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Early understanding of subject and object wh-questions

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Abstract

In the current study, we used the splitscreen preferential looking paradigm to test 13-, 15-, and 20-month-olds' developing understanding of simple matrix what-questions of the forms "What hit the X?" (subject-question) and "What did the X hit?" (object-question). Infants responded appropriately to subject-questions by 15 months of age and to both subject- and object-questions by 20 months. At no age, did infants look longer toward the object overtly mentioned in the question, as might be expected based on a surface account of early language acquisition. This suggests that infants may have some understanding of these complex structures long before they are produced.

Early understanding of subject and object wh-questions

Competence in a language includes competence in syntax. In the last few years, a growing body of research, which relies on data from looking times gleaned from both eye-tracking (Sekerina, Trueswell & Hill, 1998) and preferential looking studies (Hirsh-Pasek & Golinkoff, 1996; Naigles, 1996; inter alia), has greatly increased our understanding of children's early abilities to process complex syntactic relations. For example, Hirsh-Pasek and Golinkoff (1996) used the preferential looking paradigm to test 19-month-old infants' sensitivity to word order in active sentences. They found that even before infants are able to formulate multi-word utterances, comprehension is guided by word order. Thus, from early on, infants appear to process more than just the individual meanings of words.[1] In addition, younger infants have been shown to exploit both phonological and morphological regularities in language (Gerken, 1996; Jusczyk, Luce & Charles-Luce, 1994; Mattys & Jusczyk, 2001; Saffran, Aslin & Newport, 1996; Shi, Werker, &Morgan, 1999;Waxman and Booth, 2001), setting the stage for later syntactic achievements, such as appropriate parsing of wh-questions.

According to linguistic theory, wh-questions are complex structures. For example, for toddlers to comprehend or produce a question such as "what do you think Minnie tried to put on?", they must both control the relevant syntactic structures and have sufficient processing resources to hold in mind the questioned object for the duration of the sentence. Empirical evidence that these structures are difficult to process comes from production, where children often make errors. For example, Thornton (1995) found that 5-year-old children produce sentences with medial wh-words as shown in (1). Thornton proposes that these errors reflect

children's immature syntax, specifically, problems with the successive cyclic movement of wh-words.

(1)   a. Who do you think who's under there?   *Thornton (1995)*

         b. What do you think what Minnie tried to put on?

Given that 5-year-olds make errors in production, one might ask when in development any aspect of these structures is acquired. One possibility is that these structures are not acquired until close to the time when production (even errorful production) begins. Another possibility is that some aspects of these structures are acquired quite early –as are other aspects of syntax (Gerken, 1996; Hirsh-Pasek & Golinkoff, 1996; Naigles, 1996).

Regardless of whether or not infants actually possess the complex syntactic structures necessary for comprehension, attentional factors would seem to make wh-questions particularly problematic for infants. Consider example (2a). If infants were only to respond to surface features such as the words present in the sentence, one might expect them to look longer at the object that is overtly mentioned (i.e., apple) rather than the one that provides the answer to the question (i.e., flower). In contrast, where questions such as (2b) have a focus of attention that is also the target, which may make them easier to comprehend. That is, both surface features and deep structure point to the same answer.

(2)   a. "What hit the apple?" (When a flower hits an apple)

         b. "Where is the apple?"

Thus, the successful understanding of wh-questions appears to require not only syntactic knowledge, but also the ability to use this knowledge to guide attention even when the correct focus is the object that is not overtly mentioned.

Given such difficulties, it is reasonable to expect that full comprehension of these questions is a relatively late achievement. Indeed, most previous studies on this topic focused on children who were three years old and older and who could produce answers to questions (Cairn and Hsu, 1978; Gazdar, 1981; Klima and Bellugi, 1966; Philip, Coopmans, van der Meer, van Atteveldt & van der Meer, 2000; Radford, 1990).

In this paper, we ask whether infants who are not yet readily producing such questions can nevertheless show sensitivity to their form. Because comprehension usually precedes production in language acquisition (Brown, 1973; Gerken, 1996; Hirsh-Pasek and Golinkoff, 1996; Shipley, Smith and Gleitman, 1969; inter alia), it seems reasonable to ask, what, if anything, children understand about simple matrix wh-questions before the age of two. Our study examines the development of infant's understanding of questions of the form: "What hit the X?" (called a subject-question because the entity being questioned is the grammatical subject of the verb) and "What did the X hit?" (called an object-question because the entity being questioned is the grammatical object of the verb) following a short video event.

Specifically, given models of development which suggest a change in the weighting from attentional to formal linguistic factors (Hollich, Hirsh-Pasek, and Golinkoff, 2000; Smith, 1999), we asked whether young infants might look at the object that is explicitly mentioned in the question, only later coming to look at the syntactic focus of attention. Furthermore, we asked whether infants would respond appropriately to subject wh-questions earlier than object wh-questions: The object wh-questions are more formally complex and may make more resource demands than the subject wh-questions. Such a subject-object asymmetry in complexity and resource demands has been demonstrated in the adult sentence processing literature (Gibson, 1998; King & Just, 1991) and is also supported by evidence from the processing and acquisition

of relative clauses in Korean second language acquisition (O'Grady, Lee and Choo, 2001; see also Demuth 1992).[2,3] In addition to their formal complexity, object wh-questions may also be more difficult to process than subject wh-questions because they are less frequent in the input, as has been suggested for object and subject relative clauses (Tabor, Juliano & Tanenhaus, 1997).

Wh-comprehension in 13-, 15- and 20-month-olds

In this Experiment, we tested 13-, 15- and 20-month-olds' comprehension of subject what-questions, object what-questions, and where questions. For both what-questions, we showed the infants a video of an event, followed by a what-question that focused attention on one of the objects in a split-screen display. For the where questions, we simply posed the question while showing infants the split-screen display. We measured whether the infants looked longer at the object that was the answer to the question or the other object on the screen.

Method

Participants. A total of sixty infants were included in the study. The 20-month-old infants had a mean age of 20 months and 14 days (range: 19 months, 26 days to 20 months, 29 days). One additional 20-month-old was excluded from the study due to extreme restlessness. The 15-month-old infants had a mean age of 15 months and 4 days (range: 14 months, 22 days to 15 months, 17 days). The 13-month-old infants had a mean age of 13 months and 4 days (range: 12 months, 24 days to 13 months, 12 days).

Design

The general design is depicted in Table 1. There were five trial blocks: Two tested subject-questions ("What hit the X?"), two tested object questions ("What did the X hit?"), and one control block tested where questions ("Where is the X?"). This control was included to establish whether or not the infants could perform when the correct answer was the last noun of

the question. For the first four blocks, a block began with an action trial (e.g., a book hitting some keys), shown twice in a row (see Figure 1). Then, there were two test trials in which a split-screen display appeared for six seconds with an accompanying audio track asking either a subject or an object wh-question. In order to reduce memory load and to give infants time to process the question, the subject, object or where question started one second into the trial and was repeated at four seconds. There were two such test trials for a total of twelve seconds of testing for each block. The video presentation orders and objects were counterbalanced for the first four blocks. The where-block was always given last.

Stimulus materials. The auditory stimuli consisted of recorded versions of subject and object what-questions as well as where questions. The objects used in the experiment (an apple, a flower, a book and some keys) were chosen because the mapping from word form to word meaning for these objects is reportedly known to infants aged 13-months and older according to the MacArthur Communicative Development Inventory norms (Fenson et. al., 1994). Examples of the questions used are shown in (3). Observe that (3a) and (3b) are identical except for the slight change in word order and the addition of 'did' in (3b). The control where question (3c) is the only question that overtly mentions the object that answers the question.

(3)   a. Subject-question: "What hit the apple?"

        b. Object-question: "What did the apple hit?"

        c. Where question: "Where is the apple?"

These sentences were recorded by the female author and were read in a happy and child-friendly voice. The durations of the sentences were matched at approximately 1.5 seconds. Digitized versions of these stimuli were saved in a format readable by a Macintosh computer for

use in making an audiotrack of the film that the infants heard during testing. During the

experiment, the auditory stimuli were presented at 72dB.

Objects were constructed using a 3D Drawing program. They were brightly colored and

large so as to attract the infants' attention, yet designed to be of approximately equal salience.

The resulting pictures were turned into action trials, in which they performed a hitting/bumping

action (Figure 1).[4] These actions were created using a digital video construction program

(EditDV produced by Digital Origin). Split-screen displays were created in which the two

objects appeared side by side (Figure 2). The individual pictures were 18"x12" and were placed

20" apart from center to center. (A sample of the video is available at

http://www.infancyarchives.com.) The same program was then used to combine the audio and

video into the counterbalanced orders that were finally shown to the participants.

Apparatus

A Sony TRV-7000 Digital8 camcorder was attached to a Sony KLW-9000 LCD

presentation display (a 56" screen). A second camcorder was mounted above this display to

record infant looking times. A large white plywood barrier surrounded the front of the display

and camera in order to minimize looks to non-essential sections of the testing apparatus. In this

way, the infant or toddler was prevented from seeing anything except the screen and the lens of

the camera.

Procedure

Upon arrival at the lab, parents and their infants were escorted to a playroom. There, the

experimenter explained the study and gave the parent a consent form. The infant and parent were

then led to a testing room where the infant was seated in the center of their parent's lap and the

parent was directed not to interact with the infant during the experiment. During the experiment

the parent wore a visor with a long piece of felt hanging from the front. This blocked the

parent's view of the screen and prevented the parent from influencing the child to look in any

particular direction. The parent and child were seated 46" from the screen. The entire experiment

took two minutes and sixteen seconds.

Coding

For each subject, durations of looking time to the left or the right were coded off-line,

frame-by-frame, and without sound in order to minimize the possibility of bias. The first author

coded all the data. The second author coded ten percent of the data. Intercoder reliability was .96

or better (this is the percent of agreement between coders).

Results

Table 2 shows mean looking times in seconds to the target and the non-target for the

three question types across all the age-groups as well as the number of infants whose means are

positive (meaning they looked longer toward the target during the test trial). The data show

different patterns for the different age groups. Planned comparisons for the 20-month-olds

showed that there were significant differences in target and non-target looking times for the

subject, $t(19) = 3.482$, $p = .0025$, the object, $t(19) = 5.256$, $p < .0001$, and the where questions,

$t(19) = 5.950$, $p < .0001$. 15-month-olds showed reliably longer looking times to the target for

the subject-, $t(19) = 2.218$, $p = .0389$ and the where questions $t(19) = 2.576$, $p = .0185$, but not

for the object-questions $t(19) = .721$. For the 13-month-olds, none of the three comparisons

revealed statistical significance (subject $t(19)=1.014$, ns, object $t(19) =-.101$, ns, or where

questions $t(19) = .904$, ns).

These findings indicate that 20-month-olds are able to respond appropriately to simple

subject, object and where questions and that 15-month-olds do so for simple subject and where

questions, but not for object-questions.[5] The 13-month-olds were unable to respond

appropriately to any of the question types. It was especially surprising that the 13-month-olds

were unable to respond appropriately to the simple where questions. Because of this result we

ran an additional experiment with only the where questions. In this experiment, we exposed

infants to the actions immediately before each where question and then repeated each question

four times during each test trial. Nonetheless, the results were the same as in Experiment 1: the

infants did not respond above chance.[6]   Given the results of this control study, it appears that our

task may have been too difficult for the youngest infants, i.e., the attentional demands of

processing the moving stimuli and quickly shifting to a question proved too difficult for infants

at this age. Indeed, given other studies that suggest infant word learning is extremely tenuous at

this age (Werker, Fennell, Corcoran, and Stager, 2002), perhaps it should not come as a surprise

that attentional distraction may disrupt competence in this case as well. Thus, in the subsequent

analyses, we consider only the data from the 15-and 20-month-olds. Nonetheless, the 13-month-

old data is reported, because, although the 13-month-olds did not significantly look at the object

overtly mentioned in the subject questions, their data does fall in line with the results of the older

age groups.

Planned comparisons on 15- and 20-month-olds' difference scores show a developmental

trend for object questions [$F(1,38) = 12.12$, $p = .0013$], but not for subject-questions [$F(1,38) =$

.358, $p = .5533$]. These results suggest that although comprehension of all questions improves

and looking times to targets increase with age, comprehension of object-questions shifts between

15 and 20 months.[7]

Discussion

The results of the present study indicate that by 20 months of age infants are sensitive to simple matrix what-questions of both subjects and objects. Infants correctly looked at the target object when asked both, "What hit the flower?" (the apple) and "What did the apple hit?" (the flower). This finding is significant, given findings from previous studies suggesting that comprehension of such questions is quite a late achievement. For example, some of the youngest children (three-year-olds) previously tested in studies by Ervin-Tripp (1970) and Tyack and Ingram (1977) were unable to correctly answer either subject (Ervin-Tripp, 1970) or object (Tyack and Ingram, 1977) questions. However, Stromswold (1995), in her review of the literature on acquisition and the comprehension of wh-questions, mentions that the low success rate of these studies may be related to the high task-related demands of these studies. Consistent with Stromswold's discussion, it may be that the infants in these earlier studies did, in fact, understand some aspects of the questions they were asked. However, requiring children to produce a verbal response masked their understanding. In contrast, the low task demands in our study reveal that syntactic competence may begin at an earlier age than might have been previously expected.

Aside from the 20-month-olds' overall competence, we also observed a shift in performance between 15 and 20 months. Only the 20-month-olds showed understanding of both the object and the subject what-questions. This suggests that there may be a developmental change that is a prerequisite for understanding of object-questions. What would account for this developmental change? We consider three alternatives.

One possibility is that infants parse language based simply on surface features or semantic features. Namely, when young infants hear a question word such as *what* or *where,* they

either look at the word overtly mentioned in the sentence containing the wh-word or focus on the agent of the action. This finding would be predicted by accounts that argue that early on infants rely on attentional, social/pragmatic, or sematic foci to process language (Baldwin, Markman, Bill, Desjardins, and Irwin, 1996; Pinker, 1984; Smith, 1999; Tomasello, 1999). We can rule out this first alternative for 15- and 20-month-olds. The fact that children respond appropriately to what-questions eliminates the possibility that they are merely looking at an object overtly mentioned in the target sentence. In fact, in these questions, they look longest at an object that is *not* mentioned in the sentence. It is also true that toddlers do not just focus on an agent or patient of some action, because by 20 months of age they were able to respond appropriately regardless of which object (agent or patient) was being questioned, although an agentive preference could explain the performance of the 15-month-olds.

This result has implications for a central debate in the language acquisition literature which focuses on whether infants begin the task of acquisition by exploiting linking rules from thematic roles (agent/patient) observable in scenes to syntactic categories (subject/object) (Grimshaw,1981; Pinker, 1984; et seqq.) or whether infants rely on information in the syntactic frame together with other information in the scene to infer the meaning of a verb (Brown, 1957; Gleitman, 1990; Landau & Gleitman, 1985). We have found that even if infants begin with a preference for agent, by 20 months of age they are able to override this preference and rely primarily on syntactic information to answer these questions.

In addition, it is clear that the strategy of focusing on the noun which is not overtly mentioned in the sentence is unique to these types of questions, because in where questions, infants looked at the item that *was* overtly mentioned in the sentence. At the very least, our data show that infants distinguish what- and where questions. This is particularly interesting given

that the two sentences are phonologically similar (e.g., "Where is the flower?" vs. "What hit the flower?").[8]

A second possibility is that 20-month-old infants have control of complex syntactic structures, but 15-month-olds do not have full control of these structures (either do-support (insertion of the dummy verb *do*) or movement chains (movement of the question word *what* to its surface position in the sentence)).[9] It may be that the 15-month-old infants are thus forced to use a simpler strategy based on semantic roles rather than the deeper syntactic strategy exploited by the 20-month-old infants and that exploiting this strategy rather than the syntactic one may lead them astray.[10] The syntactic strategy, according to a standard theory of wh-movement, is that the wh-word moves to the specifier position of the complementizer phrase (Chomsky, 1981). Given this view, object questions may be acquired later than subject and where questions for several reasons.[11] First, do-support may make object questions harder than subject questions.[11] Second, object questions may be harder to understand than subject ones because they involve longer movement.[13] This is true whether or not one favors a theory that involves successive cyclic movement (Chomsky, 1995) or one such as Tree Adjoining Grammar (Joshi, 1986), which involves a long chain between a wh-trace and its surface position. In that case, the object needs to move a bit farther than the subject, which may mean more working memory is involved.

This brings us to a third possibility: 15-month-olds' problems with object questions may result from a lack of resources either in terms of working memory or central executive function. In a similar way, it has been argued that patients with Parkinson's disease (patients who have problems with working memory and central executive function) have resultant problems with complex sentence processing (Caplan & Waters, 1999; Grossman et al, 1992; Natsopulos et al, 1991). It has also been shown that normal adults have more difficulty in processing object

relative clauses when they have the additional resource demands of a secondary task (Gibson, 1998; King & Just, 1991). Similarly, Santelmann and Jusczyk (1997) found changes in infants' processing between 15 and 18 months of age. Thus, it may be that infants have complete control of the structures necessary to process both object and subject wh-questions, but at 15 months, do not have sufficient working memory to process questions that require more resources. Ongoing research is examining the degree to which attentional demands may cause infants to have difficulty in processing more complex structures.

Regardless of which explanation ultimately turns out to be correct, the current study indicates that long before infants are producing wh-questions, they understand them in ways few would have suspected.

Footnotes

[1] Similarly, in recent work Lidz and Musolino (2002) show that children's scopal interpretations are guided primarily by surface syntactic position at a young age.

[2] For example, in production, either subject and object agreement emerge simultaneously or subject agreement precedes object agreement (Demuth, 1992), but it is not the case that object agreement precedes subject agreement.

[3] Because of the structure of Korean, O'Grady et al (2001) are able to take out the linear distance confound and focus on structural distance. They find that subject relatives are easier than object relatives even when linear distance should make them more difficult.

[4] Both the agent of the action and the patient were affected by the hitting action so that an infant's attention would not focus only on the object that moved.

[5] A time-course analysis of these results revealed that a substantial portion of infants shifted their looking to the target object approximately 1 second after the onset of the critical word; well after the sentence had ended. This suggests that it was the sentence as a whole that was driving their looking times rather than any particular word per se.

[6] We also ran individual item analyses in order to ascertain whether the infants were simply unable to understand the target nouns in the questions. However, again, a null result was found for each individual item. We therefore conclude that the difficulty with all of the questions for the 13-month-olds may have more to do with attention than specific vocabulary.

[7] We also analyzed these data by the longest look, instead of overall looking time. Because these analyses overlapped completely with the overall results, we do not include them here.

[8] It is also possible that the 15-month-olds had an easier time with both subject and where

questions (than object questions) because these questions end with nouns. These nouns may have heightened 15-month-olds *overall* attention to the meaning of the utterance, in the case of subject questions. Indeed, work by Golinkoff, Alioto, and Hirsh-Pasek (1995; see also Fernald, McRoberts, & Herrera, in press.) suggests that infants find it easier to recognize words presented in sentence final position. While current studies are addressing this issue, certainly by 20 months, infants have overcome this limitation.

[9] Note that the problems we suggest 15-month-olds may have with object questions are problems of processing, not of the grammatical system. Syntactically, objects have fewer restrictions on extraction than subjects, but this does not necessarily contribute to helping, or hindering, the processing of sentences with extracted objects.

[10] Something similar is suggested in Hirsh-Pasek and Golinkoff (1996): Two-year-old boys treated sentences such as, "Big Bird is squatting with Cookie Monster," as a transitive sentence, girls appeared to use syntactic cues to correctly interpret these sentences as intransitive sentences with conjoined subjects.

[11] Although children may not have higher projections such as CP in their production (as suggested in Legendre et al, 1999), it does not necessarily follow that they cannot comprehend sentences with higher projections at an earlier age.

[12] In a GB account of English, do-support occurs because lexical verbs do not raise. Thus, in order to check tense features that occupy C (a complementizer-head above TP), the formal features of a verb may move to C. In object questions, when a subject is present in Spec *v*P (the specifier position of a phrase headed by voice, or in an account without *v*P, Spec VP) it blocks the feature checking relationship between C and the lexical verb (cf. (5) and (4)). But these

features must be checked for the derivation to go through, thus *do* is inserted as a last-resort

operation and checks off the features in C and T (Chomsky, 1995).

(4) $[\text{what}_i[\text{C}[\text{t}_i[\text{tns}[\text{t}_i[_v[\text{ hit } [\text{flower}]_{NP}]_{VP}]_{v'}]_{vP}]_{T'}]_{TP}]_{C'}]_{CP}$

(5) $[\text{what}_i[\text{C}[\text{t}_i[\text{did}[\text{apple}[_v[\text{hit}[\text{t}_i]_{NP}]_{VP}]_{v'}]_{vP}]_{T'}]_{TP}]_{C'}]_{CP}$

[13] An anonymous reviewer points out that our argument about the length of the

movement chain does not explain why it is that children understand where questions before

object questions since both involve long movement chains. Although the chain may be equally

long in where questions and object questions, the movement is of an adjunct not an argument in

where questions and thus we do not necessarily predict the same pattern of results. In addition,

in where questions it is possible to understand the target in the absence of processing it as a

question at all. Nonetheless, it could be that a combination of factors (both the length of the

chain and the fact that the entity being questioned is not overtly mentioned) is what makes object

questions especially difficult.

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Table 1

Trial Order

Block	Trial	Video	Audio
	beginning	sunset	
Block 1	Training trial 1 (x2)	apple hits flower	
	Test trial 1 (x2)	split screen of apple & flower	"*What* did the apple hit?"
Block 2	Training trial 2 (x2)	book hits keys –	
	Test trial 2 (x2)	split screen of book & keys	"*What* hit the keys?"
Block 3	Training trial 3 (x2)	apple hits flower	
	Test trial 3 (x2)	split screen of apple & flower	"*What* hit the flower?"
Block 4	Training trial 4 (x2)	book hits keys	
	Test trial 4 (x2)	split screen of book & keys	"*What* did the book hit?"
Block 5	Test trial 5	split screen of apple & flower	"*Where* is the apple?"
	Test trial 6	split screen of book & keys	"*Where* is the book?"
	Test trial 7	split screen of apple & flower	"*Where* is the flower?"
	Test trial 8	split screen of book & keys "	*Where* are the keys?"

Table 2

Overall mean looking times (and standard error) for all age groups

Age	Question type	Target	Non-Target	Diff	Means to target
	Subject	1.92 (.16)	1.61 (.16)	.31	n=11
13	Object	1.64 (.16)	1.67 (.15)	-.03	n=9
	Where	1.73 (.11)	1.61 (.13)	.12	n=11
	Subject	2.11 (.15)	1.49 (.13)	.62*	n=17
15	Object	1.81 (.13)	1.66 (.09)	.15	n=10
	Where	1.95 (.12)	1.38 (.13)	.57*	n=14
	Subject	2.25 (.12)	1.41 (.12)	.84*	n=18
20	Object	2.43 (.14)	1.17 (.12)	.126*	n=17
	Where	2.45 (.12)	1.23 (.09)	1.22*	n=18

Note. * indicates $p < .05$

Figure Captions

Figure 1. Book hitting keys

Figure 2. Book and keys in split-screen display

- - · - - · → Path of book
············· → Path of keys