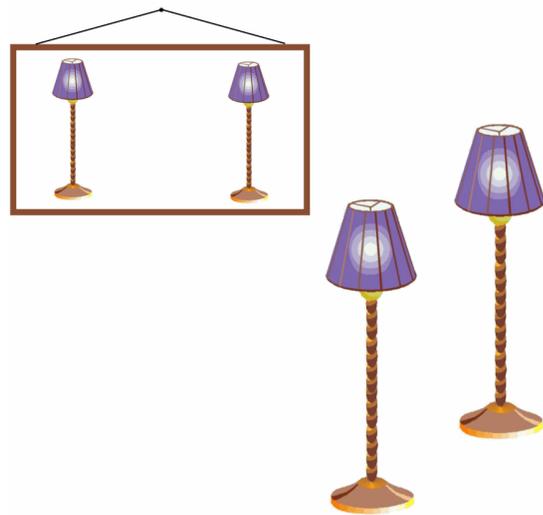


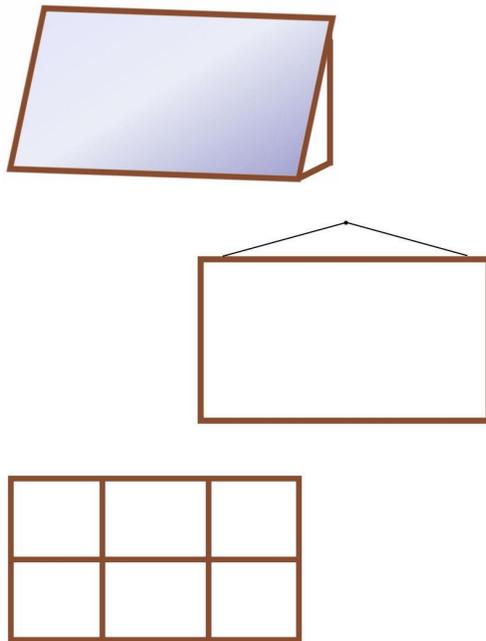
Figure 3.4: Picture frame with lamps



c) Other

The last stimulus was composed of the mirror, picture frame, and window arranged vertically on a single page. (See: Figure 3.5 below and Appendix D)

Figure 3.5: All frames



4) Procedure:

a) Identification

The experimenter and subject sat at a table with the experimenter to the subject's left. As before, the experimenter would begin each session by identifying the three frames and stating what each was intended to represent.

b) Questions

The subjects were asked four questions about each of the frame and split-object displays over the course of the session. These questions were "How many X?" (X being the type of object used for that picture), "How many things?," "How many real X?," and "How many real things?," resulting in a total of eighty questions. The forty "How many X?" and "How many things?" questions (the *standard* questions) were always asked before the forty "How many real X?" and "How many real things?" questions (the *real* questions). There was a brief pause between these two sets during which time some demographic information was taken from the subject. Within each set, the subjects were alternately asked *specific questions* ('How many X?' or 'How many real X?' depending on the set) and *general questions* ('How many things?' or 'How many real things?' depending on the set). The experimenter recorded the responses.

c) Presentation Order

Each question set was broken into two blocks, one for the frame conditions and one for the split object conditions. The ordering of these blocks was the same within subjects for the two sets and was balanced between subjects. The stimuli in these blocks would cycle through chair, lamp, and tree pictures until all questions in that block relating to those pictures had been exhausted, and then the car pictures would be shown. As a

result, the object and thing questions about a particular chair, lamp, or tree picture never immediately followed each other. However, the object and thing questions about the car stimuli always immediately followed each other. The ordering of the various frame conditions and split object conditions was balanced within blocks.

C. Analysis and Results

Split-Object Conditions

A 2 x 2 x 2 repeated measures ANOVA was run on the rates at which subjects combined both halves of the split object into one. When subjects responded ‘three’ they were coded as having combined the split halves in their counts (see: table 3.1 below). A response of “two” was considered indicative of subjects having counted only the whole objects. A responses of “four” indicated they had counted both of the whole items and both of the split halves individually in their counts. Subjects were asked a total of four questions for each of the eight possible combinations of separate vs. adjacent visual conditions, and specific-general and standard-real question conditions. Each subject was assigned a score of 0 to 4 for the number of times they combined the halves in their count for each cell.

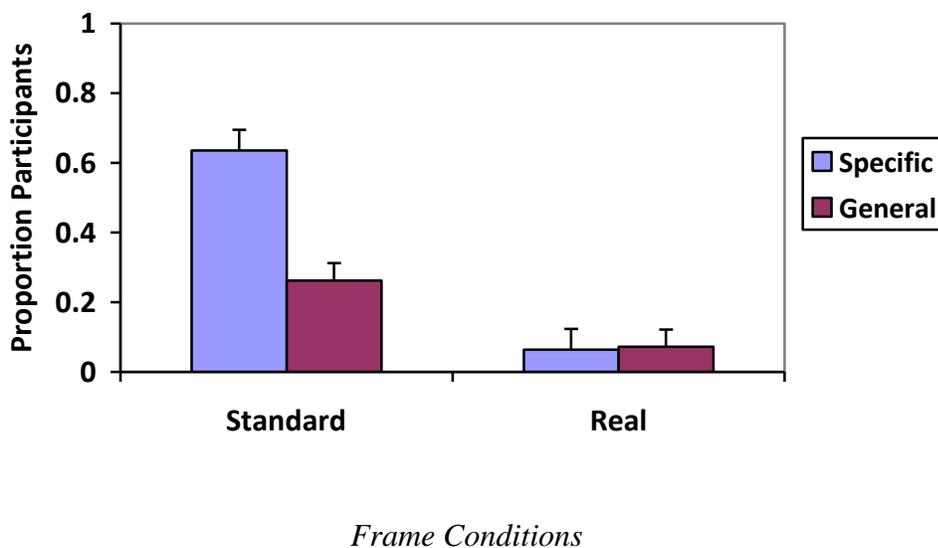
Table 3.1: Coding Rules for combined counting

Response	Combined halves?
0, 1, 2	No
3	Yes
4	No

1) Did the subjects combine the two halves of the split object in their counts?

Subjects were significantly more likely to combine halves in the standard question condition than in the real condition ($F(1, 60) = 62.341, p < .0005$) and in the specific question condition than in the general condition ($F(1, 60) = 36.553, p < .0005$). There was also a significant interaction between the two question conditions ($F(1, 60) = 41.254, p < .0005$) and a marginally significant three-way interaction between the separate vs. adjacent arrangement of the split halves and both question conditions ($F(1, 60) = 3.714, p < .06$). No main effect of separate vs. adjacent arrangement was found ($F(1, 60) = .558$).

Figure 3.6: Proportion of the time participants combined halves in the various question conditions in Study 4 (N=61)



The analyses focused on whether the subjects included all paired objects (chairs, lamps, trees, or cars) in their counts and whether the subjects included the frame itself in their counts. Responses were coded in the same manner as in Study 1. Four variables were examined to see how they affected the subjects' counting rates. These were object type, frame type, specific vs. general question type, and standard vs. real question type. No effects of object type were detected, and subsequent analyses were collapsed across

this variable. Thus, each subject was asked four questions for each of the twelve combinations of frame and question variables. Each subject therefore received a total of twenty-four scores between 0 and 4: Twelve for (a) the number of times out of four that they counted all the objects in each of these twelve question conditions; and twelve for (b) number of times out of four that they counted the frame in each of these twelve question conditions.

1) Did the subjects count all the cars, chairs, trees, or lamps?

A 3 x 2 x 2 repeated measures ANOVA was run on the frequency with which subjects included all of the paired objects in their counts.

a) Frame: Mirror, Picture frame, or Window

Frame identity had a very strong effect on object counting rates. Subjects were more likely to count all the pairs of objects inside and outside the frame for the picture condition than the mirror condition. They also were also more likely to count all the pairs of objects in the window condition than in the picture condition ($F(2, 20) = 304.7, p < .0005$). A sign test showed the Mirror < Picture < Window rank ordering to also be significant for both standard and real question conditions ($z(61) = 5.99$ and 6.959 respectively, $p < .0001$), collapsed across specific-general question type.

b) Question

Subjects were significantly less likely to count all the inside and outside of the frame in the real than in the standard question conditions ($F(1, 60) = 43.449, p < .0005$). However, there was no main effect of the specific-general question type on the rate at which subjects counted all of the objects.

c) Interactions

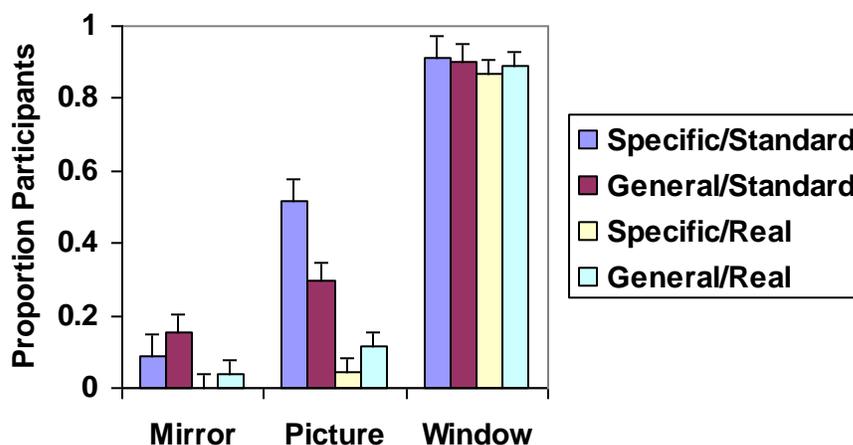
The ANOVA also revealed a reliable interaction between frame type and standard-real question type ($F(2, 120) = 35.815, p < .0005$). In the mirror condition and especially the picture frame condition subjects were less likely to count all of the paired objects when 'real' was included in the question. Conversely, there was hardly any drop in their rates of counting all paired object sets in the window condition.

Further, there were interactions between frame identity and specific-general question type ($F(2, 120) = 8.469, p < .0005$), between standard-real question type and specific-general question type ($F(1, 60) = 6.370, p < .05$), and a three-way interaction between frame identity, specific-general question type, and standard-real question type ($F(2, 120) = 19.191, p < .0005$). Subjects counted items contained by the picture frame 75% more frequently when the question was 'How many X?' than when it was 'How many things?' Significantly more subjects showed the largest difference between their paired item counting frequencies for specific/standard and general/standard questions when the visual frame was a picture frame than when the visual frame was either a mirror or a window (sign test, $z(61) = 2.09, p < .05$). The drop was not seen between specific/real and general/real questions.

By comparison, the specific-general question condition generated no significant interactions in Study 1. Even if one only considers participants in Study 1's visually interpretable frame conditions, those participants counted items in the picture frame only 43% more frequently in the specific/standard than general/standard question conditions, as opposed to Study 4's difference of 75%. In Study 1's rectangle conditions, it was the general/standard question conditions that had the higher counting rate of the two, although the difference was only 11%. The specific-general question variation was

apparently having a larger effect in this repeated measures study than was seen in the interview studies.

Figure 3.7: Proportion of the time participants counted all paired objects in Study 4 (N= 61)



2) *Did the subjects count the frame?*

Specific-general question type was not considered a factor in frame counting, as it was assumed that subjects would not count the frame (e.g., mirror) when asked about specific objects (e.g., cars). Thus, only data from trials where the questions “How many things?” or “How many real things?” were asked were used in the analysis of frame counting rates.

a) Question

There was no effect of standard-real question type, so subsequent analyses were collapsed across this condition.

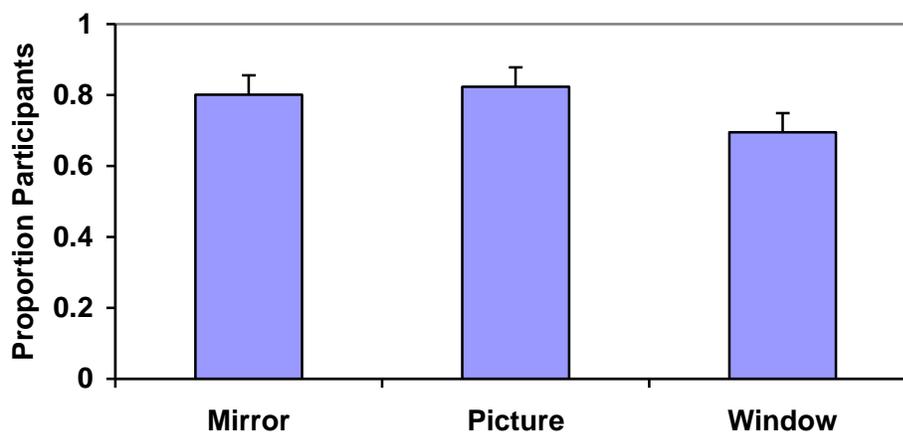
b) Frame

Subjects were asked eight relevant questions for each of the three frame conditions, and each received a score between zero and eight reflecting how many times

their answers were coded as frame counting. A 3 x 1 repeated measures ANOVA showed the main effect of frame identity to be significant ($F(2, 120) = 8.539, p < .0005$).

Subsequent two-tailed paired samples t-tests showed no significant difference in frame counting frequency between the mirror and picture conditions. However, the frequency of frame counting was significantly lower in the window condition than in either the mirror condition ($t(60) = 2.798, p = .007$) or the picture frame condition ($t(60) = 3.156, p = .003$)

Figure 3.8: Proportion of the time participants counted the frame in Study 4 (N=61)



D. Discussion

1) Subjects are more likely to include frames in their counts, when give more time

As predicted, subjects in Study 4 included the frame in their count more often than in Study 1. This indicates that people are instead less likely to consider the possibility that frames might be included in their counts, rather than that they consciously reject the idea. Once a person has considered that a specific kind of item might be in the countable set, it tends to be included in the countable set unless there is a particular reason to believe it should not be included. Thus, subjects in the interview studies who did not include the frame in their counts tended to claim that they “didn’t think about it,”

rather than that they actively decided against it.

2) Adults treat combined objects as less real

A bias to count real items continued to be seen in this study. Of particular interest are the split-object conditions. The subjects were seen to replicate the behavior of those in Shipley and Shepperson's (1990) study to a certain extent. The majority of the time (64%) subjects combined the two halves of the items in their counts when asked "How many [specific objects]?" This counting rate dropped precipitously to 26% when the question was "How many things?" Again, a similar effect was seen in Shipley and Shepperson's adult subjects. This indicates that Rutgers students participating in Study 4 had the same biases as to how this variation in questioning should influence their answering patterns as did the adult subjects in Shipley and Shepperson's study.

It is particularly interesting that the subjects in Study 4 changed their behavior when the qualifier "real" was added to the question. The combined counting frequencies in both the real/specific and real/general question conditions are nearly at floor level (6% and 7% respectively). It seems clear that the subjects do not give equal status to the reconstituted items and whole objects. The reconstructed objects are in some way less 'real' than the wholes and less worthy to be included in a count. Drops in their status as countable items become apparent with simple shifts in the wording of the questions.

3) Items that are conceptually more real are counted more frequently

The behavior of subjects in the frame conditions is also quite telling. Again, it appears to be the case that the more 'real' an item is, the more likely it is to be counted. This explains the large effect frame type has on whether or not subjects count the objects inside the frames. There are definite differences between the contexts offered by the

different frame types. In the case of windows, both the objects in the foreground and the objects seen through the window are equally real. If one were in a room and viewing objects through a window, those objects could be used and manipulated in the same general fashion as objects in the room, if one were able to get to them. This is not the case with the mirror and the picture-frame. Neither reflections nor pictures of objects can be used and manipulated in the same manner as objects in a room. That said, there is a major difference between pictures and reflections. Reflections are produced by foreground objects interacting with a mirror, while pictures exist independently of the other objects in the area. In other words, there is a causal connection between reflections and objects, but none between pictures and objects. We can therefore describe items framed by a window as real and independent, those in a picture frame as not real and independent, and those framed by a mirror as not real and dependent.

The frames vary the 'realness' of the cars they contain by invoking dual-representation. A picture of a car is not a car, but it represents a car. In order for people to successfully use a picture or other symbol to refer to another entity, they must simultaneously represent the picture and the entity (DeLoache, 2000). In the window condition, there is no need for the subjects to maintain a dual representation. They can represent all the cars in the image equally as either cars, or as pictures of cars, and it would not change their status relative to the experimenter's question. However, the mirror and the picture conditions add an extra layer of representation for the framed items. They no longer have the same representational status as the items in the foreground. This means that the subject must create a dual representation of the framed objects in those conditions.

4) Items in the picture frame are more real than items in the mirror

Young children find it difficult to maintain dual representations (DeLoache et al., 2003). One way to make the task easier for them is to create a setup that allows them to treat both the symbol and the referent as the same object. This allows them to operate while maintaining only one representation in their minds (DeLoache et al. 1997). This is essentially what is done in the mirror condition. The reflections are of the objects in the foreground, so it is not necessary to maintain two separate representations for both the framed and foreground items. The referent is already represented elsewhere. A way to make dual representation harder is to decrease the salience of the difference between the symbol and what it stands for (DeLoache, 2000). This is what is done in the picture-frame condition. The foreground items are pictures of cars, and the framed items are pictures of pictures of cars, and are thus pictures of cars themselves. The items framed by the picture frame thus require a mental representation separate from the foreground items, even though they have a different representational status. The difference in realness of the framed and foreground items is thus weaker in this condition than in the mirror condition, resulting in a higher proportion of subjects counting both the foreground and background items than in the mirror condition.

5) Specifying 'real' in the question raises the realness criterion for countable items

Bearing the foregoing discussion in mind, the large effect of including 'real' in the questions is also quite understandable. This shift impels the subjects to raise their 'realness' criterion for what is to be included in their counts. While it would be legitimate in this instance to reply "zero" to all of the 'How many real' questions given that the stimuli are pictures rather than actual objects, this was almost never seen in Study 4 (only

one subject did so). What instead happened is that the subjects almost entirely ceased counting the objects inside the mirror and picture frames which, as discussed above, are 'less real' than the foreground objects. As the foreground and background objects are equally real in the window condition, little if any decrease in the counting rates of the framed items would be expected. Again, this is exactly what was seen.

6) Contrast strengthened the effect of Specific-General question variation

In Study 1, subjects did not show any significant variation in the answers they produced to the various specific ("How many cars?") and general ("How many things?") questions. This was not the case in Study 4. While specific-general question type did not produce a main effect, it interacted with frame type and with standard-real question type, and also produced a three-way interaction with both of these other factors. This supports the contention that, in fact, the reason Shipley & Shepperson (1990) only found a significant effect of the specific-general question variation in their adult subjects was because these questions were more explicitly contrasted for their adult than their child subjects. In Study 1, specific-general question type was not contrasted for the adult subjects and did not have a significant effect on the counting rates of the paired items. In Study 4, specific-general question type was directly contrasted for the adult subjects and did influence their responses. It is also possible that the contrast may have contributed to the increased frequency of frame counting in this study as compared to the interview studies. Of the 61 subjects in Study 4, 73% included the picture frame in their counts upon first being asked to count things. While this is lower than the mean proportion of responses that included the picture frame (82%), it is still higher than the frequency with which subjects counted the visually interpretable picture frame in Study 1 (65%). By the

interpretability principle (Clark & Schober, 1992) and the Gricean maxim of relation (Grice 1975), the subjects would have expected the change from a specific kind term to a general term to have been for some purpose. This may have caused them to actively consider alternative countable sets, thus enabling them to realize that the frame might be included in the set sooner than would otherwise have been expected.

7) *The Specific-General question variation invoked 'realness' criterion*

The effect of the specific-general question variation on the counting of the paired items seemed to involve realness. Asking “How many things?” may decrease the level of realness an object must have in order to be considered countable. This would explain the slight increase in the count rates of the framed items between the specific and general question conditions for the items in the mirror, and also the difference seen between the real/specific and real/general question conditions in the picture frame condition. They may not be real, but reflections and pictures are still things. This also explains why the counting of objects in the window remains fairly stable across these conditions. As discussed above, all of the objects in the window condition were equally real to begin with. It remains an anomaly, however, that in the picture frame condition, *and only in the picture frame condition*, we find that subjects are much less likely to include framed objects in their counts when asked standard/specific vs. standard/general questions. The dual representation dynamic discussed earlier may help to explain this.

First it must be noted that to see this answering pattern at all is odd. Logically, there cannot be more cars (or trees, or lamps, or chairs) in a display than there are things. However, this response pattern is not only seen, it is seen quite often. It seems likely that this is due to the fact that the cars in the picture frame have an independent aspect of

‘carness’. While they are representations of representations, they have an existence independent of the objects in the foreground. This is in direct contrast to the ‘reflections’ in the mirror, which are representations of representations of items already represented. When the subjects are asked “How many ‘cars’?,” this brings the independent ‘carness’ (or ‘chairness’ or ‘lampness’ or ‘treeness’) of items in the picture frame to the subjects’ attention. This thus drives the subjects to treat the objects inside the picture frame as countable. When the logical contradiction of their answers is pointed out to subjects after they have completed all trials, most will see it and agree that there cannot be more specific items than things. However, some will be very adamant that their answers are correct and state that “of course there are 4 cars and 3 things”.

8) Perceptual boundaries may influence counting

It is also important to address the issue of visual grouping. Note that the frequency with which subjects count all the objects in the window condition is close to but not at ceiling (~88%), even though that frequency is unaffected by the various question conditions. This is despite the fact that objects inside and outside the window are, as previously discussed, equally real. Some of this variation may be explained by the subjects interpreting the items framed by the window as reflections off the glass, as was reported in more than one case, but not to the extent seen. It seems likely that this is an effect of visual grouping. The framed items are both visually separate from the foreground item by virtue of the frame, and visually distinct from the foreground items by virtue of being smaller. It is possible that having to cross these set boundaries makes it less likely that subjects will count all of the items. This possibility is explored further in the visual contrast study (see: Chapter 4).

Of further interest is the fact that subjects do not always include the frames themselves in their counts of things. Obviously there is some individual variation between subjects which makes them more or less likely to consider the frames to be countable entities, but as predicted, they include the frames in their counts at a much higher rate than subjects in the interview studies. There may be some improvement due to contrastive context between the specific and general questions, but there is also a trend that the subjects will ‘notice’ the frame after a number of trials and then continue to include it in their counts thereafter.

9) Subjects may show a bias to count separately movable objects

One difference from the results of the interview studies is that subjects in Study 4 are less likely to include the window in their counts than either the mirror or the picture frame. In contrast, the mirror was the least likely object to be counted in the interview studies. After they had completed all trials, the subjects in Study 4 were questioned as to why they had not included the window. Among those who were able to explain their reasoning, most claimed that the window was not a legitimate thing. A typical response was: “A window isn’t a thing; it’s a hole in the wall. It’s a lack of thing.” This reasoning would tend to indicate that subjects have a bias towards counting separately movable objects. That would explain why subjects are less likely to count the fixed window than the movable picture frame and mirror, and might also feed into why the items in the picture frame and mirror are counted so much less frequently than those in the window and in the foreground. If the window’s known immovable nature is still inhibiting counting even when the inhibition due to visual nesting is overcome, it would explain why it shifts to the bottom of the ranking even as the picture frame and mirror maintain

their relative positions in frame counting frequency.

10) People have difficulty explaining why items are excluded from their counts

Many subjects who were questioned in these studies, however, were unable to explain their reasoning. Subjects stated that while they understood that including the frame object (mirror, picture frame, or window) in their counts of things was legitimate, they “didn’t think about it.” They had not considered the possibility of counting the frame while they were performing the task, but they were immediately able to see it upon questioning. This result seems to parallel what Shipley and Shepperson (1990) found in a second split-object study, which was run on older three year olds and young four year olds. A large majority (83%) of these subjects counted both wholes and parts when first shown the objects. After this initial presentation, the experimenter proceeded to show those subjects that the two halves of the objects could be fit together to make one whole. The subjects were then again asked to count the objects. There followed a sharp decrease in the number of subjects counting both parts and wholes (down to 38%), and also an increase in subjects who counted wholes only and wholes plus the parts combined as one. In both Shipley and Shepperson’s study and in Study 4, the majority of subjects, child or adult, were able to reevaluate their answers quickly if given prompting by the experimenter. However, in both studies, this was not always the case. Thirty eight percent of the children continued to count parts and wholes despite the prompting (Shipley & Shepperson). In Study 4, one of the few subjects who never counted any frames had great difficulty coming to realize that such a countable set could ever be considered. Taken together, these results seem to suggest that a subject’s ability to interpret the experimenter’s question influences that subject’s responses.

STUDY 5

How Many: Mixed Model

A. Purpose

The results of Study 4 give good insight into whether the effects observed in Study 1 can be further influenced by context and pragmatics. While the effects of both question and frame type on counting rates are similar in Study 4 to those found in Study 1, they appear to be magnified by the contrastive nature of the frames and questions presented to each subject. However, the nature of that study only allowed for visually interpretable frames to be tested. Study 5 investigates contrast effects in rectangle frame conditions as well visually interpretable frame conditions.

B. Method

1) Design:

This study used a 3 x 2 x 2 x 2 mixed within and between subjects design. The variables were the same as those in Study 1:

a) Frame identity

The subjects were told the frame represented a mirror, a picture frame, or a window. This was varied between subjects.

b) Frame appearance

The frame was either visually interpretable or was a plain rectangle. This was varied between subjects.

c) Standard-real question type

Subjects were asked “How many?” questions that sometimes included the qualifier “real.” For example:

Standard: “How many cars?”

Real: “How many real cars?”

This was varied within subjects.

d) Specific-general question type

Subjects were asked “How many?” questions that sometimes specified that certain kinds of items be counted. For example:

Specific: “How many cars?”

General: “How many things?”

This was varied within subjects.

2) *Subjects:*

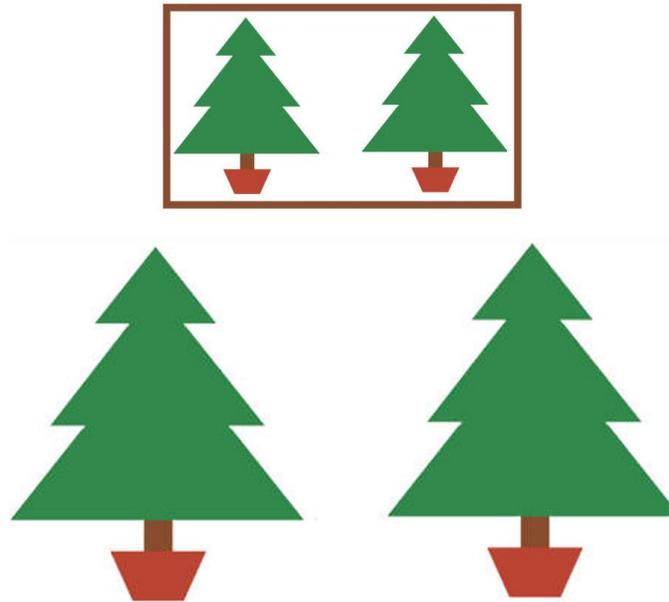
The subjects were 215 students at Rutgers University New Brunswick. They were recruited from various sections of Psychology 101 and participated for course credit. Of these, 125 were male and 89 were female. All participants were fluent in English.

3) *Stimuli:*

The visual stimuli consisted of twenty unique pictures. As in Study 1, three of these were visually interpretable frames, which looked like a mirror, a picture frame, or a window. A fourth was a plain rectangle, sized proportionately to the other frames. The sixteen other stimuli were of the same general composition as those in the previously discussed studies. In the foreground were two objects of the same kind, either cars, chairs, trees, or lamps. Above this pair was one of the four visual frames. Within this frame was a second pair of matched objects, again cars, chairs, trees, or lamps. The pair in the foreground was always of the same kind as the pair inside the frame. When pairs appeared inside the frame, they were always smaller than when they appeared outside the

frame. (See: example below and Appendix E). The pictures were all generated on a computer using clipart and Paintshop Pro©. They were printed in color on white paper, and inserted into plastic sheet covers. These were then placed in a three ring binder.

Figure 3.9: Rectangle with trees



4) Between subjects conditions:

The subjects were divided into six groups of approximately thirty-five subjects each. Assignment to these groups was random. Each of these groups received one of three different kinds of frame identification: they were told the frame was a mirror, picture frame or window. The frame stimulus was either visually interpretable (a visually interpretable mirror, picture frame, or window) or a rectangle. Stimuli with visually interpretable frames were identical to those used in Study 4. Stimuli where the frame was a rectangle were like stimuli for that condition used in Study 1 (see: example above and Appendix E).

5) Procedure:

a) Introduction

The participant and investigator sat together at a table with the subject to the investigator's right. The binder of pictures was placed on the table in front of them. After demographic information was taken, the investigator showed one of the four pictures of lone frames to the participant. Approximately one third of the subjects in the visually interpretable condition (thirty; nineteen male, eleven female) were shown the visually interpretable mirror, one third (thirty-four; sixteen male, eighteen female) the picture frame, and one third (forty-eight; thirty male, eighteen female) the window. All of the subjects in the rectangle condition were shown the rectangle.

The experimenter went on to explain what the picture was intended to represent, in the same manner as in Study 1. Approximately one third of the subjects in the rectangle condition (thirty-five; twenty-one male, fourteen female) were told the frame was a mirror, one third (thirty-five; twenty-two male, thirteen female) were told it was a picture-frame, and one third (thirty-three; nineteen male, fourteen female) were told it was a window. All of the subjects in the visually interpretable condition heard the verbal label that was consistent with the frame's appearance. They were told the mirror was a mirror, the picture frame was a picture frame, or that the window was a window.

b) Presentation and Questions

After this, the investigator proceeded to sequentially display a set of pictures to the subject. These consisted of multiple copies of the four illustrations out of the stimuli described above that used the frame to which they had been introduced. After each display, the subjects were asked one of four "How many [HM]?" questions about the

picture. The possible questions were “HM X?”, “HM things?”, “HM real X?”, and “HM real things?” (‘X’ refers to the kind of items inside and outside the frame [e.g., “HM cars?”]). Subjects were asked all four HM questions about each of these pictures over the course of the experiment. They were first asked all of the “HM things?” and “HM X?” questions, and then the “HM real things?” and “HM real X?” questions were asked.

c) Follow up

Once the subjects had been asked all of the HM questions, they were asked follow-up questions in order to make sure that the investigator had correctly interpreted which items they had been counting. Subjects were also asked why they had decided to count that subset of possible items.

C. Analysis and Results

Subjects were each asked a total of four questions of the form “HM things?” (standard/general), four of the form “HM X?” (standard/specific), four of the form “HM real things?” (real/general), and four of the form “HM real X?” (real/specific). Thus subjects were each asked four questions in each cell of the resulting 2 x 2 within subjects design. Answers were coded to indicate both whether the subject had included all the paired items in their count and if they counted the frame itself, in the same manner as in Study 1. As a result, subjects were given two scores of zero to four for each question type.

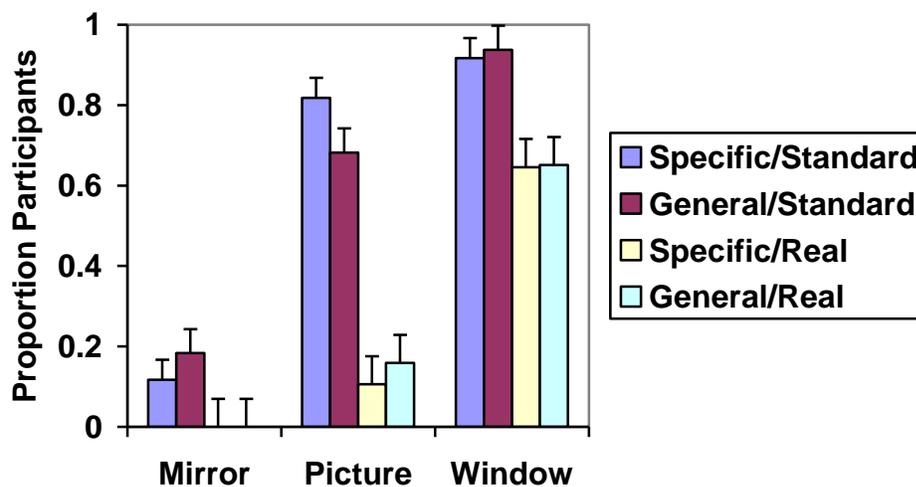
1) Did the subjects count all the paired items?

a) Visually interpretable condition

A 3 x 2 x 2 repeated measures ANOVA was run on the rates at which subjects in the visually interpretable condition included all of the paired items in their counts.

Subjects were more likely to include all of the paired items in the window in their counts than those in the picture frame, and were more likely to count those items in the picture frame than those in the mirror ($F(2,108) = 96.123, p < .0005$). Also, subjects were more likely to include all of the paired items in their counts when the question was ‘How many ___?’ than when the question was ‘How many real ___?’ ($F(1,108) = 91.261, p < .0005$). No main effect of specific-general question condition was found. There was an interaction between the standard-real question condition and frame identity ($F(2,108) = 13.389, p < .0005$), as well as a three-way interaction between frame identity and both question types ($F(2,108) = 4.726, p < .012$). As in Study 4, subjects were most likely to change the frequency with which they counted all the paired items between the specific/standard and general/standard question conditions when the frame was identified as a picture frame.

Figure 3.10: Proportion of times participants in the visually interpretable condition counted all paired items in Study 5

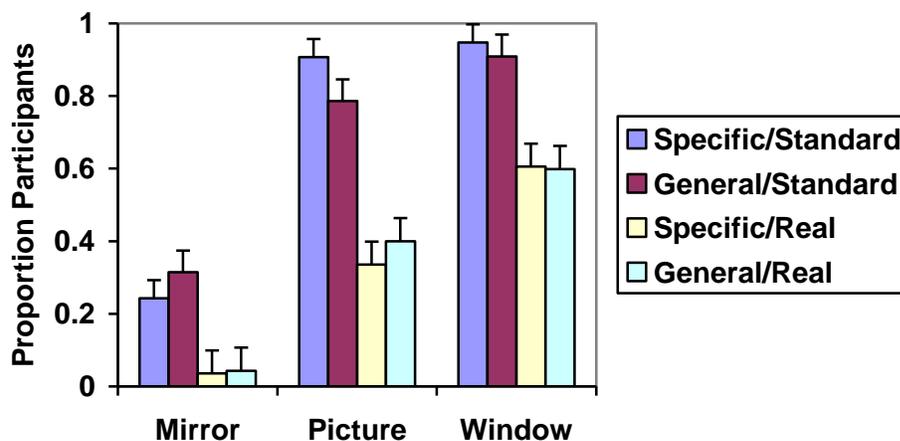


b) Rectangle condition

A second 3 x 2 x 2 repeated measures ANOVA was run, this time on the rates at

which subjects in the rectangle condition included all the paired items in their counts. A main effect of frame identity was seen here also ($F(2, 100) = 45.748, p < .0005$), with the now usual rank ordering of window, picture frame and mirror conditions. Subjects were again more likely to include all the paired items when the question was ‘How many__?’ than when the question was ‘How many real__?’ ($F(1, 100) = 73.698, p < .0005$). Again, no main effect for specific-general question condition was found. The interaction between the standard-real question type and the frame identity was again seen, though it was only marginally significant ($F(2, 100) = 3.038, p < .053$). There was a significant three-way interaction between the frame identity and both question types ($F(2, 100) = 6.154, p < .004$). Again as in Study 4, subjects were most likely to change the frequency with which they counted all the paired items between the specific/standard and general/standard question conditions when the frame was identified as a picture frame.

Figure 3.11: Proportion of times participants in the rectangle condition counted all paired items in Study 5

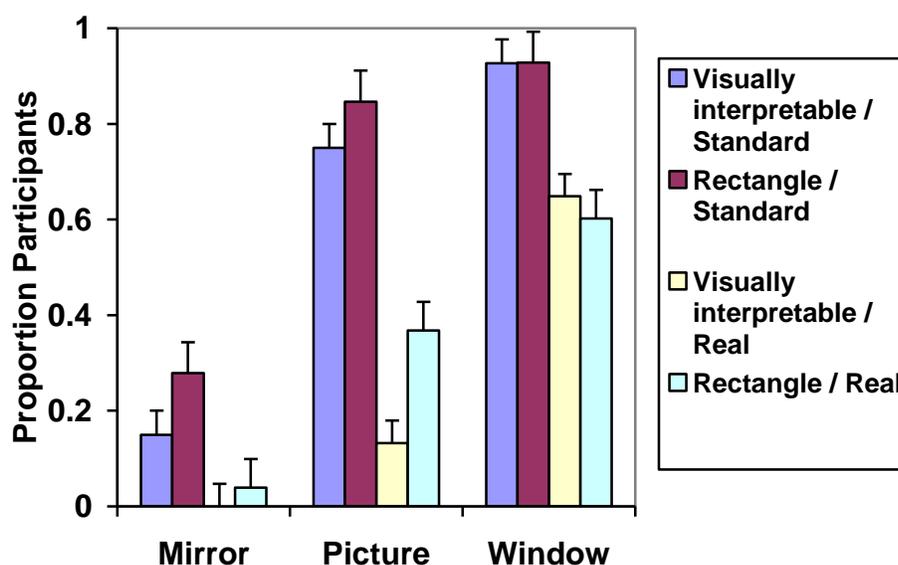


c) Visually interpretable frames vs. Rectangle

A third repeated measure ANOVA, this time $3 \times 2 \times 2 \times 2$, was run over all the subjects' paired item frequencies. Subjects counted all of the paired items less often in

the visually interpretable condition than in the rectangle condition ($F(1, 208) = 4.894, p < .03$). This was due to an increase in the picture frame condition and to a lesser extent the mirror condition. The window condition appeared unaffected. The main effect of frame identity was seen again ($F(2, 208) = 126.254, p < .0005$), as well as the effect of including 'real' in the question ($F(1, 208) = 163.924, p < .0005$). A main effect of specific-general question type again failed to be present. The interaction between frame identity and standard-real question type was also seen ($F(2, 208) = 14.202, p < .0005$), as was a significant three-way interaction between frame identity and both question types ($F(2, 208) = 10.318, p < .0005$). As in Study 4, subjects were most likely to change the frequency with which they counted all the paired items between the specific/standard and general/standard question conditions when the frame was identified as a picture frame.

Figure 3.12: Proportion of times the participants in all conditions counted all of the paired items in Study 5, collapsed across the specific-general question condition



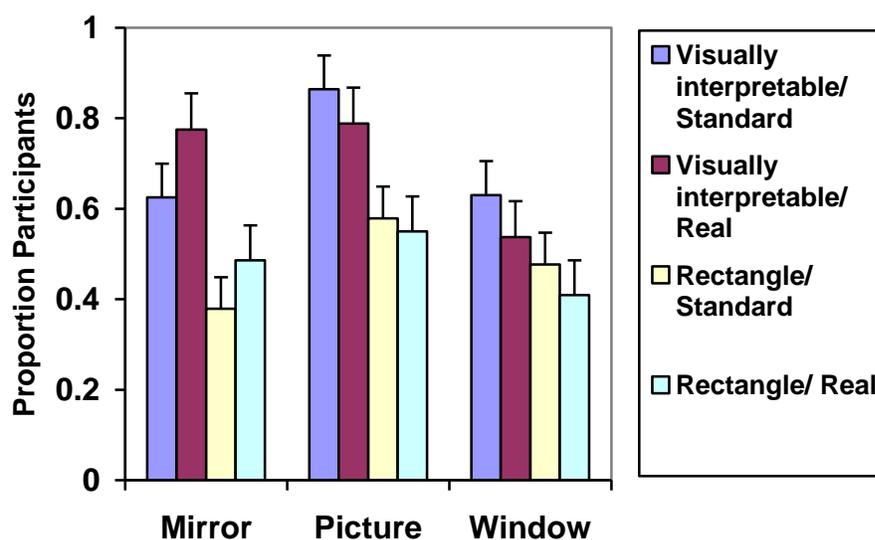
2) *Did the subjects count the frame?*

A 3 x 2 x 2 repeated measures ANOVA was run on the rates at which subjects

include the frame in their counts. While only answers to the general questions were used for this analysis, the data from all subjects in both the visually interpretable and rectangle conditions were included. A significant main effect of frame identity was found ($F(2, 208) = 4.165, p < .018$). It was also determined that subjects were significantly less likely to count frames in the rectangle than in the visually interpretable condition ($F(1, 208) = 17.428, p < .0005$). No main effect of standard-real question type was found, though an interaction was found between frame identity conditions and standard-real question condition ($F(2, 208) = 6.372, p < .003$).

When two separate 3 x 2 ANOVAs were run on the scores from subjects in the visually interpretable frame and rectangle conditions, no significant effects on frame counting frequency were found for subjects in the rectangle condition. However, subjects in the visually interpretable frame condition were reliably influenced by frame identity ($F(2,108) = 4.563, p < .014$). Further, there was an interaction between frame identity and standard-real question condition ($F(2, 108) = 4.476, p < .015$) for this group of subjects.

Figure 3.13: Proportion of times participants included the frame in their counts in Study 5



D. Discussion

1) Conceptual knowledge influences counting

These results are in line with those found in Study 4. As was found in the interview study and in the first repeated measures study, frame identity had an effect on what people treat as countable entities. This seems to be true even if the frame identity is defined merely by the experimenter's statement of what it is meant to represent. Further, when there is no perceptible difference between the frames, people will still respond to a rectangular outline based on what they have been told it represents, in a manner consistent with how they respond to more representative visual stimuli. This strongly indicates that an individual's conceptual knowledge of what the drawn frames represent influences what they take to be the countable entities. In addition, we saw that the more representative a known item is, the more strongly people are influenced by the actual characteristics such items have as 3-dimensional objects. All the effects on item counting found in this study presented themselves more strongly in the visually interpretable frame condition than in the conditions where the frame was merely a rectangle.

2) Perceptual properties influence counting

We again see that subjects did not count the frame all that often. The overall counting rate for the frames was less than that of Study 4 in both of the visual frame conditions. Further, subjects counted the frame significantly less often in the rectangle than visually identifiable condition. This supports the hypotheses that frame counting is suppressed not because of the conceptual properties attached to the identity of the frames presented, but rather because the frames are perceived as containing other items. If the reverse were true, then one would have expected frame counting rates instead to be lower

in the visually interpretable condition, as all other effects of frame kind were enhanced in that condition.

3) Contrastive conditions influence counting

As expected, the results of Study 5 include an effect of contrastive questions. While the effect of the frame identity condition is diminished as compared to the results Study 4, effects of question kind are magnified for both visually interpretable and rectangle conditions as compared to the results of Study 1. This is the pattern expected if subjects were using contrastive contexts to determine what the experimenter intended for them to count in a given situation. Conversational pragmatics would indicate that if a person first asked someone to count specific objects ('cars') and then asked that same person to count 'things', that the questioner was referring to different kinds of sets between these questions. Otherwise, it does not make sense for the wording to have changed (Brennan & Clark, 1996; Clark & Schober, 1992; Grice, 1975).

Subjects in Study 5 responded 'zero' with higher frequency than subjects in Study 4. This was particularly true of subjects in the window condition. This appears to be another case where conversational pragmatics influenced subjects' counts. Subjects who were trying to "figure out the trick" would tend to switch to answering "zero" or "none" as the study progressed-- often when "real" was introduced--declaring "there are no real things, they are just drawings." As previously discussed, both framed and foreground items in the window condition were equally real. Lacking differing levels of 'realness' within or between the presented stimuli, subjects in the window condition were in the worst position to see "the point" of the questioning, and thus most prone to producing "zero" answers. This may have inflated the effect of the standard-real question condition

on the frequency at which subjects counted all the paired items. However, answers of zero were not unheard of in the interview studies, though they were rare in Study 4.

4) Biases can be overcome with time and prompting

Though the frame counting rates are lower than in Study 4, they are still higher than those in the interview studies. This again supports the hypothesis that a lack of frame counting is due the subjects failing to entertain the possibility the frame should be counted, rather than people consciously rejecting the idea. As was the case in Study 4, the subjects in Study 5 have more time and contextual cues helping them to overcome this interference. Thus, frame counting rates are higher than in the studies where fewer questions were asked of each subject, though they were lower than in Study 4 where more questions were asked of each subject.

CHAPTER FOUR

Visual Contrast Study

STUDY 6

How Many: Mismatched Pairs

A. Purpose

In all of the studies discussed so far, subjects counted framed objects less frequently than foreground objects. While this can be attributed to the conceptual realness of the items in the picture frame and mirror conditions, it does not explain the lack in the window condition. However, in the above studies, counting all of the paired objects requires crossing the perceptual boundary created by the frame. It is possible that this factor contributes to the relative lack of counting of items in the frame, over and above the conceptual realness those frames convey. If this is the case, then one should expect that, if the question limited the possible set of countable objects to those in the frame, then the frequency with which framed items are counted would be higher, as the frame boundary would not need to be crossed. Study 6 investigates this possibility by placing different kinds of items inside and outside the now familiar frames. This allows interior and exterior items to be separately specified by the question.

B. Method

1) Design:

This study used a 3 x 2 x 2 x 2 within subjects design. The variables were:

a) Frame identity

The subjects were told the frames represented a mirror, a picture frame, or a window.

b) Standard-real question type

Subjects were asked “How many?” questions that sometimes included the qualifier “real.” For example:

Standard: “How many cars?”

Real: “How many real cars?”

c) Specific-general question type

Subjects were asked “How many?” questions that sometimes specified that certain kinds of items be counted. For example:

Specific: “How many cars?”

General: “How many things?”

d) Specific item location

Questions that specified a particular kind of item referred to items that appeared either inside the frame or outside, in the foreground of the drawing.

2) *Subjects:*

The subjects were forty-nine students at Rutgers University, New Brunswick. They were recruited from various sections of Psychology 101 and participated for course credit. Twenty-six were male and twenty-three were female. All participants were fluent in English and all but five claimed it as their first language.

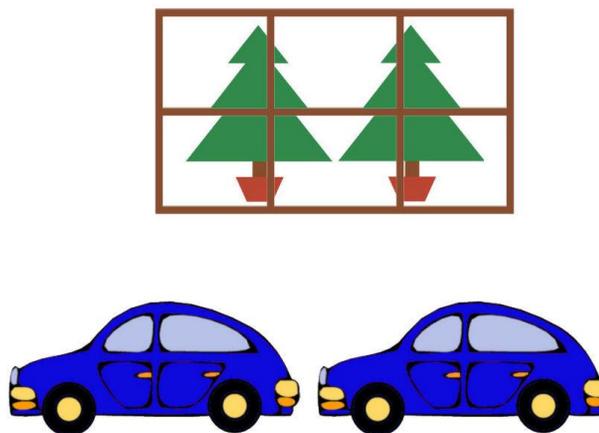
3) *Stimuli:*

The visual stimuli consisted of thirty-seven unique pictures. Thirty-six of these displays had the same kind of composition. In the foreground there was a matched pair of objects. These objects were either cars, chairs, trees, or lamps. Placed above that pair was one of three visually interpretable frames: a mirror, a picture frame, or a window. Within

each of these frames was a second matched pair of objects, again either cars, chairs, trees, or lamps. The pair in the foreground was never of the same kind as the pair inside the frame. The pairs that appeared inside the frame were always smaller than those appearing outside the frame. (See: examples below and Appendix F) The remaining display was the image depicting each of the three frames used in Study 4.

The illustrations were all generated on a computer using clip art and Paintshop Pro©. Two copies each of the thirty-six main stimuli were printed in color on white paper and inserted into plastic sheet covers. These were then placed in a three ring binder. A print of the stimulus displaying the three frames was inserted into the cover of this binder. All stimuli were printed in color on white paper.

Figure 4.1: Window with trees inside the frame and cars in the foreground



4) Orders:

The main stimuli were divided into three different sets: A, B, and C. Set A included all pictures with trees in the foreground and cars in the frame, chairs in the foreground and trees in the frame, lamps in the foreground and chairs in the frame, or cars in the foreground and lamps in the frame. Set B included all pictures with chairs in the foreground and cars in the frame, lamps in the foreground and trees in the frame, cars

in the foreground and chairs in the frame, or trees in the foreground and lamps in the frame. Set C included all pictures with lamps in the foreground and cars in the frame, cars in the foreground and trees in the frame, trees in the foreground and chairs in the frame, or chairs in the foreground and lamps in the frame.

These sets constituted three different groups of displays. Group 1 contained the pictures in set A where the frame was a mirror, the pictures in set B where the frame was a picture frame, and the pictures in set C where the frame was a window. Group 2 contained the pictures in set A where the frame was a window, the pictures in set B where the frame was a mirror, and the pictures in set C where the frame was a picture frame. Group 3 contained the pictures in set A where the frame was a picture frame, the pictures in set B where the frame was a window, and the pictures in set C where the frame was a mirror. Thus, while the groups had no pictures in common, each group contained two copies of twelve unique stimuli, and had equal numbers of pictures with the same foreground/framed item pairing, as well as equal numbers of pictures with each kind of frame.

Each subject was randomly assigned to one of three orders of stimulus presentation. For Order 1, the subjects were first shown the pictures in Group One (discussed above), then those in Group Two, then those in Group Three, and finally those in Group One again. For Order 2, the subjects were first shown the pictures in Group Two, then those in Group Three, then those in Group One, and finally those in Group Two again. For Order 3, the subjects were first shown the pictures in Group Three, then those in Group One, then those in Group Two, and finally those in Group Three again. Seventeen subjects, ten male and seven female, saw the pictures in order one, while

orders two and three were each seen by sixteen different subjects, eight male and eight female.

5) Procedure:

a) Introduction

The participant and investigator sat together at a table with the subject to the investigator's right. The binder of pictures was placed on the table in front of them. After demographic information was obtained, the investigator showed the picture with the three frames and described what each was intended to represent, just as in Study 1.

Presentation and Questions

After this, the investigator proceeded to show the subject the stimuli one at a time, in one of the orders described above. They were asked exactly one "How many [HM]" question about each illustration. When viewing the first two groups, the question "HM things?" was asked half the time (twelve times per group). One quarter of the time (six times per group) the question "HM X?" was asked, where 'X' referred to the kind of item inside the frame (exp. "HM cars?"). The other fourth of the time (six times per group) the question asked was "HM X?," with "X" referring specifically to the kind of item of in the foreground.

The questioning was much the same for the last two groups of pictures the subjects saw, except that the qualifier 'real' was added to the questions. Though the proportion of general, inside specific, and foreground specific questions remained the same, the questions were now of the form "HM real things?" and "HM real X?" It should be noted that the first and last group of stimuli viewed by the subjects were exactly the same, and only the standard-real question condition differentiated them.

c) Follow up

Once the subjects had been asked about the numerosity of all of the stimuli, they were asked follow-up questions in order to make certain that the investigator had correctly interpreted which items they had been counting. For example: “When I showed you this drawing and asked ‘how many real things,’ you said ‘two’. Can you tell me what you counted?” Typically, the subjects asked this question indicated they had counted the foreground objects. Subjects were also asked why they had decided to count those particular subsets of possible items.

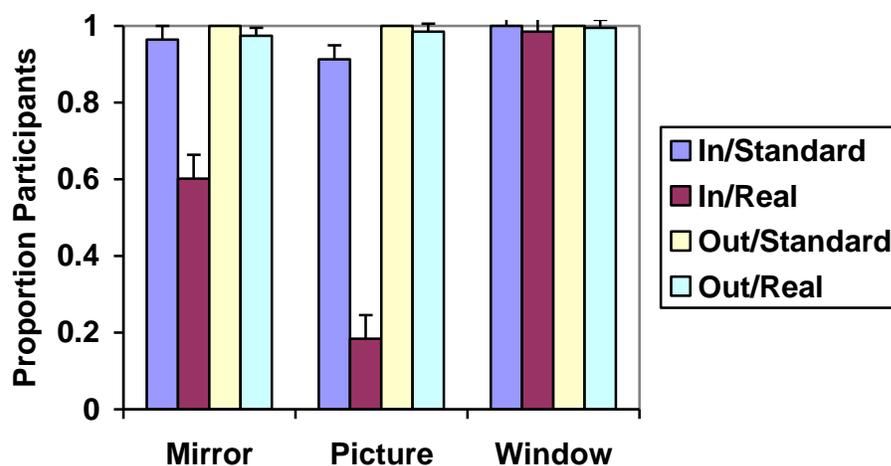
C. Analysis and Results

The responses to the “HM things?” and “HM X?” questions were coded and analyzed separately. Responses to the “HM X?” questions were coded to indicate if the subject counted both of the specified objects. For example, if a subject responds “Two” to the question “HM cars?” they were coded as having counted both cars. This code was used regardless of whether the specified items were inside or outside of the frame. Subjects were asked a total of twenty-four questions of the form “HM X?” and twenty-four of the form “HM real X?” For twelve of each of these question types, ‘X’ referred to the items inside the frame, and for the other twelve, ‘X’ referred to the items outside the frame. For each of the resulting four subsets of twelve questions, four of the questions were asked about drawings where the frame was a mirror, four where the frame was a picture frame, and four where the frame was a window. As a result, subjects were given scores of zero to four for each question/location/frame identity cell indicating how often they had included both specified items in their counts.

1) Responses when subjects were asked to count specific items: Did they count the pair?

Subjects nearly always counted both items in a specified pair, save when the question referred to ‘real’ items inside the frame. In the latter case, although subjects nearly always counted items in the window, they did not do the same in a mirror condition. Then, they counted both items in the mirror less than two thirds of the time, and items in the picture frame less than one quarter of the time. A 3 x 2 x 2 repeated measures ANOVA was run on the rate at which subjects counted both of the specified items. Subjects were much more likely to count items located in the frame than foreground items ($F(1, 48) = 146.281, p < .0005$). They were also less likely to count the specified pair in the real than the standard question conditions ($F(1, 48) = 131.471, p < .0005$). There was also a main effect for the frame identity ($F(2, 96) = 78.769, p < .0005$). Numerous interactions were found, including one between item location and frame identity ($F(2, 96) = 77.039, p < .0005$), item location and standard-real question type ($F(1, 48) = 125.514, p < .0005$), frame identity and standard-real question type ($F(2, 96) = 56.674, p < .0005$), and also a three-way interaction between location, frame, and question ($F(2, 96) = 56.373, p < .0005$).

Figure 4.2: Proportion of the time participants counted both items in the specified pair in Study 6 (N=49)



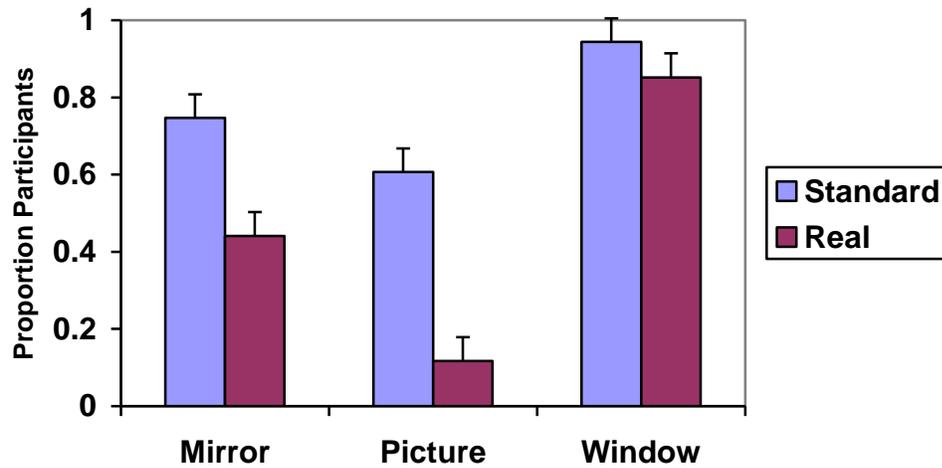
2) *Responses when subjects were asked to count things in general:*

Subjects were asked a total of twenty-four questions of the form “HM things?” and twenty-four of the form “HM real things?” For each set of the questions that share ‘real’ status, eight were about displays when the frame was a mirror, eight when the frame was a picture frame, and eight when the frame was a window. As in the other studies, answers were coded twice, indicating both whether the subject had included all the paired items in their count and whether they counted the frame itself. For example, a subject responding “four” would have counted all of the paired items, but not the frame, and a subject responding “three” would have counted the frame, but not all of the paired items. As a result, they were given two scores of zero to eight for each subset of questions.

a) Did subjects count all the paired items?

Subjects were more likely to count all the items in the standard than in the real question condition. Counts were also influenced by the identity of the visual frame. A 3 x 2 repeated measures ANOVA was run on the frequency with which subjects included all the paired items in their counts when asked “HM things?” or “HM real things?” Main effects were found for both frame identity ($F(2, 96) = 83.068, p < .0005$) and standard-real question kind ($F(1, 48) = 45.205, p < .0005$), as well as an interaction between them ($F(2, 96) = 21.409, p < .0005$).

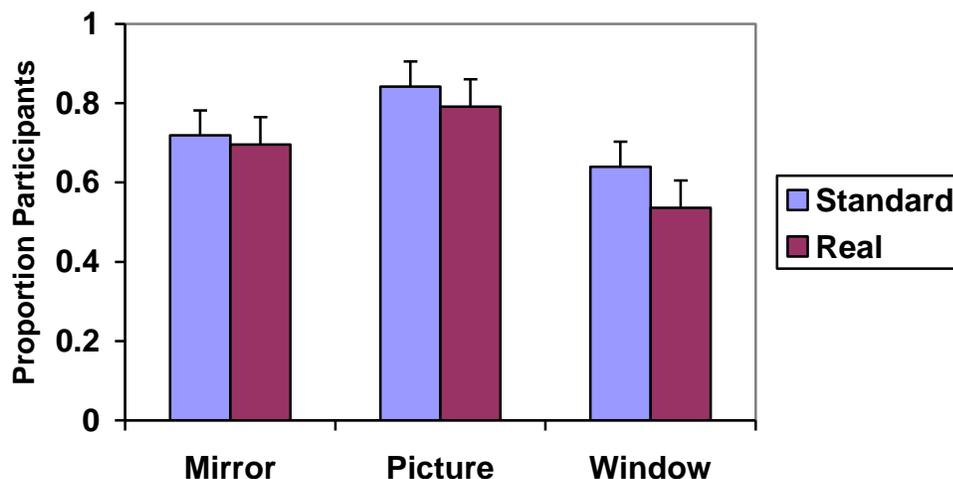
Figure 4.3: Proportion of the time participants counted all paired items in Study 6 (N=49)



b) Did subjects count the frame?

Subjects did not always include the frame in their counts, though as previously seen they were more likely to count the picture frame than the mirror, and the mirror than the window. A 3 x 2 repeated measures ANOVA run on the tendency to count frames found a main effect of frame identity ($F(2,96) = 13.439, p < .0005$). No significant main effect of standard-real question was found. No interactions were significant. Subjects counted the picture frame most often, and counted the window least often.

Figure 4.4: Proportion of the time participants counted the frame in Study 6 (N=49)



D. Discussion

1) Conceptual knowledge of realness biases counting

The results of this study are consistent with those of the interview and repeated measures studies. It was found that both question and frame type influenced the rate at which subjects counted all the paired items. The rate at which they counted the frame itself was affected only by its identity. I conclude that the subjects' counting of the paired items was influenced by both the frame and the question type because the frame altered the conceptual realness of the framed items but not the unframed items.

Subjects in the visual contrast study treated the framed and unframed items very differently from each other. While foreground items were almost always counted even when the question included the qualifier "real," this was not the case for the items contained by the visual frame. When "real" was specified, the counting rates of items framed by the mirror dropped nearly 50% from a near ceiling level, while counting rates of the items inside picture frames fell by more than 75%. Subjects' counting frequency of items inside the window remained steady, regardless of the 'real' qualifier. It seems clear

that the subjects were sensitive to the nature of the frame when determining which items were to be considered countable.

Another point of interest is that the relative counting frequency of items in the picture frame versus items in the mirror are reversed in the visual contrast study from those in the interview and repeated measures studies. Again, this would be predicted if a person's bias towards treating an item as countable increased with its level of conceptual realness. In the interview and repeated measures studies, items framed by the picture frame were more likely to be counted than items in the mirror. I suggest that this result was obtained because, though the items framed by the mirrors and those framed by picture frames are representations of representations, the items in the mirror were representations of items already represented by the drawings in the foreground. The findings from the visual contrast study add weight to this proposal.

The items pictured in the foreground in Study 6 were not the same items, nor even the same kind of items, as those appearing in the mirror. Thus, the items framed by the mirror have an existence independent of the foreground objects. Also, the reflections are taken to be caused by real foreground items that are 'off screen' and not otherwise represented on the page. This dual nature of the objects framed by the mirror was explicitly referenced by a number of subjects. In fact, more than one subject responded "four" to the "How many X?" questions that specified items contained within the mirror, counting both the reflections and the 'real' off screen counterparts that were implied by the existence of those reflections. However, items in the picture frame remained representations of representations unrelated to the foreground objects, just as they were in the repeated measures studies. Thus, the objects framed by the mirror were more 'real'

than the items in the picture frame. This is reflected by the observed counting frequencies. In the visual contrast study, items in the mirror were counted more often than items in the picture frame. Items in the window were still just as 'real' as items in the foreground, and thus were almost always counted. A similar pattern is seen in the general question condition. Subjects counted all pairs of items in the mirror condition at a much higher rate than did the subjects in the repeated measures studies. The rate more than tripled as compared to Study 4. However, the count rates for all paired items in the picture frame and window conditions were quite similar between these two studies.

2) Crossing perceptual boundaries and conceptual categories inhibits counting

The counting frequencies of framed items were higher overall in the visual contrast than in the repeated measures studies. This was predicted on the grounds that subjects were more likely to count foreground than framed items in part due to a resistance to crossing grouping boundaries. The role of grouping is a well known perceptual device for separating items and sets of items. The framed objects are perceptually grouped away from the foreground items by size, location, and the frame boundary itself.

Further, the contrast between framed and non-framed items would also decrease the likelihood that the framed items would be put together for a given count, even though one might think it reasonable to include both pairs in a count. The foreground items are more real than the framed items in the mirror and picture frame conditions, and thus including both pairs in one's count would require crossing a conceptual boundary as well as a perceptual boundary. Subsequently, the framed items would be counted less often due to their relative lack of realness.

In the interview and repeated measures studies, the same kinds of items appear both inside and outside the frame. The subjects were required to cross a group boundary in order to include both sets in their counts. In the visual contrast study, however, the framed and foreground items are of different kinds. A question referring specifically to the kinds of items inside the frame, such as “How many cars?,” would not result in a boundary crossing nor emphasize the contrast in realness level between framed and non-framed items. Supporting this interpretation, the overall rate at which subjects count framed items increased in these conditions relative to the rates seen in Study 4. This interpretation is also supported by the rates at which subjects counted all the paired items in the “How many things?” and “How many real things?” question conditions. The frame identity and question variables still had an effect, but the rate at which subjects counted all paired items (both inside and outside) were much like those in the repeated measures studies, especially in the window condition. Importantly, subjects in the visual contrast study counted framed items less often in the general question condition than the specific question condition. This was the case even in the window condition, where the foreground and framed items could be taken to be equally real. These data together support the conclusion that if a person needs to cross the boundaries of a perceptual group in order to count items, they will be less prone to count the items inside that boundary. This influence is seen over and above the effects created by the representative nature of the frame itself.

3) The perceptual feature of containment appears to bias counting

The frame counting rates in the visual contrast study were consistent with the results of the repeated measures studies. Again, the subjects did not always include the

mirror, the picture, or the window in their counts. Again, the picture frame was counted most often and the window least often. Again, only the frame condition had an effect on whether or not the frame was included in the subjects' counts. This lack of frame counting would be surprising if only the 'realness' of an item biased whether or not it is counted. One would expect, in that case, that the frame would be counted at the same rate as the items in the foreground. However, while the rate at which subjects counted foreground objects was near ceiling in the visual contrast study, frames are included in subject's counts only about seventy percent of the time over all. As these items are equally real, the reason for this observed lack of frame counting warrants further investigation.

Taking into account the lack of frame counting observed in the repeated measures studies, one might suppose that the reason the frame is sometimes not counted is because it is the only different item. Given a display that includes four cars and a frame, one might think the question "How many things?" refers only to the cars. However, if this were so, subjects should have counted the frame in the visual contrast study when the display was heterogeneous. Instead, people included the frame in their counts at a lower rate in the visual contrast study than in the Study 4. This is despite the fact the subjects in the visual contrast study were asked more questions than those in Study 4. In both studies, there was an observed tendency of subjects to initially fail to count the frame, and then to begin to count it part way into the questioning. This by itself could have caused frame counting rates in the visual contrast study to be higher than those in Study 4, regardless of any issues of homogeneity. That the rates of frame counting were nevertheless lower in the visual contrast study would seem to indicate that the dearth of

frame counting seen in the interview and repeated measures studies is not merely due to issues of homogeneity. Rather, as previously discussed, it is more likely to be due to effects of the perceptual feature of containment.

4) The perceptual feature of containment may hinder counting

If this perceptual feature of containment makes it more difficult for people to count both the frame and the items it contains, then people may be less inclined to count these items. It seems to be the case that the non-verbal number system is “always on” and can influence behavior even when we are not consciously consulting it. For example, Stroop studies have shown that number will interfere with the speed and accuracy of subjects asked to make area judgments (Hurewitz, Gelman, and Schnitzer, 2006). It is not particularly odd, therefore, to suspect that what hinders non-verbal number ability will also influence what people count verbally. It follows that there should be a correlation between what people prefer to count and what their non-verbal number systems are better at counting. This explains the lack of frame counting seen in the interview, repeated measures, and visual contrast studies. The frames contained other items and thus are less likely to be counted themselves.

CHAPTER FIVE

Reaction Time Study

STUDY 7

Which is More? Circles vs. Digits

A. Purpose

The results of the interview, repeated measures, and visual contrast studies support the conclusion that frame counting is inhibited by containment. However, it must also be shown that the arrangement of items, specifically the nesting of items, can influence how easily items are non-verbally counted. Specifically, one should find that nonverbal counting becomes more difficult as nesting (containment) increases. Also, difficulties individuating both the contained and containing items may result in only a subset of these items being accumulated. Thus, one should find that people tend to produce lower numerosity estimates of sets with higher levels of nesting relative to sets with lower levels of nesting. The level of difficulty people experience in arriving at correct counts of sets non-verbally should correlate to which sets it has been shown people prefer to count. The following study (Study 7) investigates these predictions.

B. Method

1) Design

This study used a 7 x 3 x 3 within subjects design. The variables were:

a) Number of circles

Three to nine circles were flashed on the screen in each trial.

b) Configuration

The circles were in one of three possible kinds of topological configurations: Concentric, Separate, or Mixed. These are described in more detail below.

c) Comparison digit

In each trial, subjects were asked to compare the number of circles to one of three digit values: 5, 6, or 7.

2) Subjects:

The subjects were 50 undergraduate students (28 male, 22 female) at Rutgers University, New Brunswick, participating for course credit.

3) Stimuli:

Circles were presented on a seventeen inch flat screen LCD monitor (res. 1280 x 1024). These circles were composed of one pixel thick black lines and displayed against a white background. Each presentation consisted of three to nine circles. The total average perimeter of the circles was held constant over the numbers of circles presented, such that the average total perimeter for presentations of three circles equaled that for presentations of four, five, six, seven, eight, and nine circles. Circles, or in some cases subgroups of circles, were randomly placed by the computer in non-overlapping positions, usually in the central 880 x 824 pixel region of the screen. In cases where the computer was unable to general a non-overlapping configuration in this central region within ten-thousand iterations, the entire screen was used. Circles were in one of three general topological arrangements: Concentric, Separate, and Mixed.

a) Concentric

In the concentric condition, the circles were all centered on the same point. The average spacing between adjacent circles was held constant between cardinalities, with

the minimum spacing being 10 pixels. The smallest allowable circle size was twenty-four pixels in diameter. Otherwise, the size of the circles was randomized.

b) Separate

In the separate condition, all circles were separated from each other. They did not overlap and did not contain any others. Sizes of individual circles in a group were set equal to those of a group of concentric circles of the same cardinality that appeared in the same block of trials. This group was chosen randomly and without replacement.

c) Mixed

In mixed condition, some circles contained others and some did not. Each stimulus was composed of various numbers of sub-sets of circles arranged in specific configurations henceforth known as Singles, Doubles, Duples, and Triples. A Single was, as the name suggests, a single circle. A Double was made up of two circles: a concentric pair. A Duple was made up of three circles: one outer circle containing two equally sized smaller circles equally spaced on the outer circle's diameter, and arranged either horizontally or vertically. A Triple was made up of four circles: one outer circle containing three inner circles of equal size arranged in an upward or downward pointing equilateral triangle around the outer circle's center. Orientation was randomly determined. (See: examples below and Appendix G)

Figure 5.1: Single

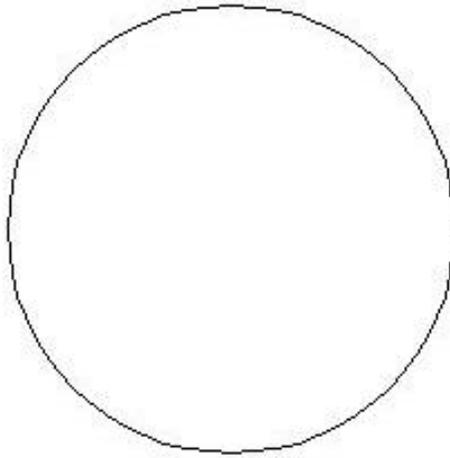


Figure 5.2: Double

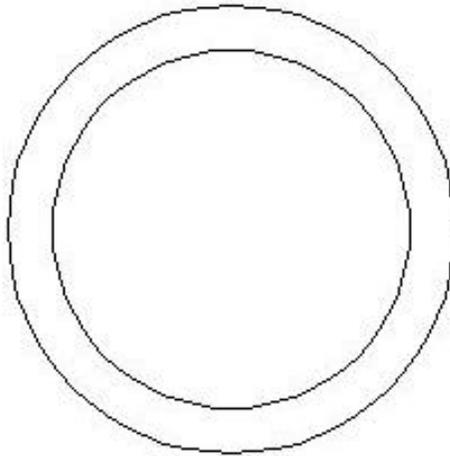
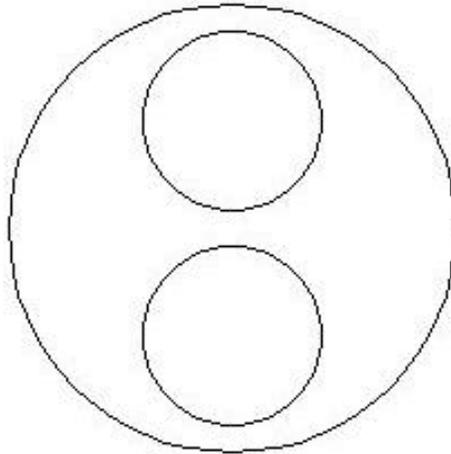
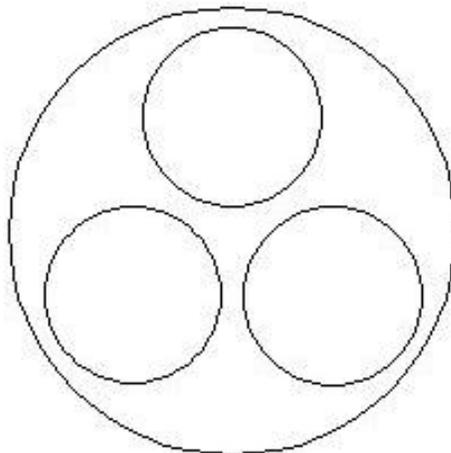


Figure 5.3: Duple**Figure 5.4: Triple**

Sizes of the individual circles in the mixed condition were determined by first selecting a group of concentric circles of the same cardinality that were generated in the same block of trials. Groups were chosen randomly and without replacement. Singles were set equal to a randomly chosen circle within that group (without replacement). The total perimeter of the circles composing the Doubles, Duples, and Triples was set equal to the total perimeter of, respectively, two, three, or four circles chosen randomly (without replacement) from the remaining circles in the chosen concentric group. The minimum

distance between adjacent circles within these configurations was set equal to the average distance between adjacent circles in the chosen concentric group. The number of Singles, Doubles, Duples, and Triples used for each cardinality was randomly drawn from one of three predefined cases, as described in table 5.1 below.

Table 5.1: Mixed Cases

Number of circles	Case Number	Singles	Doubles	Duples	Triples
3	1 & 2	0	0	1	0
	3	1	1	0	0
4	1	1	0	1	0
	2	0	0	0	1
	3	2	1	0	0
5	1	2	0	1	0
	2	1	0	0	1
	3	0	1	1	0
6	1	3	0	1	0
	2	0	1	0	1
	3	0	0	2	0
7	1	4	0	1	0
	2	1	1	0	1
	3	1	0	2	0
8	1	5	0	1	0
	2	2	1	0	1
	3	2	0	2	0
9	1	6	0	1	0
	2	0	1	1	1
	3	0	0	3	0

3) Procedure:

Subjects sat approximately two feet in front of a computer monitor and were asked to place their hands on the keyboard such that their right index finger was on the J key and their left index finger was on the F key. Subjects were told that they would see a number of circles flash briefly (250 milliseconds) on the screen followed by a mask (a plaid pattern of 24 x 24 pixel white squares on a black background, 125 milliseconds)

which they could ignore. They would then see a digit (bold, copperplate, 1.5 cm in height) in the center of the screen. This digit remained on the screen until the subject responded. The time between digit presentation and subject response was recorded by the computer. Responses were followed by a grey screen which prompted subjects to hit any key to continue.

a) Instructions

Subjects were instructed to hit the ‘J’ key when the numerosity indicated by the digit was greater than the numerosity of the circles they had just seen, and ‘F’ if it was less. Subjects were specifically instructed to include all of the circles when determining numerosity, no matter where they appeared on the screen or whether or not they were contained by another circle. The verbal instructions were as follows:

“You are going to see a bunch of circles flash on the screen. This is going to be followed by a mask, which you can ignore. Then you will see a digit in the middle of the screen. If the digit is more than the number of circles, hit the ‘J’ key. *[The experimenter mimes this action with her right hand.]* If the digit is less than the number of circles, hit the ‘F’ key. *[The experimenter mimes this action with her left hand.]* Another way to think about it is, they are both ‘more’ keys, but ‘J’ is the ‘digit more’ key, and ‘F’ is the ‘circles more’ key. If you get confused you can look at the signs there. *[The experimenter points to pair of hand drawn notes, one to the bottom left of the monitor with a circle and an ‘F’ drawn on it, and one to the bottom right of the monitor with a # and a ‘J’ drawn on it.]* Now, the circles can appear anywhere on the screen. They can be inside each other. They can be scattered about. Count all of them. Do you have any questions? *[pause]* Okay, let’s get started. Remember: Digit more ‘J’ *[mimes]*; Circles more ‘F’ *[mimes]*.”

b) Practice

After hearing the instructions, subjects completed a set of practice trials. The practice session consisted of nine trials: three each of the concentric, separate, and mixed formats. Every practice stimulus consisted of four circles. These (as the subject was informed) were presented on the screen longer than the stimuli in the test trials (a full

second rather than 250 milliseconds). Also, the circles were somewhat larger. The comparison digits used here were 3, 4 and 5. Each was used once for the concentric, separate, and mixed cases. Trial order was random. If the experimenter observed a subject consistently responding in the wrong direction, she would point this out to the subject and reiterate the instructions. When the nine practice trials were completed, the subjects were asked if they wished to proceed to the test trials. If subjects asked for more practice, another practice session was initiated. Otherwise they would continue on to the test trial.

c) Testing

Some minimal demographic information was taken (age, gender, first language), and then the testing program was initiated. While the program loaded, the instructions were reiterated to the subject, with the added admonishment to answer as quickly as possible without making too many mistakes. Subjects were also told that while they could take a break whenever they wished, they were to do so when the grey screen prompting them to hit any key was being displayed rather than while a digit was on the screen, as the computer was timing them.

The testing consisted of 1134 trials in random order. Three to nine circles would appear on the screen in a concentric, separate, or mixed, configuration, followed by the digit 5, 6 or 7. This resulted in sixty-three unique circle/configuration/digit combinations, each of which was used eighteen times over the course of the testing. Both the subjects' responses and their reaction time were recorded by the computer.

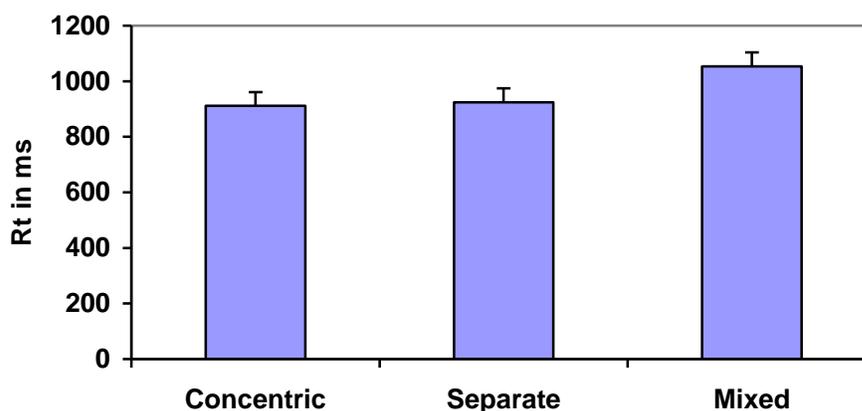
C. Analysis and Results

Analyses focused on both response time and the frequency with which subjects indicated that they believed the value of the digit was greater than the number of circles.

1) Did the subjects take longer to answer for nested configurations?

A 7 x 3 x 3 repeated measures ANOVA was run on reaction time. As predicted, the subjects took longer on average to respond in the mixed vs. the separate configuration conditions ($F(2, 98) = 7.637, p < .01$). This was true for 46 of the 50 individual subjects (binomial, $p < .0001$). Further, as is to be expected in a numerical comparison tasks (Hurewitz et al., 2006), subjects took longer to respond as the ratio between the digit value and the number of circles approached one. There was a significant main effect for set size ($F(6, 294) = 61.392, p < .0005$), as well as significant interactions between configuration and digit ($F(4, 196) = 6.447, p < .01$), configuration and circles ($F(12, 588) = 13.915, p < .0005$), digit and circles ($F(12, 588) = 13.919, p < .0005$), and between configuration, digit, and circles ($F(24, 1176) = 3.286, p < .05$).

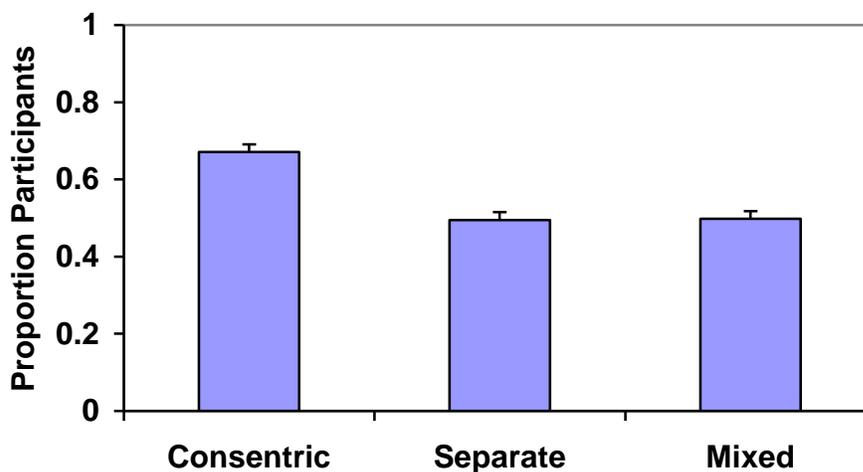
Figure 5.5: Mean Response Time, in milliseconds



2) *Did the subjects think nested configurations had lower numerosities values?*

A 7 x 3 x 3 repeated measures ANOVA was run on the proportion of “digit more” responses subjects produced. Again, as would be expected in a numerical comparison task (Hurewitz et al., 2006), subjects responded incorrectly more often as the ratio between the digit value and the number of circles approached one. There were significant main effects of digit ($F(2, 98) = 209.9, p < .0005$) and number of circles ($F(6, 294) = 791.448, p < .0005$). There were also significant interactions between configuration and circles ($F(12, 588) = 50.869, p < .0005$), digit and circles ($F(12, 588) = 53.663, p < .0005$), as well as between configuration, digit, and circles ($F(24, 1176) = 12.506, p < .005$).

Figure 5.6: Proportion “Digit More” responses



Subjects were more likely to respond “digit more” in the concentric conditions than either the separate or mixed conditions ($F(2,98) = 60.477, p < .0005$), indicating that they were in fact arriving at lower numerosity values for the circles in the concentric case than the other two cases. However, there was no difference between “digit more”

response frequencies in the separate and mixed conditions. This is contrary to the expectation that subject should derive lower numerosities for the circles in the mixed case as compared to the separate case. However, spontaneous reports from subjects indicated that they were aware that there were “more circles than they thought” when there was nesting present, and that they subsequently shifted their rates of “digit more” responding downwards from their natural inclination in these instances.

3) Did the amount of nesting in the mixed condition influence “digit more” response rates?

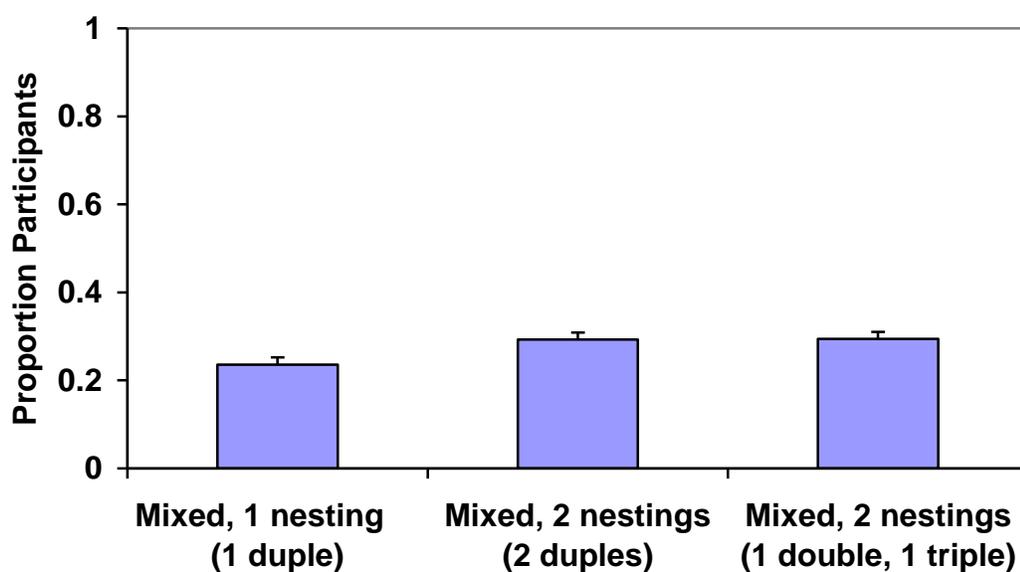
A 3 x 3 x 3 repeated measures ANOVA was run comparing the three different mixed configuration cases used for sets of 6, 7, and 8 circles. These cases were designed such that there was one mixed configuration case with one nesting resulting from one Duple, another mixed configuration case with two nestings resulting from two Duples, and a third mixed configuration case with two nestings resulting from one Double, and one Triple. This allowed for different amounts of nesting to be compared within the mixed condition while also controlling for different forms of nesting.

On average, subjects responded “digit more” less frequently in the mixed condition with one nesting than in the conditions with two nestings, indicating that they had derived higher average numerosity values in the one nesting conditions. Significant main effects were found for configuration ($F(2, 92) = 10.428, p < .0005$), digit ($F(2, 92) = 116.912, p < .0005$), and number of circles ($F(2, 92) = 183.250, p < .0005$). There were also significant interactions between configuration and digit ($F(4, 184) = 2.653, p < .05$), between configuration and circles ($F(4, 181) = 3.165, p < .05$), and between digit and circles ($F(4, 184) = 25.491, p < .0005$). Post Hoc testing showed no difference in the

“digit more” response rates between the two mixed conditions with two nestings.

However, a significant difference was found between the mixed configuration with one nesting and the mixed configuration with two nestings from two duples. Also, 39 out of the 50 (binomial, $p < .0005$) individual subjects responded “digit more” more frequently in the two Duple than the one Duple condition. The same proportion of individual subjects responded “digit more” with greater frequency in the one Double and one Triple case than in the one Duple case.

Figure 5.7: Proportion “digit more” responses for 6-8 circles in mixed configurations

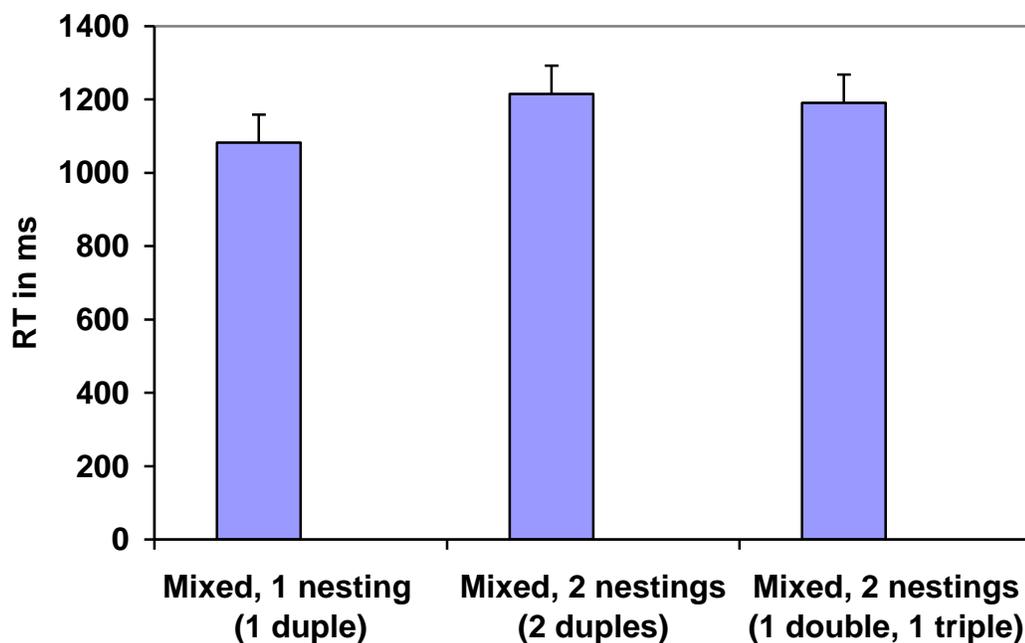


4) *Did the amount of nesting in the mixed condition influence reaction time?*

A 3 x 3 x 3 repeated measures ANOVA was also run on reaction time in these mixed conditions. As predicted, subjects took longer to respond on average in the conditions with two nestings than the conditions with one nesting. Significant main effects were found for configuration ($F(2, 92) = 8.541, p < .0005$), digit ($F(2, 92) =$

13.838, $p < .0005$) and number of circles ($F(2, 92) = 39.524$, $p < .0005$). There was also a significant interaction between digit and number of circles ($F(4, 184) = 3.309$, $p < .05$).

Figure 5.8: Mean Response Time for 6-8 circles in mixed configurations, in milliseconds



D. Discussion

1) Non-verbal counting was influenced by nesting

It is clear from these results that the topological arrangement of the various circles in the visual stimuli influenced how subjects counted. Subjects responded “digit more” with significantly higher frequency when the circles were in concentric configurations than when the circles were in configurations with lower levels of nesting. Also, subjects took significantly longer to respond in the mixed condition than in the separate condition. Further, some subjects spontaneously reported that they were aware that they were consistently underestimating the number of circles present in the mixed and concentric

conditions (“I knew there were more circles than I thought,”) and tried to adjust their responses accordingly. Such an “add X” procedure is commensurate both with the response and reaction time data, and with the conclusion that it is more difficult for people to non-verbally count items that are in nested arrangements. Subjects may only be able to count a subset of the nested items quickly, but they detected that the nesting is present, and subsequently adjust their numerosity estimates upwards.

2) As nesting increased, subjects’ non-verbal numerosity estimates decreased

This was further investigated by comparing the responses to mixed condition cases that included different numbers of nested groupings. Subjects were more likely to report that they thought the numerosity of the circles was greater than the value of the digit in cases where there was only one nesting as compared to cases with two nested groups. This implies that, as predicted, subjects were arriving at higher average numerosity estimates for the mixed condition stimuli with only a single nesting. Subjects were able to enumerate a subset of the circles and detect that there was nesting present. They subsequently adjusted their numerosity estimates upwards such that, on average, their responses in the mixed conditions were not significantly different from those given to stimuli in the separate condition. However, the response pattern suggests subjects were not as successful in tracking the number of nested groups present. This led to the higher frequency of “more circles” responses in the one nesting mixed cases versus the two nesting mixed cases. This rank ordering was seen regardless of the particular topological configuration of the two nesting cases (a Double and a Triple vs. two Duples).

An examination of the individual subjects’ response patterns supports these conclusions. Seventy-five percent of the subjects responded “circles more” with greater

frequency in the one nesting mixed case than in the two nesting mixed cases that include two Duples. An independent seventy-five percent of subjects responded “circles more” with greater frequency in the one nesting mixed cases than in the two nesting mixed cases that include a double and a triple. Further, subjects’ responses times were longer in mixed conditions with multiple nestings.

It is clear that as visual nesting increased, subjects had more difficulty accurately assessing the numerosity of the circle sets. They took longer to respond and arrived at lower estimates of set size. This is not to say that they were completely unable to quickly assess the numerosity of nested sets. Even for the concentric conditions, the likelihood that subjects would respond “circles more” increased as the numerosity of the circle set increased. However, there is no doubt that increased levels of nesting made precise enumeration of the stimuli more difficult.

CHAPTER SIX

GENERAL DISCUSSION

A. People have biases on what they consider to be countable objects

Although adults in the interview and repeated measures studies (Studies 1 through 6) did not all give the same answers, the kinds of answers they produced were typically drawn from a very limited set. Given a stimulus constructed of two foreground objects, two framed objects, and a frame, people would almost invariably compose a countable set made up of those two foreground objects and/or the two framed objects and/or the frame. The vast bulk of the participants limited themselves to counting items within this subset of basic level objects. For example, subjects normally counted the cars rather than tires, headlights, or other possible parts of those cars. This held true even when people were asked the single open end question “How many things?” This is quite similar to behavior that has been previously reported in children. Both Shipley and Shepperson (1990) and Wagner and Carey (2003) observed that the children in their studies focused on counting such basic level objects, rather than attached parts of those objects.

This is not to say that people never count parts. One should also note that, while certainly in the minority, there were a few subjects in the interview and repeated measures studies that included parts, like tires, in their counts. Though such super-counting is not seen often, it was still seen. This is expected if the bias to count basic level objects increases the probability that such counts will be produced, rather than acting as a prohibition against producing other possible counts. (Note: such a prohibition would violate the abstraction principle (Gelman & Gallistel, 1978).) As is shown in Giralt and Bloom’s (2000) study, children can be induced to count parts of objects (such as feet)

and even non-objects (such as holes) with felicity equal to that with which they count basic objects, if they have been sufficiently clearly instructed to do so. Children in Giralt and Bloom's study counted more accurately when requested to count more familiar kinds of parts. Taken together, these findings show that people are merely unlikely to include connected parts of objects in their to-be-counted sets, rather than that they are unable to include such parts. People can think of these kinds of items as members of a countable set, but they are unlikely to do so without intervention.

B. Perceptual features of a stimulus can bias what people count

The perceptual system can influence non-verbal counting. Cordes et al. (2001) found a continuous Weber function in the variations of adults' non-verbal enumerations of auditory stimuli (beeps) while Revkin et al. (2008) found the coefficient of variation was lower when comparing one, two, three, or four visual objects (dots) versus ten, twenty, thirty, and forty objects. It appears that there are some differences in people's numerical abilities across sensory modalities. This is also supported by Lana Trick and her colleagues' work on subitizing. People were only able to subitize (that is, non-verbally enumerate at great speed) items that can be pre-attentively individuated (Trick & Enns, 1997a; Trick & Enns, 1997b; Trick & Pylyshyn, 1994; Trick & Pylyshyn, 1993; Trick & Pylyshyn, 1990). This is another instance where people's counting abilities are greatly influenced by the perceptual system. If the very rapid enumeration we call subitizing can only be performed on items that can be pre-attentively individuated, then, almost by definition, items that are easiest for people's perceptual systems to individuate are also those that are easiest to count.

These findings parallel the results of the reaction time study (Study 7). Just as Trick and Pylyshyn's (1994) subjects did not show a subitizing curve for nested objects, subjects in Study 7 responded more slowly in conditions with greater amounts of nesting. Also, these subjects arrived at lower average numerosity estimates in nested conditions, as indicated by the relative dearth of "circles more" responses. It appears to be the case that nested objects are not only more difficult to pre-attentively individuate, but they are also more difficult to enumerate. Considering that items that cannot be individuated cannot be counted, this is likely a causal relationship.

However, it is not sufficient to show that perceptual factors influence how well people count. One must also show that they influence what people count. In the reaction time study, there was no ambiguity as to what set the subjects were to count. All the circles on the screen were to be enumerated regardless of nesting or location. However, in the interview and repeated measures studies (Studies 1, 2, 3, 4, 5, and 6), the to-be-counted set was not so clearly specified. The nature of the visual frames and the inclusion of questions such as "How many things" and "How many real things" created ambiguity as to what the countable set might be. Following from the principle of interpretability (Clark & Schober, 1992), this would have resulted in the subjects counting whatever set was most obvious to them. Subjects in these studies included the visual frames in their counts less often than they included the foreground objects, even while the nature of those frames influenced how they counted the objects they contained. People attended to how the frames influenced the realness status of contained items, while simultaneously ignoring them for counting purposes.

It would seem that people's apparent bias against counting the frames is at least partially the result of this visual nesting. The frames used in the interview and repeated measures studies contained other items just as some circles in the mixed and concentric conditions of the reaction time study contained other circles. This was most clearly shown by comparing the results of Study 1 and Study 3. The frequency with which participants included the visual frames in their counts was nearly doubled when items were removed from the interior of the frames. It would appear that some biases on what people count are of perceptual origin. People will tend to count the kinds of sets they are more adept at counting. Since these biases are based on perceptual factors, it is quite likely they would be present from infancy.

C. Conceptual knowledge biases what people count

People are able to construct sets of items which include members that are not automatically pre-attentively individuated by the perceptual systems. In fact, people are quite able to count items that have no presence in the real world, such as the number of songs that have gotten stuck in one's head in a given week. That we can and do count things that only exist as mental constructs is not entirely surprising. If one considers the matter, everything that we might wish to count must first be instantiated as a mental representation before we have access to it. However, once items have been established as mental constructs that are valid for counting purposes, one is once again faced with the problem that the number of possible countable sets increases exponentially. Without some biases to influence what is and is not considered countable, the likelihood that two people will converge on the same countable set in a given situation approaches zero. One must therefore posit that there are conceptual biases, in addition to perceptual biases, on

what people consider to be countable. If all possible sets of mental representations were considered equally countable, at the very least the interview and repeated measures studies would have produced wildly variable data on what adults choose to count in ambiguous situations.

Prior research suggests that children prefer to count items that are more real. The results of studies by both Shipley and Shepperson (1990) and Wagner and Cary (2003) show that children prefer to count items that are presently instantiated in the stimuli over items that would need to be mentally reconstructed from separate pieces. The results of Sophian and Kailiwiwa's (1998) studies further show that children prefer to count pieces that are physically separated from whole objects than those that must be mentally separated from the whole. Also, young children in Shipley and Shepperson's (1990) study demonstrated a preference for counting sets of real physical objects over the set of intentional kinds they represented.

Adults show this same preference for counting real objects. In the interview and repeated measures, the identification of the various visual frames as mirrors, picture frames, or windows places the items contained by these frames at differing levels of conceptual realness relative both to other framed items and to the items in the foreground. Items in the foreground are representations of chairs, lamps, trees, or cars, as are the items contained by the window. Items appearing in picture frames are to be interpreted as representations of representations, and are thus less real than either the objects in the foreground or items in the window. Commensurate with this, items in the picture frames are counted less frequently than the foreground objects or the items in the windows. Items appearing in mirrors are to be interpreted as reflections, and are thus less real than

the foreground items or the items contained by the window. As was the case in the picture frame condition, subjects were less likely to include items framed by the mirror in their counts than items in the foreground or framed by the window.

The relative realness status of the items framed by the mirrors compared to those framed by picture frames is more complex. Items framed by the picture frame are representations of pictures. They are less real than foreground objects, but they do exist. Meanwhile, objects framed by the mirror are representations of reflections. Reflections indicate the presence of 'real' items, but they have no existence independent of those items. In the interview and repeated measures studies (Studies 1, 2, 4, and 5), the objects in the foreground are of the same kind as the items in mirror. At a certain level of interpretation, the foreground objects *are* the objects framed by the mirror. Thus, the items in the mirror represent objects that are already represented by the items in the foreground. Lacking independence from the foreground objects, the items framed by the mirror are less real than the independently existing items framed by the picture frame. Accordingly, participants in these studies were less likely to include the items framed by the mirror in their to-be-counted sets than the items framed by the picture.

However, the stimuli used in the visual contrast study (Study 6) were somewhat different. The items in the frames are of different kinds than the items in the foreground. This does not affect the realness status of the items framed by the picture frame. As before, they are interpretable as representations of representations with an existence independent of the foreground items. However, the status of the items framed by the mirror is affected. They are interpretable as reflections and, while reflections do not have an independent existence from the items that they are reflections of, they do indicate the

existence of real items. Since the foreground objects are of a different kind than the framed objects, it is difficult to parse the items framed by the mirror as being reflections of the foreground objects. In fact, the objects that the mirrors appear to be reflecting are nowhere on the page. The reflections indicate the presence of real objects not otherwise represented and can therefore be seen as more real than the items inside picture frames. Accordingly, subjects in the visual contrast study are more likely to include objects framed by the mirror in their counts than objects framed by the picture frame. Further supporting that the relative “realness” of the framed items influences their counting frequency, counting rates of these framed items was even lower in the “How many real X?” question conditions than in the “How many X?” conditions.

A typical explanation given by subjects who did not count the items framed by the window was that they had interpreted the items framed by the mirror as being “reflections off the glass”. This would serve to explain the minor drop in counting frequency of the items framed by the window when real is specified. That is, knowing that windows could act as reflective surfaces and given the presence of foreground objects of the same kind as those in the frame, some subjects constructed an interpretation of the stimuli that allowed them to put the framed and unframed items at different levels of ‘realness’. This in turn allowed them to answer the question “How many real X?” sensibly. Given the Gricean maxims of quantity, manner, and relation (Grice, 1975) and the principle of interpretability (Clark, & Schober, 1992), the adults in these study would have had the expectation that the term ‘real’ was included in the question to resolve some ambiguity, and subsequently search for items that that may be interpreted as less real than others.

It appears to be the case that the adults in these studies were showing the same kind of biases as to what is a countable object as children have shown. Granted, realness was manipulated at a more conceptual level in the interview and repeated measure studies than in Shipley and Shepperson (1990), Wagner and Carey (2003), and Sophian and Kailiwiwa's (1998) studies, but a preference of adults to count real items is clearly demonstrated. This suggests that there are conceptual biases on what people prefer to count that are present early in life and continue to influence behavior into adulthood.

D. Conceptual information can influence perception

One should not assume that one's conceptual understanding of a stimulus cannot influence one's perceptions. Even something as basic to the visual system as pop-out can be influenced by one's conceptual understanding. Jonides and Gleitman (1972) describe a situation where an oval would pop out of a field of numbers when subjects had been told to look for the letter 'O', but not when they had been told to look for a zero. Conversely, the same oval would pop out of a field of letters when subjects had been told to look for a zero, but not when they had been told to look for the letter 'O'. Invoking the concept of letter versus number altered how the subjects pre-attentively individuated the scene.

This may partially explain why subjects consistently counted the items labeled picture frames more often than items identified as windows or mirrors, even when those visual frames were all simply rectangles. Rather than parse the various cars, trees, chairs and lamps independently from the frame which contained them, subjects may have instead perceived them as simply features of "the picture". Thus, the perceptual system may pre-attentively parse "the picture" from the scene rather than the items the picture

frame contained, thereby increasing the likelihood that a subject would consider “the picture” to be a countable object. This may even contribute to the odd cases of subjects in the repeated measures studies who would count both the framed and unframed pairs of items when asked questions of the form “How many [cars]?”, but only the unframed pair of items when asked “How many things?” Asking about specific kinds of items may direct the visual system to parse out all items of that form. Lacking this specific direction, the likelihood that a person will instead parse framed items as features of “the picture” may increase.

E. Context and pragmatics can influence what people count

Evidence suggests that participants were not *deciding* not to count the frame, but rather that they were failing to consider that the frame might be countable. Subjects in the repeated measures studies who counted the frame only some of the time tended to switch to - as opposed to from - counting the frame as the trials progressed. Many participants in the interview studies could not explain why they did not include the frame in their counts. Also, upon questioning, it sometimes was quite difficult to convey the possibility that the frame might have been considered countable. Questions such as “Why didn’t you count the mirror?” were sometimes met with non-sequiturs such as “Because they’re reflections.” These adults did not treat the window as a countable item, not because they consciously decided against counting it, but rather because it simply never occurred to them to count it. Similarly, Shipley and Shepperson (1990) showed that many children could be induced to count mentally constructed objects or kinds when given sufficient prompting that they should do so. It is not that people are unable to construct this kind of countable set, it is simply that they are unlikely to think to do so without prompting.

The interaction between people's perceptual and conceptual counting biases creates a probability distribution of countable sets a person is more or less likely to generate. When asked to count, the principle of interpretability is invoked (Clark & Schober, 1992). People treat counting biases as common ground and resolve ambiguities as to which set the questioner wants them to enumerate by counting the set that is most obvious to them based on their own counting biases. While no sets are impossible (as evidenced by the creative range of counts produced by the participants in the interview studies) some are more probable than others.

Before a person can arrive at a correct count, one must first correctly determine what set a questioner wishes for them to count. The differences observed by Shipley and Shepperson (1990) and Wagner and Carey (2003) regarding adults' and children's rates of counting mentally constructed objects may simply indicate that adults are better at overcoming their biases as to what a countable set might be, and instead forming and enumerating alternative sets that may better fit what the questioner intended. This task invokes some of the same difficulties as mind reading tasks. People must suppress their own beliefs about what the countable set should be and instead count the set which the situation suggests the experimenter believes should be counted. Prior research has shown that young children may lack sufficient inhibition to act on other people's beliefs when they are contrary to their own (Friedman & Leslie 2004; Leslie, 2000). In other words, children's poor performance at counting mentally constructed objects may not be because they cannot count such sets, but rather because it does not typically occur to them that the set should be counted.

In this same vein, the reason why adults do not include the frame in their counts is not because they cannot do so, but because they do not think to do so. More to the point, they do not consider that the experimenter wishes them to include the frame, following from the belief that the experimenter has the same preconceptions as to what kind of items are countable as they themselves do. When one is asked to count, one must construct the same countable set as the questioner if one is going to arrive at the “correct” answer. However, conversational pragmatics can change how people interpret a scene. As previously discussed, this may have contributed to Shipley and Shepperson’s (1990) finding that adults’ counts of sets that included split objects were influenced by the use of a specific (“forks”) or general (“things”) term, but children’s counts were not. The specific-general term was varied within block for their adult subject, but not for their child subjects. Adults would likely have thought that the variation in the term the experimenters used implied some corresponding variation in the sets they were to count, and altered their response accordingly (Brennan & Clark, 1996; Clark & Schober, 1992; Grice, 1975). This conclusion is supported by the results of the interview and repeated measures studies. Effects of the specific-general question variation were stronger in repeated measures studies, where the term the subject heard was varied within block, than in the interview studies, where the participants only heard one question.

The answers adults in these frame studies produced in response to the standard and real question conditions also seem to be influenced by pragmatics. When the experimenter asked the subjects specifically to count real items, it implied via the Gricean maxims of relation and quantity (Grice, 1975) that there must have been some items present that did not qualify as real. Further, by the maxim of manner (Grice) and the

principle of interpretability (Clark & Schober, 1992), listeners expected that this difference in realness status was obvious. In the mirror and picture conditions, the nature of the containing object *a priori* establishes the items that are contained as being less real than the foreground objects. Since the window condition implies no such obvious differences between the realness of the various items on the page, the subjects endeavor to construct an interpretation of the scene such that the realness of some of the items is privileged over others. Thus, as discussed above, some subjects strike on the idea that the framed items are reflections.

It should also be noted that people were most likely to develop this interpretation in the interview studies where they only saw one type of frame and thus did not see the realness status of framed and unframed items contrasted between stimuli. Further, these were also the studies where the people were most likely to declare that none of the items were real and respond that there were zero real items present in the stimulus. This response preserves the equivalent realness status of the framed and unframed items in the window condition just as well as do responses of four or five, but does so by excluding both inner and outer item pairs from the count rather than by including both. Further, these 'zero' responses allow the subjects to take into account the experimenter's injunction to count "real" items. Since all the items in the stimulus are merely pictures, none of them are real in the common sense, and therefore none should necessarily be counted. This again illustrates the wide range of possible counting sets people can conceivably produce in a given situation. While constructing an empty counting set was not typical, neither was it impossible. Similarly, there were a few subjects that, when

asked to count things, counted kinds of things (“Two, cars and mirrors”). Again, while this behavior was by no means typical, it was still occasionally observed.

Further, while specifying that people count real items drops the rate at which they count framed items, specifying real also reduced the rate at which all the paired objects were counted even when there was no frame present. The stimulus for the no-frame condition in the second interview study (Study 2) was created by deleting the frame from the stimulus used in the rectangle condition. This left behind two small and two large items in two separate visual groupings. As discussed above, it seems that the pragmatics of including real in the “how many?” questions reinforced the idea that there must be both real and non-real items in the stimuli. Lacking any more concrete differences between the visual items, some subjects would count only one of the object pairs. A similar pattern was seen in the rectangle condition. This supports the conclusion that perceptual groupings other than containment can serve as cues when determining which items might be countable in a given situation.

These examples also serve to illustrate both how flexible people can be when determining what kinds of items might be counted, and how rigidly people adhere to the principle that if one item of a kind should be counted, then all items of that same kind should be counted. Despite the arbitrariness of counting only the smaller items or the larger items, people will tend to count both of the small items or both of the larger items, not just one of a pair.

Further, it appears that contrasting various levels of conceptual realness between stimuli presented to the same subject increased the effect of realness on counting. Looking at the results, one can see that the variation of frame kind had a stronger effect

on counting rates in the first repeated measures (Study 4) where subjects saw all three of the different visual frames and heard them labeled, than in the first interview studies, where each participant saw only one frame. In fact, in the case of the second interview study (Study 2), it seems that specific kind of frame indicated by the visual features of the drawing ceased to have an effect, though subjects still counted the framed items less often than the foreground item. Further evidence that contrast enhances the effect of realness on counting is seen in the results of the visual contrast study (Study 6). Subjects in this study were less likely to count framed items when asked to count things in general as opposed to specific kinds of items inside the frame. The term “things” could be construed to include the framed and the foreground items both. This drop is not just a result of boundary crossing, as there was a larger drop in the count rates of items framed by the mirror and picture frame than for items framed by the window, when the general term “things” was used.

F. Counting must be conceptually consistent

It appears that there are two fundamental rules that govern which items may be members of a countable set. In order for an item to be counted, it must first be individuated, at least on a conceptual level. In order for an individuated item *not* to be counted, it must be conceptually differentiated from the items already present in the countable set. In all the studies, individuals were very consistent in their counts for a given trial. If they counted one of the foreground objects, they would count both of the foreground objects. If they counted one of the framed objects, they would count both of the frame objects. Further, even on the rare occasions when adults counted subparts of items, they did so in a very consistent manner. If a subject counted the tires on one of the

cars in a pair, they counted the tires on both of the cars in that pair. This is consistent with the behavior of small children as reported by Sophian and Kailihiwa (1998). Sophian and Kailihiwa's results showed that even children as young as five will be internally consistent in their counting strategies. Here in particular we see parallel patterns of counting behavior evidenced in both adults and children, despite the use of quite disparate stimuli.

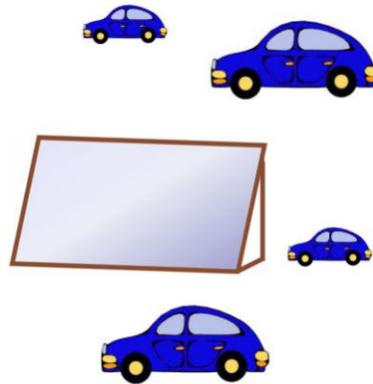
However, in the visual contrast study (Study 6), this prohibition on inconsistency appeared to be violated by some of the subjects. In the mirror condition, three out of the forty-nine subjects only included one of the framed items in their counts. Upon follow up questioning, it became clear that these apparent violations were the result of the unique nature of the visual contrast study. In the other frame studies (studies 1 through 5) the items in the foreground and the items in the frame were of the same kind. This allowed the items framed by the mirror to be interpreted as reflections of the items in the foreground. However, in the visual contrast study, this was not the case. Items inside the mirror were of a different kind than items outside the mirror, and therefore could not legitimately be parsed as reflections of these foreground objects. Instead of attributing the appearance of these items in the mirror to artistic license or taking them as an indication of matching items "off screen," three subjects determined that one item was standing directly in front of the mirror such that both itself and its reflection seemed to be framed by mirror. One framed item was the reflection while the other item was that which was reflected. One was real and the other was not. Despite the similarity of the items' appearance and location, this interpretation placed the items framed by the mirror at different levels of re-representation. Thus, the subjects could legitimately count only one

of the items, specifically the ‘real’ one. The subjects did, in fact, consistently count all members of the same conceptual subset. However, their higher order interpretation of the stimuli allowed these subjects to construct consistent subsets which were different from those that had been expected.

This clearly illustrates two important findings: First, one’s conceptual interpretation of a stimulus can have a strong impact on what is counted; Second, the number of ways a person might construct a countable set increases greatly when conceptual interpretations of the stimuli are allowed to influence what is counted. The need for biases to constrain what one counts becomes increasingly more evident. Case in point, neither the experimenter nor the other forty-six subjects in the visual contrast study had entertained the notion that the objects framed by the mirror could be interpreted as one real object and one reflection. Yet, upon reflection, this interpretation is clearly a valid one. How then can different individuals ever hope to arrive at the same numerical interpretation of a given stimuli, if there were no common constraints on how they interpret the scene? Yet even these subjects, with their rather unique interpretation of the mirror stimuli, showed one particular bias in what they considered to be countable. Specifically, they preferred to count real objects.

While it seems that “if one item is included in the count, then all items of the exact same kind should be included in the count,” is a rule that must be followed, the notion of “same kind” is quite flexible. For example, consider this stimulus:

Figure 6.1: Mirror with four cars



Two people, having been told that the frame was a mirror, only counted a subset of the cars and declared that the others were reflections. This is despite the fact that none of these “reflections” were contained by the mirror. These individuals differed in their assessment of which cars were reflections. One counted the larger cars and one counted the lower pair. Yet, having conceptually differentiated the various items and considered them to be on different levels of re-representation (real vs. reflections), both could legitimately count whichever subset of the items they preferred. It appears that while perceptual individuation and differentiation may support conceptual individuation and differentiation, it is neither necessary nor sufficient.

G. Future research possibilities

It is beneficial to language learning and communication in general for children and adults to have the same biases as to what items are countable. It would increase the likelihood that, when presented with a particular stimulus, different individuals would parse out the same countable set. These biases could therefore act as common ground between participants in a communicative event. This would subsequently increase the likelihood that a listener will properly decipher which set the speaker is indicating when

referring to a particular numerosity, say “three.” In turn, this would increase the likelihood that a language learner will correctly infer what numerosity that word may stand for. Biases based on perception would be particularly useful as the human’s perceptual systems are potentially quite universal. By comparison, conceptual biases might depend on one having the cultural background, for example, to know what a mirror is. It would therefore be quite interesting to run developmental studies to investigate that perceptual features that bias adult counting also lead to the same counting biases in young children. Eye tracking studies and studies with second language learners are also potentially interesting investigative pathways.

CONCLUSIONS

This flexibility of people's interpretation of what is a countable set demonstrates the power of the abstraction principle (Gelman & Gallistel, 1978). People can count anything. Using basic counting principles, adults are able to enumerate any set as long as they are able to identify the set's members, distinguish items which have already been counted from those that have not, and maintain the current tally. The range of countable sets is limited only by the bounds of human ingenuity, whether that set is the number of left hands in one's immediate family or how many times someone has thought of the word "beatific" in the last six months. In accordance with this, the research described in this dissertation has focused not on what people can count, but rather on what people do count.

People share biases as to what kinds of items they will consider to be countable in a given situation. Thus, when different adults are asked to count the same stimulus, their answers converge on a very limited range of possible countable sets. Biases that are detectable in young children continue to be present through adulthood. These biases can be perceptually or conceptually based. Adults, just like children, are biased towards counting items that are conceptually more real. Perceptual factors also bias counting. Specifically, people's counts are influenced by visual boundaries. Items that act as visual frames are less likely to be counted, as are sets whose members cross perceptual groupings. Verbal cues and pragmatics also influence what sets are counted in a given situation by indicating what set one is *intended* to count. Further, in order for an item to be collected into the countable set, it must be at least conceptually individuated. In order

for an individuated item *not* to be collected into the countable set, it must be at least conceptually differentiated from the members of that set. Perceptual individuation and differentiation supports conceptual individuation and differentiation, but it is neither necessary nor sufficient.

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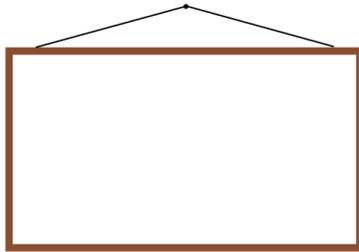
APPENDIX A
Stimuli for Study 1

A. Frames

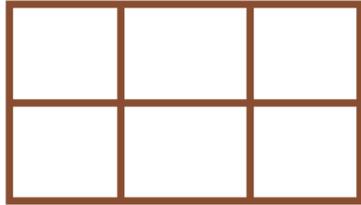
1) Mirror



2) Picture frame



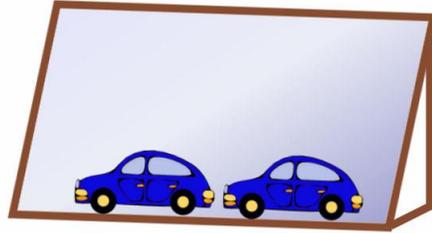
3) *Window*

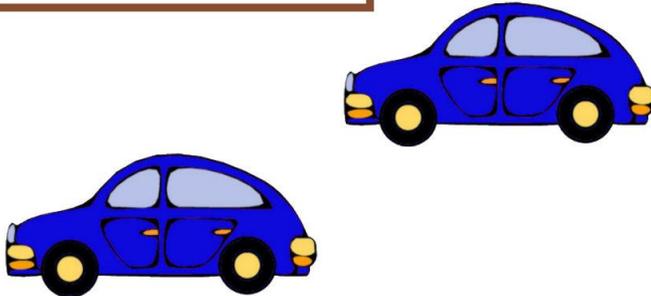
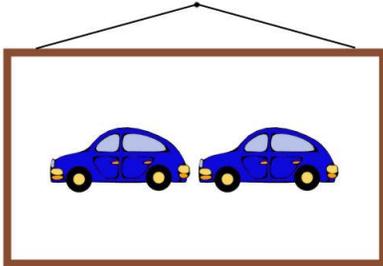


4) *Rectangle*

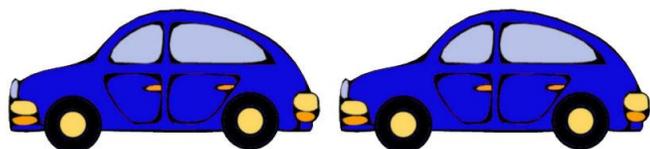
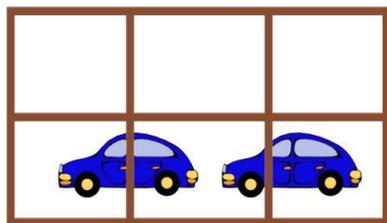


B. Stimuli*1) Mirror*

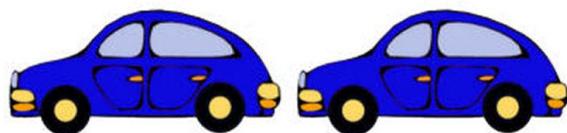
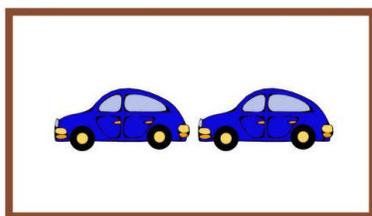
*2) Picture frame*



3) Window

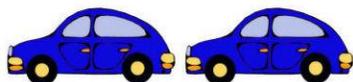


4) Rectangle



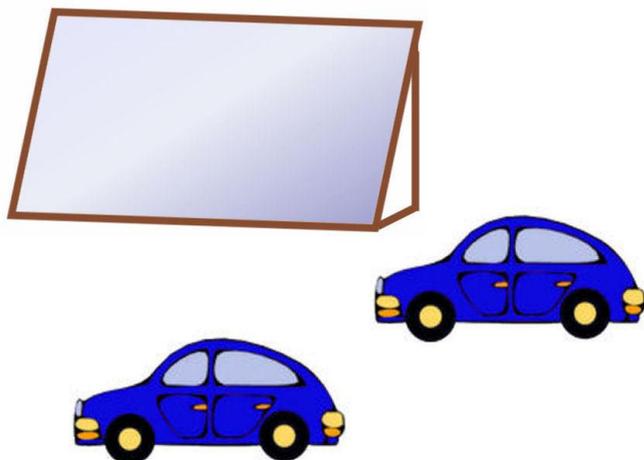
APPENDIX B
New Stimuli for Study 2

A. No Frames

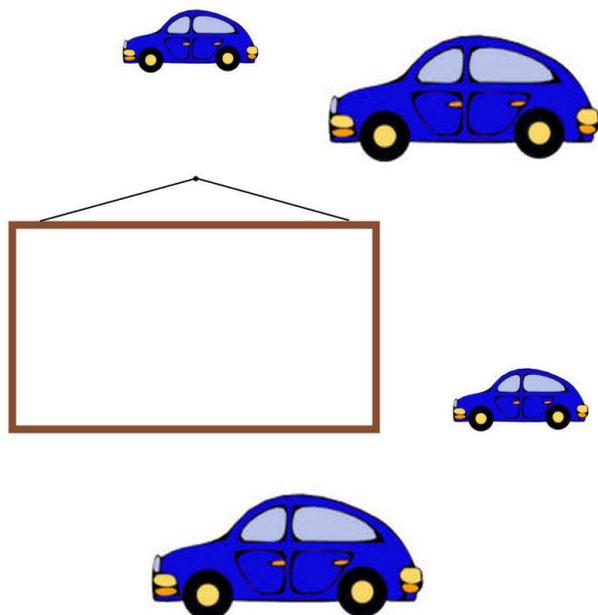


APPENDIX C
Sample of New Stimuli for Study 3

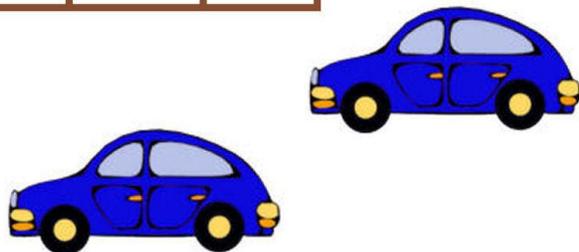
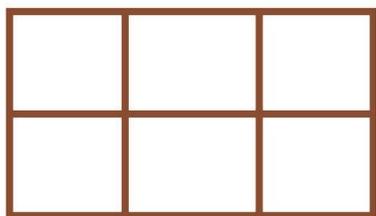
A. Mirror with two cars



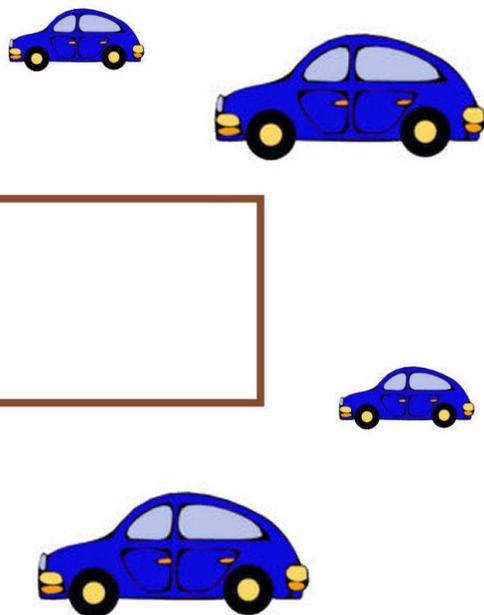
B. Picture Frame with four cars



C. Window with two cars

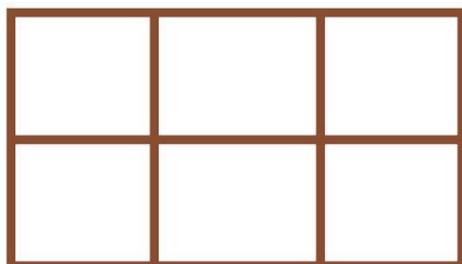
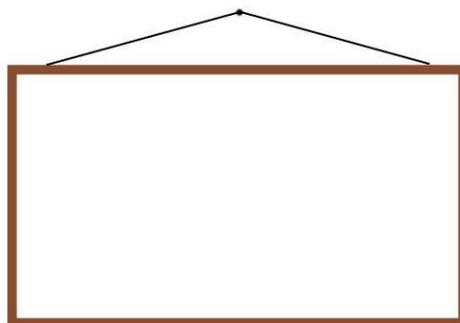


D. Rectangle with four cars



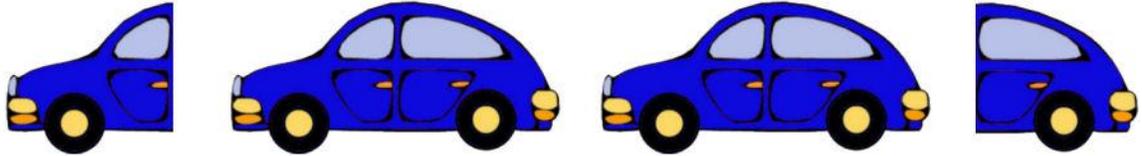
APPENDIX D
Sample of New Stimuli for Study 4

A. All frames



B. Sample split-object stimuli

1) *Separate (cars)*

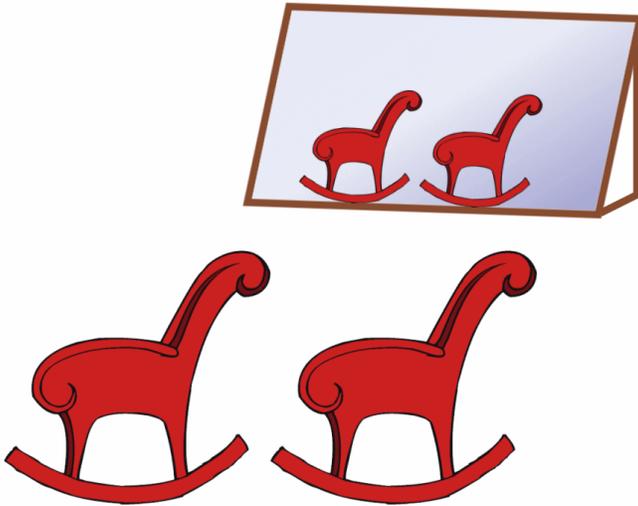


2) *Adjacent (cars)*

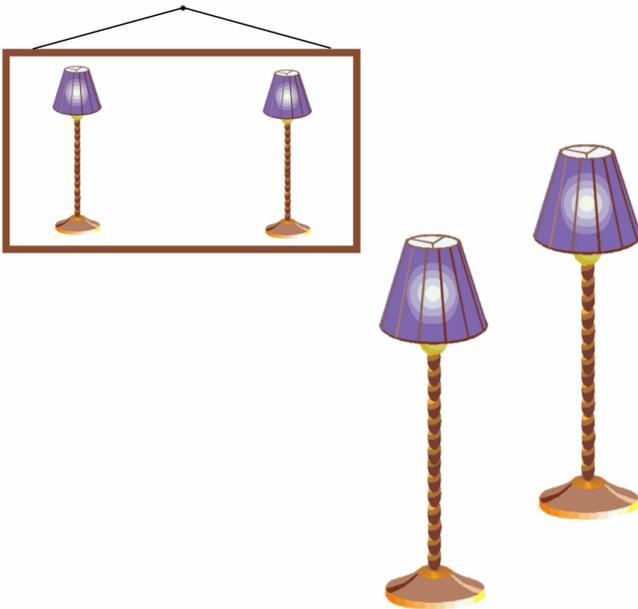


C. Sample frame stimuli

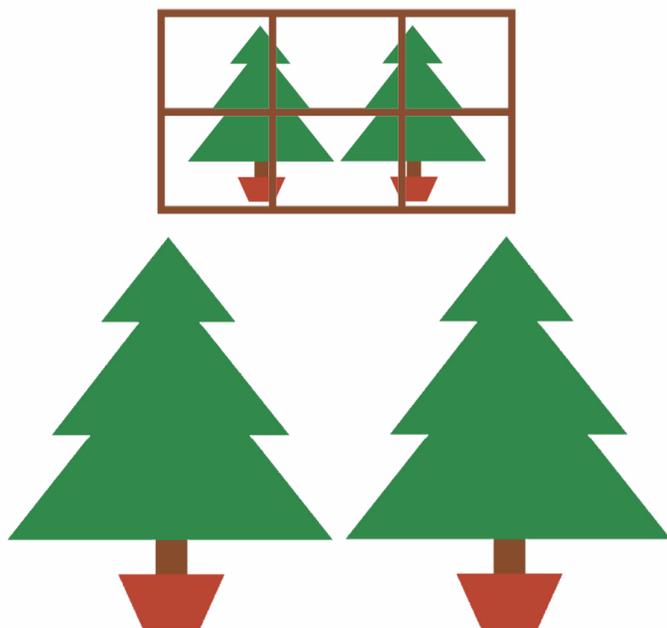
1) Mirror with chairs



2) Picture frame with lamps

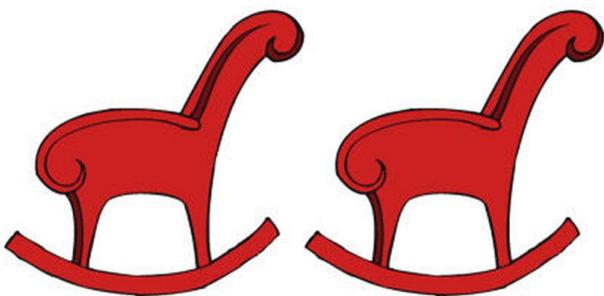
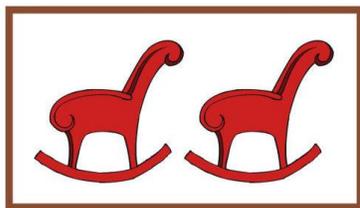


3) *Window with trees*



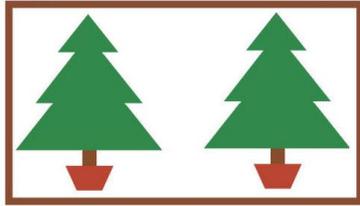
APPENDIX E
New Stimuli for Study 5

A. Rectangle with chairs



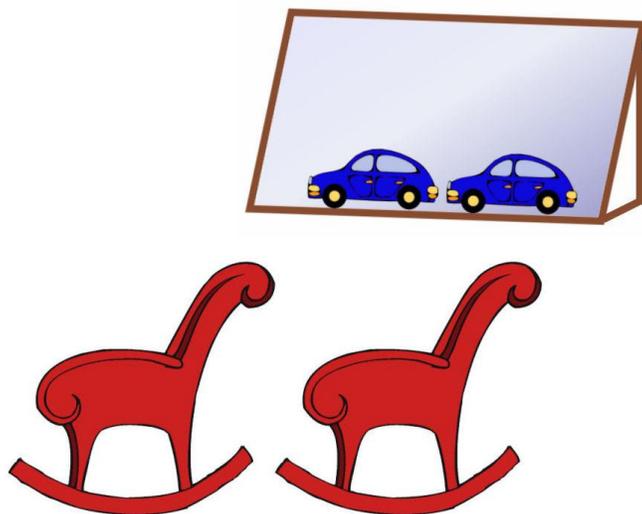
B. Rectangle with lamps



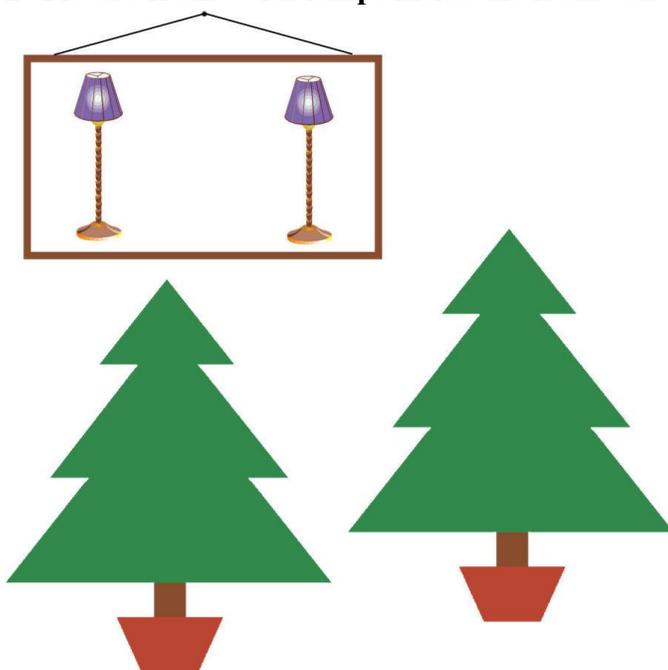
C. Rectangle with trees

APPENDIX F
Sample of New Stimuli for Study 6

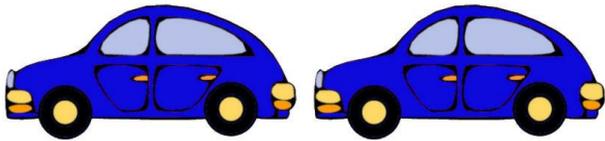
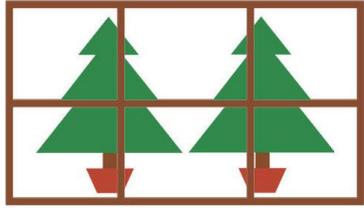
A. Mirror with cars inside the frame and chairs in the foreground



B. Picture frame with lamps inside the frame and trees in the foreground

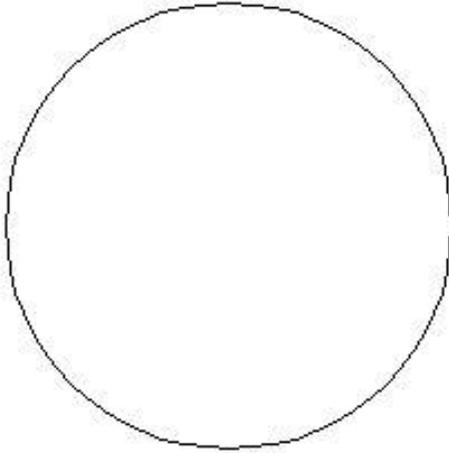


C. Window with trees inside the frame and cars in the foreground

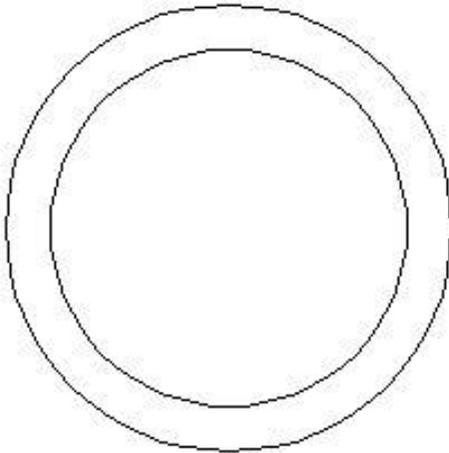


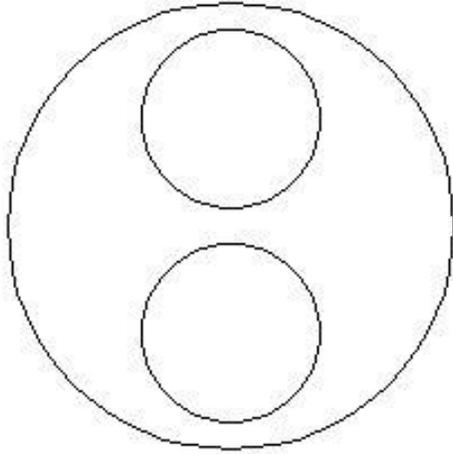
APPENDIX G
Example Nested Groups used for Mixed Stimuli in Study 7

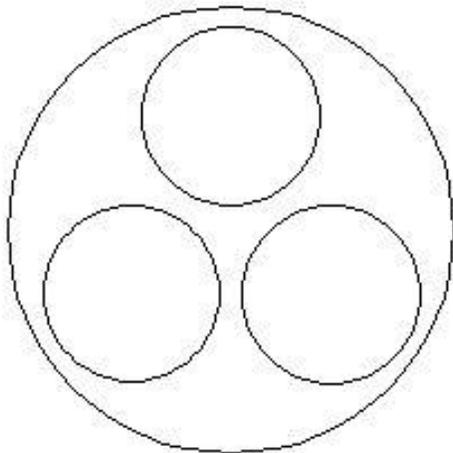
A. Single



B. Double



C. Duple

D. Triple

CURRICULUM VITA

A. Degrees earned

2003: B.A. from the University of Virginia

2005: M.S. in Psychology from Rutgers, State University of New Jersey

2009: Ph.D. in Psychology from Rutgers, State University of New Jersey

B. Professional positions

2001: Research assistant at University of Virginia, Psychology Department, with Barbara Spellman

2003-2006: Teaching Assistant at Rutgers University

2006-2007: Graduate Fellow at Rutgers University, Psychology Department, with Rochel Gelman

2007-2008: Teaching Assistant at Rutgers University

2008-2009: Graduate Assistant at Rutgers University, Psychology Department, with Rochel Gelman