Measuring the comprehension of negation in 2- to 4-year-old children

Ann E. Nordmeyer
anordmey@stanford.edu
Department of Psychology
Stanford University

Michael C. Frank
mcfrank@stanford.edu
Department of Psychology
Stanford University

Abstract

Negation is one of the most important concepts in human language, and yet little is known about children's ability to comprehend negative sentences. In this experiment, we explore how children's comprehension of negative sentences changes between 2- to 4-year-old children, as well as how comprehension is influenced by how negative sentences are used. Children between the ages of 2 and 4 years watched a video in which they heard positive and negative sentences. Negative sentences, such as "look at the boy with no apples", referred either to an absence of a characteristic or an alternative characteristic. Older children showed significant improvements in speed and accuracy of looks to target. Children showed more difficulty when the negative sentence referred to nothing, compared to when it referred to an alternative. In addition, children showed an early tendency to look towards the named noun, even when that noun was negated. This study contributes to our understanding of children's comprehension of negative sentences, as well as our understanding of the conceptual structure of negation.

Keywords: Negation; language development

Introduction

"No" is among the first words that children learn, as well as one of the most important. Negation is a fundamental element of human language — it is essential to logical systems, allows us to evaluate whether a statement is true or false, and it gives us a way to express concepts such as nonexistence. Negation is also challenging for language users; adults take longer to process negative sentences than positive ones (Clark & Chase, 1972; Just & Carpenter, 1971, 1976; Carpenter & Just, 1975). These findings lead us to an apparent paradox — how is that negation is difficult for adults, yet acquired at such a young age? By examining children's acquisition of negation, we can explore the origins and development of logical concepts.

Not all uses of negation are the same; words like "no" and "not" allow us to express multiple concepts. Three primary categories have been identified in children's early negative utterances: *nonexistence*, *rejection*, and *denial/truth-functional* (Bloom, 1970, 1993; Pea, 1980). A child expressing *rejection* might say "no go outside" when they want to stay inside, while a child who says "no more juice" to describe an empty cup is expressing *nonexistence* (Bloom, 1970). *Denial* involves making a statement about falsehood; a child might say "that not lollipop" if they believe a candy has been falsely identified as a lollipop. Additional types of negation have been identified as well. Pea (1980) identified two additional categories — *self-prohibition*, used when the child is about to engage in a forbidden action, and *unfulfilled expectations*, used when an expected action/object is not present. Choi (1988) identified a full 9 categories of negation, including *failure, inability, epistemic negation* (e.g. "I don't know"),

and *inferential negation* (i.e. negation of inferred beliefs of others). Regardless of taxonomy, negation is used in a variety of contexts to express a range of different thoughts.

The relationship between different types of negation is unknown. One possibility is that distinct categories of negation belong to a single cohesive concept. Even pre-linguistically, *nonexistence, rejection*, and *denial* could all fall under a superordinate conceptual category of negation. It is also possible, however, that these types of negation represent fundamentally different concepts. For example, the situation in which a child expresses a dislike for going outside (*rejection*) is very different from a child commenting on an empty juice cup (*nonexistence*). Perhaps it is only the common language used to describe these events that unites these concepts. One way of untangling these possibilities is by examining children's understanding of different negative concepts, and exploring how their conceptual structure changes as they develop the language to express these thoughts.

The acquisition of linguistic negation follows a long developmental trajectory. As early as 12 months, children produce negation in the form of the word "no", typically to express *nonexistence* and *rejection* (Bloom, 1970, 1993; Pea, 1980). Denial doesn't emerge until almost a year later, between 19 and 23 months (Pea, 1980). Cross-linguistic studies suggest that this stratification by type, with certain negative categories produced earlier than others, can be seen across languages (McNeill & McNeill, 1968). Even after age 2, children continue to learn about negation, showing improvements in syntactic form (Klima & Bellugi, 1966; Cameron-Faulkner, Lieven, & Theakston, 2007) as well as increases in the frequency with which they produce spontaneous negatives (Pea, 1982). Furthermore, children as old as 4 years continue to have difficulty with implicitly negative terms such as marked adjectives (e.g. *less*) (Donaldson & Balfour, 1968; Klatzky, Clark, & Macken, 1973). Thus, although "no" is among the first words that children produce, they continue to grapple with the nuances of negation for several more years.

Nearly all prior research on the acquisition of negation has focused on production. Very little work has examined children's comprehension of negative sentences (cf. de Villiers & Tager-Flusberg, 1975). While production can tell us about the contexts in which children use negation, it does not reveal the extent to which children understand concepts underlying negative sentences. Children may already have a sophisticated understanding of different types of negation before they start producing negative utterances. Alternatively, children's conceptual understanding may change as they develop linguistic negation. By examining the development of children's com-

prehension of negative sentences, we can begin to tease apart the relationship between children's conceptual understanding of negation and their linguistic abilities.

Our primary goal in this initial study was to address the lack of work on children's comprehension of negation. We conducted a study of children's understanding of negative sentences, using eye-tracking to test comprehension. Eye-gaze measures are ideally suited to our goal, because gaze following requires limited cognitive resources (Fernald, Zangi, Portillo, & Marchman, 2008). Because our ultimate goal is to understand the conceptual structure of negation, we measured comprehension of two types of negative sentences: those that refer to nothing (*nonexistence*), and those that refer to an alternative (similar to *denial*). By examining comprehension, we hoped to gather a more nuanced picture of the acquisition of negation as well as gain insight into children's conceptual understanding of different types of negative sentences.

Method

This study was designed to examine the development of the comprehension of negation from ages 2 - 4 years. Children watched a video in which they were asked to "look at the boy with/with no X". This type of negative construct was used because it involves "no", the negative element emerging earliest in children's speech (Klima & Bellugi, 1966; Cameron-Faulkner et al., 2007). Plural items were used instead of singular items to maintain maximum consistency between positive and negative sentences. Prior to each test trial, children viewed a context slide designed to set up expectations about the characters in the trial. This context was included due to work suggesting that contextual support facilitates negation processing in adults (Wason, 1965; Glenberg, Robertson, Jansen, & Johnson-Glenberg, 1999; Lüdtke & Kaup, 2006) as well as children (de Villiers, J. and Tager-Flusberg, H.B., 1975). Following each trial, Elmo appeared next to the target, to motivate children to look towards the correct character. In order to capture different types of negation, we created two between-subjects conditions. In the *nothing* condition, negative sentences referred to people with no items at all (e.g. a boy holding nothing compared to a boy holding apples). In the *something* condition, negative sentences referred to people with alternative items (e.g. a boy holding presents compared to a boy holding apples). By measuring children's comprehension of negative sentences in different contexts, we hoped to learn more about the types of negation that children understand between ages 2 and 4.

Participants

Families visiting the Children's Discovery Museum in San Jose, CA were invited to participate in this study. Our final sample was comprised of children who were exposed to English at least 75% of the time, as indicated by their parents, and who were attentive for the initial calibration phase of the experiment. This resulted in a sample of 111 children, 49 2-year-olds (mean age = 2;5, range = 2:0 - 2;11, 22 female) and 62 3-year-olds (mean age = 3;5, range = 3;0 - 3;11, 21
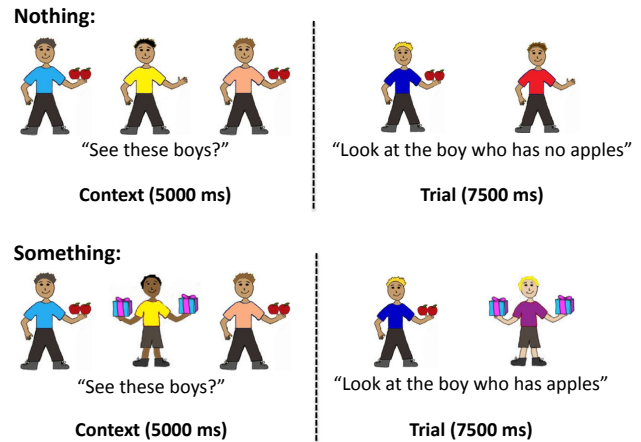

Figure 1: An example of context, trial, and feedback from the nothing and something conditions.

female). In exchange for participation, children were given a sticker and a certificate.

Of these initial 81 children, only those who completed at least 8 of the 16 trials were included in analysis. Four 2-year-olds and 5 3-year-olds were rejected due to this criterion. A further 4 2-year-olds and 4 3-year-olds were rejected due to loss of gaze data in more than 30% of the experiment. Finally, individual trials with more than 30% missing gaze data were excluded from analysis. This left a total of 91 participants whose data was analyzed; 20 2-year-olds in the nothing condition and 21 in the something condition, and 26 3-year-olds in the nothing condition and 27 in the something condition.

Stimuli

We created 16 items, each presented as an individual trial. Items consisted of boys or girls either holding nothing or holding different items (e.g. two apples). Each trial was paired with a positive or a negative sentence. Sentences were of the form "Look at the boy who has/has no apples".

Each trial contained three parts: a context, a test trial, and feedback (see Figure 1):

Context: The context consisted of three characters, two holding two target items each, and the other character holding either nothing (in the nothing condition) or two alternative items (in the something condition). A pre-recorded voice said e.g. "See these boys?". Each context lasted 5 seconds.

Test trial: Each trial consisted of two new characters, one holding two target items and one either holding nothing (in the nothing condition) or two alternative items (in the something condition). The images were presented in silence for two seconds, after which a pre-recorded voice said a positive or a negative sentence (e.g. "Look at the boy with/with no apples"), followed by an additional tag sentence (e.g. "Can you find him?"). Each trial lasted 7.5 seconds.

Feedback: Feedback involved Elmo appearing next to the target character with a chiming noise lasting 1.5 seconds.
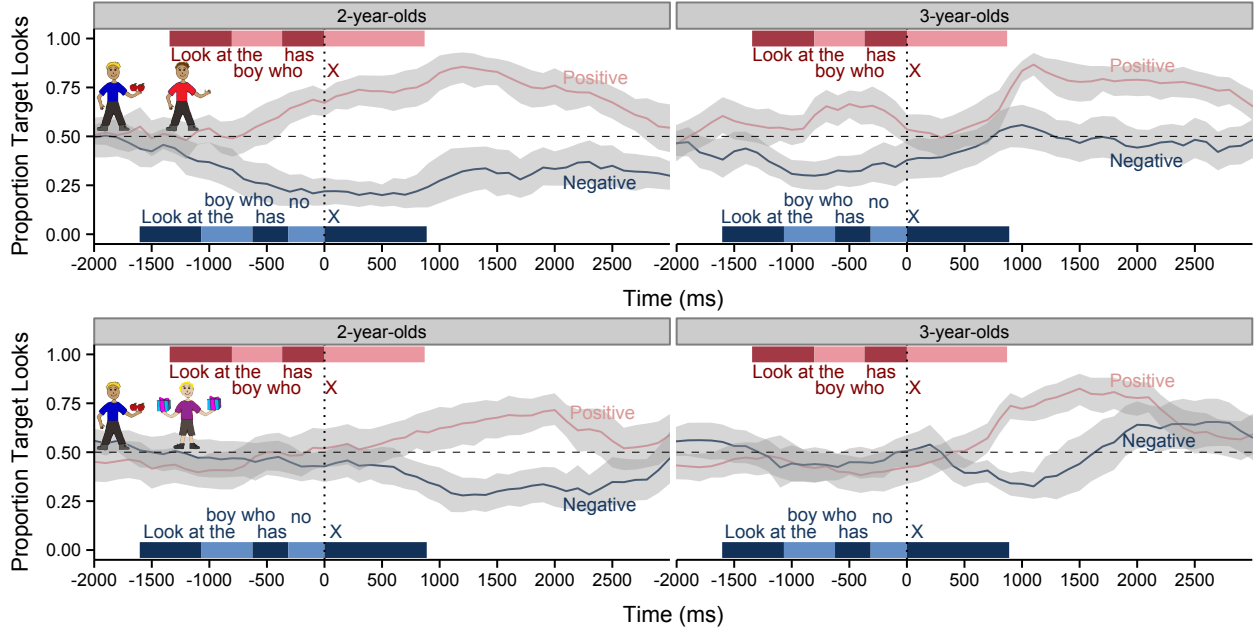
Figure 2: Proportion of 2-year-old and 3-year-old children looking to the target picture as the sentence unfolds. Nothing trials are shown above, and something trials are shown below. Error bars represent 95% C.I.

Procedure

Parents and children were led to a small research room. Children sat in a booster seat approximately 60 cm from the monitor of an SMI RED 120 Hz corneal reflection eye-tracker mounted on an adjustable arm. Some children sat on a parent's lap, depending on the child's age and level of comfort.

The experiment was presented in the form of a short video. The video began with a short Elmo clip, during which any necessary adjustments to the eye-tracker were made. This was followed by a 2-point calibration and validation of the calibration points. After calibration, children were introduced to Elmo and told that "Today, Elmo is going to visit some of his friends. Do you want to meet Elmo's friends? Let's go!". This opening sequence was created to give the video a more "story-like" feeling, and to motivate children to look to the target characters during the test trials.

Following this introduction, children saw three gaze-contingent practice trials, designed so that the video would not advance until the child looked at the target item. Practice trials involved only the trial + feedback (no context). The first practice item had only one character, while the next two practice items had two characters, as in the test trials.

The rest of the video consisted of 16 trials, as well as 6 filler pictures of Elmo and 4 Elmo video clips. Filler videos were advanced by the experimenter after a variable length of time depending on the child's attentiveness, making the video length slightly different for each child; in general the video lasted approximately 6 minutes. Two orders were created for the test videos, such that trial types were counterbalanced and trial order pseudo-randomized across the two orders.

Table 1: Coefficient estimates from mixed-effects models predicting proportion of looks to target in an early window (600-1600 ms after noun onset) and a late window (1600-2600 ms after noun onset).

	Coefficient	Std. err.	t value
(Intercept)	0.83	0.04	22.81
Sentence (Negative)	-0.55	0.06	-9.03
Condition (Something)	-0.20	0.05	-4.12
Age (3-year-olds)	-0.05	0.05	-1.15
Window (Late)	-0.10	0.05	-2.19
Sentence×Condition	0.24	0.08	2.91
Sentence×Age	0.29	0.08	3.63
Condition×Age	0.17	0.06	2.56
Sentence×Window	0.15	0.06	2.52
Condition×Window	0.15	0.06	2.27
Age×Window	0.09	0.06	1.39
Sentence×Condition×Age	-0.35	0.11	-3.19
Sentence×Condition×Window	-0.19	0.08	-2.28
Sentence×Age×Window	-0.19	0.08	-2.36
Condition×Age×Window	-0.14	0.09	-1.68
Sentence×Condition×Age×Window	0.48	0.11	4.24

Results and Discussion

We first examined developmental changes in children's ability to comprehend negative sentences between ages 2 and 4. Next, we explored the contrast between types of negation (i.e. the nothing condition and the something condition). Finally, we examined how gaze changes over the course of a trial.

Developmental changes Children's ability to process negative sentences increases considerably between ages 2 and 3. This increase can be seen both in children's accuracy and reaction time in response to negative sentences.

Figure 2 shows the proportion of children who looked to the target picture over the course of a trial. The majority of
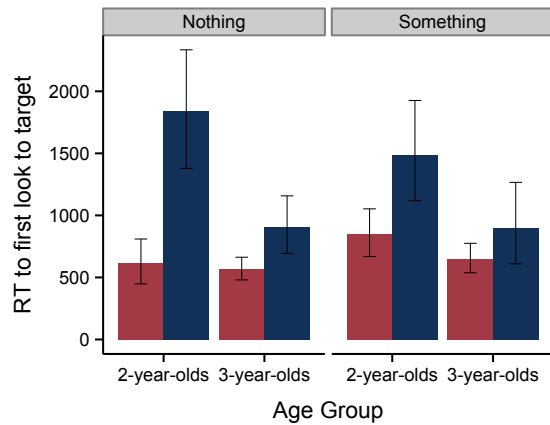
Figure 3: Reaction times of children who were looking at the distractor picture at the onset of the noun to orient towards the target picture. Error bars represent 95% C.I.

Table 2: Coefficient estimates from a mixed-effects model predicting RT to target picture following noun onset.

	Coefficient	Std. err.	t value
(Intercept)	597.28	119.69	4.99
Sentence (Negative)	1253.69	228.67	5.48
Condition (Something)	228.39	157.15	1.45
Age (3-year-olds)	9.40	150.89	0.06
Sentence×Condition	-579.63	312.21	-1.86
Sentence×Age	-969.19	297.13	-3.26
Condition×Age	-184.94	198.96	-0.93
Sentence×Condition×Age	560.83	416.24	1.35

children in both age groups and conditions responded correctly to positive sentences. However, a difference in accuracy can be seen in response to negative sentences between the two age groups. While 2-year-olds show very little comprehension of negation in this paradigm, 3-year-olds show a noticeable increase in looks to target following the onset of the noun. We ran a linear mixed-effects model analyzing the effects of sentence type, condition, age group, and time window (early: 600-1600ms following noun onset; late: 1600-2600ms following noun onset) on the proportion of children looking to the target (Table 1).[1] Results of this model indicate a significant interaction between sentence type and age group, such that 3-year-olds are more likely to look to the target in response to negative sentences than 2-year-olds.

Reaction time (RT) was measured by looking at trials in which children who were originally fixating on the distractor (non-target) picture at the onset of the noun, and calculating how long it took these children to make their first shift to the target picture (Fernald et al., 2008). Two-year-olds showed larger RTs in response to negative sentences compared to positive sentences (Figure 3). However, 3-year-olds were surprisingly quick to orient to the target picture, only slightly slower than in response to positive sentences and much faster than in response to

2-year-olds. Results from a linear mixed-effects model are reported in Table 2.[2] Note that the decrease in 3-year-olds' RTs in response to negative sentences is not due to a general increase in processing abilities; our model found no main effect of age, only an interaction between sentence type and age, such that 3-year-olds process negative sentences nearly a full second faster than 2-year-olds.

Types of negation Our results suggest that children have more difficulty identifying the referent of a negative sentence when it refers to nothing than when it refers to an alternative object. While 3-year-olds increase their looks to target following noun onset in the nothing condition, this does not increase above 50% (Figure 2). However, in the something condition, nearly 70% of children look to the target following negative sentences. This increase is seen in the later window of time, 1600-2600 ms following the onset of the noun. This can be seen in the results of our model reported in Table 1; there is a significant 4-way interaction such that 3-year-olds' responses to negative sentences in the later window of the something condition show an increase in looks to target.

Onset-contingent plots (Figure 4) provide another way of looking at children's gaze behavior. These plots split trials based on whether the child was looking at the target or the distractor at the onset of the noun, and plot the proportion of children who shift their gaze to the opposite item. Children who are initially looking at the distractor should show rapidly increasing shifts, whereas children who are initially looking at the target should continue to look at the target (Fernald et al., 2008). Note that responses to the positive sentences are typical of what these plots normally look like.

Responses to the negative sentences, however, deviate from the typical pattern. For 2-year-olds in both conditions and 3-year-olds in the nothing condition, the pattern seen is the reverse: if children are looking at the target picture, they orient away, and if they are on the distractor, they stay. 3-year-olds are slightly better, with about 50% orienting away from the distractor, but still the majority orient away from the target. However, 3-year-olds in the something condition show a different pattern; initially, children continue to fixate on the distractor and shift away from the target, but after approximately 1600 ms this pattern reverses and children shift away from the distractor and back towards the target. Thus, it is only 3-year-olds (and only in the something condition) who exhibit increased looks to target in response to negative sentences.

Real-time processing of negative sentences The data here reveal that children show a tendency to initially orient *away* from the target object, looking towards the negated noun, even amongst children who eventually do look to the target.

Two-year-olds do not look to the referent of negative sentences in either condition. Note that in the nothing condition, this preference could be explained by children's lack of interest in the boy with nothing, but in the something condi-

---

[1] All mixed-effects models were run using the lme4 package in R version 2.15.2. The random effects structure for this model was as follows: (sentence + window|subject) + (sentence + condition + age group + window|item)

[2] The random effects structure for this model was as follows: (sentence|subject) + (sentence + condition + age group|item)
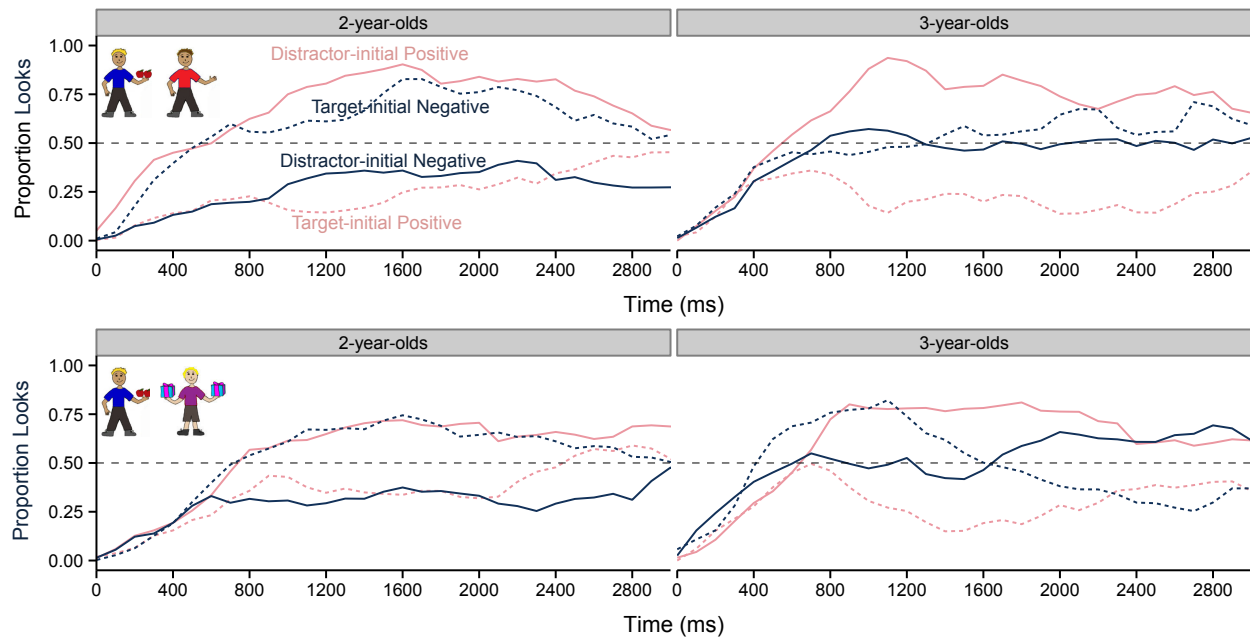
Figure 4: Onset-contingent plots of children's looking behavior starting at the onset of the noun. Nothing trials are shown above, and something trials are shown below.

tion both characters are equally salient. Thus, it appears that when 2-year-olds hear a named noun, they prefer to look at that noun, even if it has been negated.

In the earlier window of Figure 2 (600-1600 ms following the onset of the noun), 3-year-olds in the something condition show a similar pattern, showing a preference to look incorrectly to the negated noun. In the later window, however, the opposite pattern is seen: now children appear to look reliably to the target picture. This pattern can be seen more clearly in Figure 3. If children are looking at the distractor at the onset of the noun, about 50% linger until 1600 ms, when suddenly the majority of looks shift to the target. Conversely, if children are looking at the target at noun onset, the majority of children shift *away* from the target, fixating on the distractor until 1600 ms, when they look back to the target. Again, this indicates a tendency for children to initially look to the negated noun, even when both options are equally salient.

General Discussion

Little is known about children's comprehension of negative sentences, a surprising fact given the universality of negation and its importance in logical reasoning. Previous work on production suggests that children are continuing to learn about negation between 2 and 3 years of age (Klima & Bellugi, 1966; Cameron-Faulkner et al., 2007; Pea, 1982), but few studies have explored how children's comprehension changes over this period. We conducted a study of children's comprehension of negation, examining negative sentences that referred either to nothing or to an alternative. We found that 3-year-olds were much faster and more successful than 2-year-olds at correctly looking at the referent of negative sentences. In addition, we found that children at both

ages struggle to identify the referent of negatives that refer to nonexistence, as opposed to referring to an alternative.

An additional and surprising finding of this study was that children in the something condition had an initial tendency to look towards the negated noun, and only 3-year-olds were able to eventually override this preference and look to the correct target. There is some evidence that a similar pattern occurs in adult processing of negative sentences. Several priming studies have found that the representation of a negative sentence changes in the moments after the sentence unfolds (Kaup & Zwaan, 2003; Kaup, 2001; Kaup, Lüdtke, & Zwaan, 2006; Hasson & Glucksberg, 2006). In addition, ERP studies have shown N400 activation, associated with the processing of a semantically unexpected word, in sentences where the unexpected noun is negated (Fischler, Bloom, Childers, Roucos, & Perry Jr, 1983; Lüdtke, Friedrich, De Filippis, & Kaup, 2008). That is, sentences such as "A robin is a truck" *and* "A robin is not a truck" show greater negativity at the N400 than sentences such as "A robin is/is not a bird" (Fischler et al., 1983). This work has been interpreted as suggesting that adults do not immediately integrate negative elements into sentence meaning. Our findings here suggest that this may be true for children as well.

In our sample, both 2- and 3-year-olds found looking to the correct referent difficult when the target was holding nothing, i.e. *nonexistence* negation. It seems incorrect to attribute this to a lack of understanding of nonexistence, due to children's early production of negation. A more likely explanation is that orienting to the target in these trials required greater inhibitory control because the target character is less interesting to children. Identifying the specific kinds of negation that children hear in naturalistic contexts can help us under-

stand what kinds of contexts might facilitate comprehension of negation.

Overall, this study of children's comprehension of negation provides a complement to previous work on the acquisition of negation, which has primarily focused on production. Our ultimate goal is to examine young children's understanding of different negative concepts, and how this conceptual structure is influenced by the acquisition of linguistic negation. This goal speaks to a broader question about the extent to which linguistic development influences conceptual development and vice versa. Negation is an important case study for examining this question, because linguistic negation emerges early in childhood and can therefore be studied in conjunction with children's understanding of negative concepts. By exploring this relationship, we hope to shed light not only on the acquisition of negation, but also on the ways that language and concepts influence each other throughout development.

Acknowledgments

References

Bloom, L. (1970). *Language development: Form and function in emerging grammars.* New York, NY: MIT Research Monograph, No 59.

Bloom, L. (1993). *Language development from two to three.* New York, NY: Cambridge Univ Press.

Cameron-Faulkner, T., Lieven, E., & Theakston, A. (2007). What part of no do children not understand? A usage-based account of multiword negation. *Journal of Child Language*, *34*(2), 251-282.

Carpenter, P., & Just, M. (1975). Sentence comprehension: A psycholinguistic processing model of verification. *Psychological Review*, *82*(1), 45-73.

Clark, H., & Chase, W. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology*, *3*(3), 472–517.

de Villiers, J. and Tager-Flusberg, H.B. (1975). Some facts one simply cannot deny. *Journal of Child Language*, *2*, 279-286.

Donaldson, M., & Balfour, G. (1968). Less is more: A study of language comprehension in children. *British Journal of Psychology*, *59*(4), 461–471.

Fernald, A., Zangi, R., Portillo, A., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language comprehension by infants and young children. In I. Sekerina, E. Fernandez, & H. Clahsen (Eds.), *Developmental psycholinguistics: Online methods in children's language processing* (p. 98-135). Philadelphia, PA: John Benjamins Publishing Company.

Fischler, I., Bloom, P., Childers, D., Roucos, S., & Perry Jr, N. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology*, *20*(4), 400–409.

Glenberg, A., Robertson, D., Jansen, J., & Johnson-Glenberg, M. (1999). Not propositions. *Journal of Cognitive Systems Research*, *1*, 19-33.

Hasson, U., & Glucksberg, S. (2006). Does understanding negation entail affirmation? an examination of negated metaphors. *Journal of Pragmatics*, *38*(7), 1015–1032.

Just, M., & Carpenter, P. (1971). Comprehension of negation with quantification. *Journal of Verbal Learning and Verbal Behavior*, *10*, 244-253.

Just, M., & Carpenter, P. (1976). Eye fixations and cognitive processes. *Cognitive Psychology*, *8*, 441-480.

Kaup, B. (2001). Negation and its impact on the accessibility of text information. *Memory & Cognition*, *29*(7), 960-967.

Kaup, B., Ludtke, J., & Zwaan, R. (2006). Processing negated sentences with contradictory predicates: Is a door that is not open mentally closed? *Journal of Pragmatics*, *38*, 1033-1050.

Kaup, B., & Zwaan, R. (2003). Effects of negation and situational presence on the accessibility of text information. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*(3), 439-446.

Klatzky, R., Clark, E., & Macken, M. (1973). Asymmetries in the acquisition of polar adjectives: Linguistic or conceptual? *Journal of Experimental Child Psychology*, *16*(1), 32–46.

Klima, E., & Bellugi, U. (1966). Syntactic regularities in the speech of children. In R. W. J. Lyons (Ed.), *Psycholinguistic papers* (Vol. 3765, p. 183-208). Edinburgh: Edinburgh University Press.

Lüdtke, J., Friedrich, C., De Filippis, M., & Kaup, B. (2008). Event-related potential correlates of negation in a sentence-picture verification paradigm. *The Journal of Cognitive Neuroscience*, *20*(8), 1355-1370.

Lüdtke, J., & Kaup, B. (2006). Context effects when reading negative and affirmative sentences. In *Proceedings of the 28th Annual Conference of the Cognitive Science Society* (p. 1735-1740).

McNeill, D., & McNeill, N. (1968). *A question in semantic development: What does a child mean when he says "no"?* Ann Arbor, MI: Michigan University Center for Research on Language and Language Behavior.

Pea, R. (1980). The development of negation in early child language. In D. Olson (Ed.), *The social foundations of language and thought* (pp. 156–186). New York, NY: Norton New York.

Pea, R. (1982). Origins of verbal logic: Spontaneous denials by two-and three-year olds. *Journal of Child Language*, *9*(3), 597-626.

Wason, P. (1965). The contexts of plausible denial. *Journal of Verbal Learning & Verbal Behavior*, *4*(1), 7-11.