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The Recognition of Discontinuous Verbal Dependencies by German 19-Month-Olds: Evidence for Lexical and Structural Influences on Children's Early Processing Capacities

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Recent work has shown that English-learning 18-month-olds can detect the relationship between discontinuous morphemes such as *is* and *-ing* in *Grandma is always running* (Gomez, 2002; Santelmann & Jusczyk, 1998) but only at a maximum of 3 intervening syllables. In this article we examine the tracking of discontinuous dependencies in children acquiring German. Due to freer word order, German allows for greater distances between dependent elements and a greater syntactic variety of the intervening elements than English does. The aim of this study was to investigate whether factors other than distance may influence the child's capacity to recognize discontinuous elements. Our findings provide evidence that children's recognition capacities are affected not only by distance but also by their ability to linguistically analyze the material intervening between the dependent elements. We speculate that this result supports the existence of processing mechanisms that reduce a discontinuous relation to a local one based on subcategorization relations.

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In learning a language, two major problems the child must solve are the acquisition of meaningful (lexical) elements, on the one hand, and the acquisition of the rules for the formation of complex linguistic expressions using these lexical elements, on the other hand. For example, the child must acquire the rules of creating multimorphemic words, for example, *understandable;* phrases from lexical elements (e.g., *a red rose*); and sentences using both lexical elements and morphology (e.g., *John likes red roses*). In addition, learning rules for the formulation of complex linguistic expressions involves, among other things, the acquisition of the subcategorization properties of the constitutive elements, which in turn determine the other elements these constituents can be combined with.

Thus, understanding a complex linguistic expression means, first, identifying its constitutive elements and their meaning and, second, determining the relations between these meaningful elements. Spoken languages employ two general strategies to indicate that a functional (i.e., semantic or syntactic) relation holds between two elements: (a) the relation may be expressed through temporal adjacency between the elements (order) or (b) the functional relation is indicated by a modification of the linguistic element, for example, through affixation (Bouchard, 1995). These two modes for indicating functional relationships are at the basis of the typological distinction between analytic (a) and synthetic (b) languages. Which option is predominantly used by a given language has important consequences for the ordering of the functionally related elements in the speech stream. Whereas the order solution results in a fixed basically contiguous order of the related elements, affixation often makes different orders or positions available for the morphologically marked elements. Thus in English, a language with very impoverished functional morphology, the functions *subject-of* or *object-of* are encoded in declarative sentences by strict subject-verb-object-(X) order as in *the cat chases the bird in the garden.* The order *the bird chases the cat in the garden* yields an entirely different meaning. On the other hand, German, a language with relatively rich morphology, allows for the following orders with basically identical meanings: *Die Katze jagt den Vogel im Garten* 'the cat-subj hunts the bird-obj in the garden', *den Vogel jagt die Katze im Garten* 'the bird-obj hunts the cat-subj in the garden'*, im Garten jagt die Katze den Vogel* 'in the garden hunts the cat-subj the bird-obj'.

Much recent work has shown that infants have most of the necessary capacities to decode either type of relation from early on. During the second half of their first year of life, infants can isolate elements in the speech stream that correspond to lexical items, as well as bound morphemes (e.g., Blenn, Seidl, & Höhle, 2003; Höhle & Weissenborn, 2003; Jusczyk & Aslin, 1995; Jusczyk, Houston, & Newsome, 1999). At the same time, they are able to track co-occurrence patterns between adjacent elements on the basis of distributional analyses, including order relations (Gomez & Gerken, 1999; Jusczyk, Houston, et al., 1999; Mandel, Kemler Nelson, & Jusczyk, 1996; Marcus, Vijayan, Bandi Rao, & Vishton, 1999; Saffran, 2001; Saffran, Aslin, & Newport, 1996; Saffran, Johnson, Aslin, & Newport, 1999).

However, languages—especially languages with rich morphology—also include relationships between nonadjacent elements. Thus children must also be able to recognize relations between two or more nonadjacent elements that are marked by morphology and to abstract the underlying rule associated with the realization of the relationship. Little is known yet about when children are able to detect a relation between two nonadjacent elements, and under what conditions they are able to do so, that is, about the factors that may influence the child's capacity to process and to acquire discontinuous dependencies.

Several recent studies have begun to investigate children's ability to track nonadjacent relationships. Santelmann and Jusczyk (1998) tested 18-month-old infants learning English on their ability to track the morphemes *is* and *-ing* across the root of the main verb and additionally across adverbs of two, three, and four syllables using the Head-Turn-Preference Paradigm (Kemler Nelson et al., 1995). They first compared infants' preference for grammatical passages with *is* and *-ing* as in *The archeologist is digging for treasures* to ungrammatical passages with *can* and *-ing*, as in **The archeologist can digging for treasures.* They found that 18-month-olds looked longer toward the source of sound for the natural over the unnatural passages. This suggests that infants have noted and can track the relationship between the two dependent morphemes *is* and *-ing* across the root of the verb.

However when adding an intervening adverb, Santelmann and Jusczyk (1998) found that infants showed a preference for the *is* and *-ing* passages only if the dependent morphemes occurred across adverb–verb–root sequences that did not exceed three syllables. That is, when the two dependent morphemes were separated by adverb–verb–root sequences that were greater than three syllables, as in *The archeologist is/can energetically digging for treasures*, then the infants no longer showed a preference for the grammatical (natural) passages. Santelmann and Jusczyk suggested that these results may stem from limitations on the processing space in infants. That is, possibly due to time or size constraints on working memory, infants may not be able to track the co-occurrence relation between the verb be and the progressive over longer distances.

Further work by Tincoff et al. (2000) has revealed that infants' sensitivity to the relationship between auxiliary and the progressive is restricted by factors other than distance as well. They found that the lexical items involved in the relationship also influenced infants' sensitivity to these morphemes. Eighteen-month-olds showed a preference for grammatical passages when the contrast was between *is* versus *can* and *-ing* or *was* versus *could* and *-ing*. However, when the contrast was between *are* versus *will* or *were* versus *would* and *-ing*, for example, *The archeologists are digging for treasures* versus *The archeologists will digging for treasures*, infants did not show a preference for the grammatical passages. These results suggest that the relationship between the auxiliary and the progressive is first established between specific lexical items, possibly dependent on the infant's

familiarity with them based on frequency of input. Apparently, the infants have not yet established the relationship between categorically identical members of the suppletive inflectional paradigm of the auxiliary *be* and the progressive form of the verb.

Work by Weissenborn, Höhle, Kiefer, and Cavar (1998), also using the Head-Turn-Preference Paradigm, indicates that 20-month-old German-learning infants have recognized the relation between the presence of a complementizer introducing a finite subordinate clause and the obligatory sentence final position of the finite verb. Main clauses in German require the finite verb to be in second position, that is, *Lisa hilft Oma* 'Lisa helps Grandma', whereas subordinate clauses require it to be in final position verb, for example, *Bert sagt, dass Lisa Oma hilft* 'Bert says that Lisa Grandma helps'. If the children had not made a connection between the complementizer *dass* 'that' and the position of the finite verb *hilft* 'helps' (separated by the subject and the object), we would have expected that they would not have differentiated between the grammatical structures as shown above and the ungrammatical structures with the main clause word order in the embedded clause, that is, *Bert sagt, *dass Lisa hilft Oma* 'Bert says that Lisa helps Grandma'. In addition, Gomez (2002), using an artificial grammar, provided further evidence that 18-month-old English-learning infants can track co-occurrence relations between two nonadjacent words: A (e.g., *pel*) and B (e.g., *rud*), separated by one bisyllabic element X (e.g., *wadim*). She found that both adults and infants appeared to be able to acquire a relationship between the two discontinuous words A and B only if the intervening material X varied considerably. Thus, in her study, if there were 12 different items that alternatively appeared in the X slot, the learners did not acquire the relationship, but if there were 24 different items that appeared in this position, they did. This result suggests that learners focus their attention initially on adjacent elements. However, when due to the greater variability of adjacent elements in the input, the transitional probabilities between them decrease, then the increasingly prominent relation between A and B becomes established. It is an open question whether and how the variability of material intervening between dependent elements, as defined in Gomez's study, influences the processing of nonadjacent relationships under the conditions of natural language learning.

This set of recent studies indicates that by about 18-months infants can establish a relationship between nonadjacent elements in the speech stream. This ability holds not only for the focused dense presentation of the critical dependency under laboratory conditions as in the studies by Gomez (2002), but also for natural language learning. The latter is evidenced by the fact that English-learning 18-month-olds have established the dependency relation between the morphemes *is* and *-ing*—which never occur adjacent to each other—but are minimally separated by a monosyllabic verb stem. Despite children's acquired knowledge about the dependency, however, recognition of it during the processing of an actual sentence is still initially restricted as shown by Santelmann and Jusczyk's (1998) re-

sults. These results suggest that the acquisition of dependency relations may also be affected by how they are realized in the input. If, in a given language, the dependency to be learned is mostly realized across a domain that exceeds children's processing capacities it could be acquired later than a dependency that is more often realized in a way that does not exceed the children's processing capacities.

The preceding discussion shows that investigating the factors that influence how the acquired knowledge is applied may also give us clues about which factors may influence the acquisition of this knowledge in the first place. At the same time, this literature raises a number of questions about how children acquire functional relationships in languages that differ considerably from English. As discussed above, English preferentially marks functional relations by the fixed ordering of mostly adjacent elements, whereas a language like German preferentially uses the morphological marking, leading to a much less constrained form of the dependency relations in German. This typological difference means that the realization of dependency relations can appear very different, even in constructions that are structurally very similar in the two languages. One such example can be found when comparing the English auxiliary *be* + progressive construction and the German auxiliary + past participle construction as in *Pia hat gekocht* 'Pia has cooked'. As noted in Santelmann and Jusczyk (1998) and Santelmann (2003), one important difference between the English and the German construction is that in English, only subjects (in questions) and adverbs can intervene between the auxiliary and the progressive, whereas in German multiple constituents of any type may occur between the dependent elements as illustrated in the following: *Dann hat Pia schnell ein Brot in der Bäckerei gekauft* 'Then Pia has quickly a bread in the bakery bought'.

Santelmann (2003) analyzed elicited constructions in the input of 18- to 43-month-old English- and German-learning children (present progressive for English, present perfect for German) and found considerable differences between the languages. In 49% of the German utterances, the dependent elements were separated by four or more syllables, whereas this held for only 8% of the English utterances. In contrast, in 70% of the English utterances, the two dependent elements were separated by two or fewer syllables, as compared to German, where this held for only 35% of the utterances. This result shows that the German infant has to deal, on average, with greater distances between the dependent elements in this type of verb phrase than the English infant. Furthermore, as already noted, multiple different constituents can intervene between the dependent elements in German yielding a much higher variability with respect to the intervening lexical material in the German samples than in the English ones.

In addition to these input differences, there are other differences between English and German that might lead to differences in the acquisition of the nonadjacent morphemes in the present perfect relationship in German when compared to the progressive in English. Specifically, the German present perfect shows more varia-

tion with respect to morphological and further syntactic properties than the English progressive:

- In English the main verb marked with the progressive always occupies the same position with respect to the auxiliary, whereas in German the position can vary. In German main clauses the past participle follows the auxiliary, for example, *Pia hat ein Brot gekauft* 'Pia has a bread bought', whereas in subordinate clauses introduced by a complementizer, the auxiliary comes at the end of the clause, immediately following the past participle, for example, …, *dass Pia ein Brot gekauft hat* '…, that Pia a bread bought has'.
- The progressive in English invariably selects *be* as its auxiliary, whereas the past participle in German selects *be* or *have*, depending on the semantics (unaccusative: *be*; unergative: *have*) or the voice (passive: *be*; active: *have*) of the main verb, for example, *er ist ins Bett gehüpft* 'he is into the bed hopped', *er hat gelacht* 'he has laughed', *es ist gekauft worden* 'it has been bought', *er hat gekauft* 'he has shopped'.
- The morphology of the English progressive is always the same, that is, verb stem + *ing*, whereas the German past participle can take different forms depending on the individual verb: The regular form occurs with the prefix *ge-* and the suffix *-t*, whereas some verbs take the prefix *ge-* with the suffix *-en* instead, for example, *er hat gesehen* 'he has seen'. The system is further complicated by the fact that only verbs that are stressed on their first syllable take the prefix *ge-,* whereas all other verbs do not allow it, for example, *er hat trompétet* 'he has trumpeted', *er hat bestéllt* 'he has ordered'.

These facts raise the question of how the differences between English and German might affect the recognition of the respective dependencies in the two languages. One might assume that German infants could have greater difficulty in establishing a relationship between the dependent elements than English infants do, given that in the input of German children, the mean distance between dependencies is about four syllables (Santelmann, 2003), and given Santelmann and Jusczyk's (1998) finding for English that elements with more than three syllables intervening between two dependent elements disrupt infants' recognition of their dependency. Second, the greater lexical and morphological variation of the dependent elements in German (e.g., with or without *ge-,* the variation in auxiliaries) may increase the difficulty for the German-learning infants. This greater variation in forms means that the frequency of the individual forms in the input is lower in German than in English, meaning that it may take infants learning German longer to generalize to the underlying paradigmatic regularities (Tincoff et al., 2000).

On the other hand, if greater variability of the elements intervening between the related elements facilitates recognition of a dependency in both natural and artificial languages (Gomez, 2002), then the greater variability found in the input of the

German infant may foster the recognition of the dependency, possibly overriding the factors of distance and variability in form.

Thus, given the findings for English and the differences between the two constructions between English and German, the aim of our studies was to examine whether or not German infants recognize the dependency between the auxiliary + past participle construction at about the same age as English infants recognize the dependency between the auxiliary + *-ing* progressive.

EXPERIMENT 1

The first experiment was designed to replicate the Santelmann and Jusczyk (1998) study as closely as possible, given the differences between the languages. Its aim was to test German infants' ability to recognize the dependency between the auxiliary *haben* 'have' and the past participle form of the main verb over an intervening two-syllable adverb. Under this condition, English-learning infants had been able to recognize the dependency between the auxiliary and the progressive. Thus, German infants were tested with grammatical sentences, for example, *Er hat lieber getanzt* 'he has rather danced' (i.e., he would rather have danced) and with ungrammatical sentences in which the auxiliary was replaced by the modal *kann* 'can' **Er kann lieber getanzt* 'he can rather danced', because modal verbs in German, like in English, require an infinitival verb, not a participle, as their complement, for example, *Er kann tanzen* 'he can dance'.

Based on the results from English, we hypothesized that if the German infants are sensitive to the relationship between the past participle and the auxiliary they should listen longer to the grammatical sentences displaying this dependency than to the ungrammatical sentences without this dependency.

Method

Participants. We tested a group of 30 infants (15 girls and 15 boys) from monolingual German-speaking homes in the Potsdam and Berlin area. The mean age of the infants was 19 months and 4 days, with a range between 18 months and 18 days and 20 months and 16 days. They were all full term and had no known hearing deficits. Nine additional infants were tested but had to be excluded from the sample because the experimental session could not be finished with them: 8 due to the infants' fussiness or crying and 1 due to technical problems.

Stimuli. For the present set of studies, we used sentences in the present perfect formed with the auxiliary *hat* 'has' (the third person singular form of *haben* 'have') combined with main verbs that form a regular past participle with the prefix *ge-* and the suffix *-t*, for example, *gemalt* 'painted'. For the ungrammatical sen-

tences, we chose the third person singular *kann* 'can' of the modal *können,* parallel to the English studies. It was also chosen because it was the closest in frequency to the auxiliary *hat*, according to the CELEX-database for spoken German[1] (Baayen, Piepenbrock, & van Rijn, 1991): *kann* had a frequency of 3,820 occurrences per million words and *hat* had a frequency 5,753 occurrences per million.

For the construction of the test sentences, 48 verbs with monosyllabic stems that form their perfect with the auxiliary *haben* and have a regular past participle form were selected. Using these verb forms, we constructed eight pairs of matched grammatical and ungrammatical presentation blocks consisting of six sentences each. All blocks were matched with respect to the numbers of syllables and the position of the target dependencies within the sentences. The only difference between the grammatical and the ungrammatical blocks was that the grammatical sentences contained the auxiliary *hat* in the position where the modal *kann* appeared in the ungrammatical sentences (for examples see Table 1). The two elements of the target dependencies were separated by a bisyllabic adverb. All adverbs were only used in one pair of sentences.

The sentences were produced by a female native speaker of German who was asked to produce the sentences in a lively manner, as if speaking to an infant. The recording was digitized and the sentences were combined into blocks by using a speech editing program. The single sentences of a block were separated by a pause of 900 msec. The mean duration of the grammatical blocks was 20.25 sec, ranging from 19.68 sec to 20.84 sec. The mean duration of the ungrammatical blocks was 20.60 sec with a range between 19.92 sec and 21.17 sec.

Design and procedure. In the set of experiments reported here we used the Head-Turn-Preference Procedure. During the experiment, the infant was seated on the lap of a caregiver in the center of a test booth. The caregivers listened to music over headphones to prevent them from influencing the child's behavior. Inside the booth, three lamps were fixed: a green one at the center wall, and red ones at each of the side walls. Directly above the green lamp on the center wall was a hole for the lens of a video camera. On the outside of the test booth, two loudspeakers were mounted at the same height as the red lamps. Each experimental trial was started by the blinking of the green center lamp. When the infant oriented towards the green lamp, this lamp went out and one of the red lamps on a side wall started to blink. When the infant turned her head towards the red lamp, the speech stimulus was presented from the loudspeaker on the same side as the blinking red lamp. The trial ended when the infant turned her head away for more than 2 sec, or when the end of the speech file was reached. If the infant turned away for less than 2 sec, the

[1]The CELEX-Corpus of spoken German is a 600,000-word corpus extracted from adult-directed utterances recorded in formal and informal speech situations.

TABLE 1
Sample of Grammatical and Ungrammatical Sentences in Experiment 1

Grammatical	*Ungrammatical*
Das kleine unzufriedene Kind hat ***morgens*** *geheult.*	*Das kleine unzufriedene Kind kann* ***morgens*** *geheult.*
the little unhappy child has in the morning cried	the little unhappy child can in the morning cried
'The little unhappy child has cried in the morning'.	'The little unhappy child can cried in the morning'.
Der Hamster hat ***leise*** *gequiekt, weil er schlafen wollte.*	*Der Hamster kann* ***leise*** *gequiekt, weil er schlafen wollte.*
the hamster has softly squeaked because it sleep wanted	the hamster can softly squeaked because it sleep wanted
'The hamster has squeaked softly because it wanted to sleep'.	'The hamster can squeaked softly because it wanted to sleep'.

presentation of the speech file continued but the time spent looking away was not included in the total listening time.

The experiment was controlled by the experimenter from an adjacent room. She could start the visual and the acoustic stimuli by a push button box that was connected to a computer. By the same means she coded the head turns of the infant online during the experiment. From this coding, the duration of the baby's headturns during each experimental trial was calculated automatically. The experimenter observed the child's behavior on a mute video monitor. Because the sound was not transmitted to the coding room, the experimenter was blind with respect to the experimental condition to which a given trial belonged. This guaranteed that her coding behavior was not influenced by knowledge of the ongoing trial. The whole session was videotaped. In addition to the recorded picture from the testing booth, this videotape contained a code number for the baby being tested, a code number for each experimental trial, and a visual signal for the start of the acoustic stimulus. This additional information allowed an offline coding of the infants' orientation times to check the reliability of the online coding. Such an offline coding was done for 40% of the experimental sessions by a rater who was not involved in the preparation and running of the experiments. For the experiment reported here the interrater correlation is $r = 0.98$, which is in the range reported by other studies using this method (Echols, Crowhurst, & Childers, 1997; Gomez & Gerken, 1999; Jusczyk, Hohne, & Baumann, 1999).

Each infant was seen for one experimental session. The experimental session consisted of a practice phase, followed by a test phase. All infants heard the same 4 blocks (2 grammatical and the 2 matching ungrammatical ones) as practice trials to familiarize the infants with the procedure and the type of stimuli. The remaining 12 blocks were presented in a pseudorandomized order. Each infant was randomly as-

signed to one of the four possible test conditions, which varied the side and the order of the presentation of the stimuli.

Results

The mean listening times for the grammatical and the ungrammatical blocks were calculated for each infant. The mean listening time was 7,588 msec (*SD* = 3,158) for the grammatical blocks and 7,834 msec (*SD* = 3,967) for the ungrammatical blocks. According to a *t* test for dependent samples, the difference between the listening times for the grammatical and the ungrammatical blocks was not significant, $t(29) = 0.46$, $p = 0.65$.

Discussion

Our results provide no evidence that German infants of about 19 months of age prefer the grammatical over the ungrammatical sentences in our experiment. This suggests that unlike their American age mates, German infants are not sensitive to the dependency between the auxiliary and the past participle in this construction. As discussed in the introduction, two properties of the present perfect construction might make the dependency hard for German infants to acquire. First, as noted earlier, verbal dependencies in German are generally separated by a larger number of constituents than in English. If the initial processing window of German children is as restricted as found for English children, it is possible that the German infants have simply not yet identified the dependency at this age. Second, the greater lexical and morphological variability of the elements involved in the German present perfect constructions, as compared to the progressive construction in English, may also obscure the verbal dependencies for the German infants and therefore contribute to a possible delay of their acquisition.

But the present finding still does not rule out the possibility that the German 19-month-olds may already have acquired some knowledge about the verbal dependencies but were not able to recognize them within the sentences used in the experiment. One possibility is that adverbs intervening between the dependent elements may have interfered with the infants' ability to recognize the relationship. To test this hypothesis we conducted a second experiment with the same stimuli but without the intervening adverb such that the dependent elements were now adjacent in the grammatical and the ungrammatical condition, for example, *Er hat getanzt* 'he has danced' versus **Er kann getanzt* 'he can danced'. Once again, we hypothesized that if infants are sensitive to the relationship between *hat* and the past participle form, then they would listen longer to the grammatical sentences than to the ungrammatical sentences.

EXPERIMENT 2

Method

Participants. A total of 30 infants (13 girls, 17 boys) participated in this experiment. They were from monolingual German-speaking homes in the Potsdam and Berlin area. Their mean age was 19 months and 21 days (range between 18 months and 11 days and 20 months and 18 days). All infants were full term and did not suffer from any known hearing deficits. To obtain the group of 30 infants we tested 16 additional infants. Fourteen of them did not finish the experimental session due to fussiness or crying or because of technical problems with the equipment. The results of 2 infants were not included in the data analysis because the mean listening times were below 3 sec suggesting that they did not hear a single complete sentence in most of the experimental trials, given an average sentence duration of 2.8 sec.

Stimuli. The stimuli were nearly the same as for Experiment 1 (for examples see Table 2), but because the deletion of the adverb lead to a semantic inconsistency in one sentence, we had to choose a different verb for that sentence. The sentences were again recorded by a female native speaker of German who said them in a lively manner as if speaking to a child. The material was again digitized and prepared in the same way as in Experiment 1. The average duration of the grammatical blocks in this experiment was 23.27 sec (range: 21.83 to 24.21 sec) and 21.56 sec for the ungrammatical blocks (range: 20.03 to 23.38 sec).

Design and procedure. These were identical to Experiment 1. An offline coding was done for 40% of the experimental sessions by a rater who was not involved in the preparation and running of the experiments. The interrater correlation between on- and offline coding was again very high ($r = 0.99$).

TABLE 2
Sample of Grammatical and Ungrammatical Sentences for Experiment 2

Grammatical	*Ungrammatical*
Das kleine unzufriedene Kind hat geheult.	*Das kleine unzufriedene Kind kann geheult.*
The little unhappy child has cried	The little unhappy child can cried
Der Hamster hat gequiekt, weil er schlafen wollte.	*Der Hamster kann gequiekt, weil er schlafen wollte.*
the hamster has squeaked because it sleep wanted	the hamster can squeaked because it sleep wanted
'The hamster has squeaked because it wanted to sleep'.	'The hamster can squeaked because it wanted to sleep'.

Results

The mean listening times for the grammatical and the ungrammatical blocks were calculated for each child. For the group, the mean listening times were 8,986 msec (*SD* = 4,138) for the grammatical blocks and 7,843 msec (*SD* = 2,523) for the ungrammatical blocks. According to a *t* test for dependent samples this difference was statistically significant, $t(29) = 2.48$, $p = 0.019$.

Discussion

Under the changed conditions of this experiment the infants did show a significant preference for the sentences with the grammatical auxiliary–past participle combination over the ungrammatical sentences. This result suggests that the German 19-month-old infants have already acquired knowledge about the dependency relation between the auxiliary and the past participle, despite the fact that their average input contains this dependency more often across domains of four and more syllables than across domains of up to two syllables (Santelmann, 2003) and despite the high lexical and morphological variability of the elements constituting this dependency as compared to English.

But then again, we have to ask why the children did not appear to recognize this dependency with two intervening syllables between the crucial elements as found in Experiment 1. Following the reasoning of Santelmann and Jusczyk (1998) our findings thus far suggest that 19-month-old German children have acquired knowledge about the dependency between the auxiliary and the past participle but that the recognition of this dependency is not possible for them over a distance of two syllables. From this we would have to conclude that German 19-month-olds have a more restricted processing window than their English age mates, who were able to track the dependency relation in the progressive construction over distances of up to three syllables. Given the fact that the German infants are often faced with greater distances in their language input, a processing window so strictly restricted would make the task of acquiring the crucial dependency very hard if not even impossible for them. It could still be the case that German infants have abstracted the relationship from the cases in the input in which the auxiliary and the past participle occurred adjacent to each other or were separated by no more than three syllables. However, because these cases of small domains are less frequent in the German than in the English input (35% vs. 70% according to the findings of Santelmann, 2003), we would expect a general delay in the acquisition of this dependency for the German children—an expectation that was not supported by the results from Experiment 2.

Given this reasoning, an alternative explanation imposes itself, namely, that it is the nature of the intervening lexical material, and not the pure distance between the dependent elements, that kept the infant from recognizing the relationship between

them. In our Experiment 1 as well as in the English experiments by Santelmann and Jusczyk (1998) only adverbs were used as intervening material. This raises the question of why adverbs should block the recognition of the verbal dependency in the German-learning infants but not in the ones who learn English. One reason could be that in English most adverbs are formed with the suffix *-ly.* There is evidence that 18-month-old English-learning infants have established some structural knowledge about this morpheme. Golinkoff, Hirsh-Pasek, and Schweisguth (2001) found that the ungrammatical use of the morpheme *-ly* in combination with a verb stem in a verb position leads to a disruption of the sentence comprehension abilities of 18-month-olds when compared to the correct use of the suffix *-ing* in the same position. In addition, the fact that only adverbs intervene between the auxiliary *is* and the progressive form *-ing* of the main verb in declarative sentences (yielding the pattern *is-X-ly-Y-ing,* where *X* and *Y* are stems) may have led the English-learning infant to establish a functional–distributional equivalence class between elements occurring in the *X* position. This class then may end up including the few adverbs that are not formally marked by the suffix *-ly* such as *often, always,* and so forth.[2] The recognition of this frame marked by a functional element, that is, *-ly*, might have helped the English children to track the relation between the two dependent elements.

In contrast, German has no unique formal marking of adverbs. A form like *leise* 'low, soft' is ambiguous between an adjective, such as *eine leise Stimme* 'a soft voice', and an adverb, such as *leise singen* 'to sing softly'. Due to the fact that adverbs are not consistently morphologically marked in German, the sentences presented to the German children did not include an additional structural marker on the intervening element that could support its processing and thereby facilitate the recognition of the dependency relation. Thus, the contrast between the German and the English findings leads to the hypothesis that the analyzability of the intervening elements may contribute to the infants' ability to establish a relation between the dependent elements. By analyzability we mean that the child is at least able to categorize intervening elements as belonging to independently established (lexical and/or syntactic) categories, leaving open for the moment the extent to which these classes are already functionally specified.

To test this hypothesis we ran a third experiment in which we inserted bisyllabic noun phrases, containing a definite article and a noun, for example, *der Ball* 'the ball', as intervening material. Previous studies suggest that German infants of this age are able to process articles and the structural information given by them from the beginning of their second year of life. First, German-learning 12-month-olds have been shown to treat articles as independent word forms (Höhle &

[2]As suggested by one of the reviewers, one possibility of testing this hypothesis would be to compare the looking times on trials with adverbs ending in *-ly* against those with adverbs having other endings in the original Santelmann and Jusczyk (1998) data.

Weissenborn, 2000). Second, German-learning 15-month-olds use the structural information given by an article to categorize the word following it as belonging to the same class corresponding to nouns in adults, suggesting that the combination determiner + noun forms a structural unit for the child (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004). This suggests that the appearance of a determiner in a string of words helps the child to assign a structure to this string that in turn might support the recognition of dependent relationships within this string.

As in the previous two experiments, infants were tested either with a grammatical dependency, for example, *Er hat den Ball geholt* 'he has the ball fetched' or an ungrammatical dependency between the modal *kann* and the past participle **Er kann den Ball geholt* 'can the ball fetched'. We hypothesized that if the analyzability of the intervening material plays a role for the infants' ability to track the relation between the dependencies, then under this condition German-learning infants should be able to process the dependency relation and should listen longer to the grammatical sentences than to the ungrammatical sentences.

EXPERIMENT 3

Method

Participants. Again 30 infants (15 girls, 15 boys) from the Berlin and Potsdam area were tested. All infants came from monolingual German-speaking homes, were born full term and had no known hearing deficits. They had a mean age of 19 months and 20 days (range: 18 months and 16 days to 20 months and 10 days). To obtain this group of 30 infants, we tested 9 additional infants. Six of them did not complete the experiment due to crying or fussiness, the data of 2 infants were not analyzable due to computer problems, and one infant's data were excluded from analysis because the mean orientation time was less than 3 sec.

Stimuli. New stimuli had to be created for this experiment, as the intransitive verbs used in the previous studies could not be combined with an object noun phrase. The new verbs were selected according to the same criteria as in Experiment 1: They formed their perfect with a form of the auxiliary *haben* 'have' and formed a regular past particle by the prefix *ge-* and the suffix *-t*. The sentences constructed with these verbs were designed to be comparable to the material of the first two experiments with respect to sentence length and the position of the dependency. To keep the distance between the two verbal elements comparable to Experiment 1 a two syllable noun phrase was inserted between them. This noun phrase consisted of a monosyllabic determiner, that is, a definite article, followed by a monosyllabic noun (for examples see Table 3). Again, pairs of matched six sentence blocks were constructed that differed only with respect to the finite verbs (auxiliary/modal) of the sentences. The grammatical sentences contained *hat,* the

TABLE 3
Sample of Grammatical and Ungrammatical Sentences for Experiment 3

Grammatical	*Ungrammatical*
*Das kleine phantasievolle Kind hat **den Ball** geholt.*	*Das kleine phantasievolle Kind kann **den Ball** geholt.*
the little imaginative child has the ball fetched	the little imaginative child can the ball fetched
'The little imaginative child has fetched the ball'.	'The little imaginative child can fetched the ball'.
*Der Hamster hat **das Korn** genascht, weil er Hunger hatte.*	*Der Hamster kann **das Korn** genascht, weil er Hunger hatte.*
the hamster has the grain nibbled because it hunger had	the hamster can the grain nibble, because it hunger had
'The hamster has nibbled the grain because it was hungry'.	'The hamster can nibbled the grain because it was hungry'.

third person singular form of the auxiliary *haben* 'have' together with the past participle of the main verb; in the ungrammatical sentences the auxiliary was replaced by *kann,* the third person singular form of the modal *können* 'can'.

The sentences were recorded by a female native speaker of German, who was asked to speak in a lively and infant-directed manner. The material was then digitized and prepared to be presented in the experiment as in the two previous experiments. The sentences within a passage were separated by a pause of 900 msec. The mean duration of the grammatical blocks was 24.38 sec, with a range of 22.19 sec to 26.05 sec. The mean duration of the ungrammatical blocks was 24.44 sec (range: 22.53 sec to 25.51 sec).

Design and procedure. These were identical to Experiments 1 and 2. Once again the interrater correlation between on- and offline coding that was done for 30% of the experimental sessions was very high ($r = 0.99$).

Results

Again the listening times to the grammatical and the ungrammatical blocks were calculated for each child. The mean listening time was 9,659 msec ($SD = 4,628$) for the grammatical blocks and 7,704 msec ($SD = 3,904$) for the ungrammatical blocks. The difference between the listening times in the two experimental conditions proved to be statistically significant, $t(29) = 2.24$, $p = 0.019$ (see Figure 1).

Discussion

As predicted, the German 19-month-old infants showed a significant preference for the sentences containing the correct dependencies. This result shows that German infants are able to track the relation between the dependent elements across a

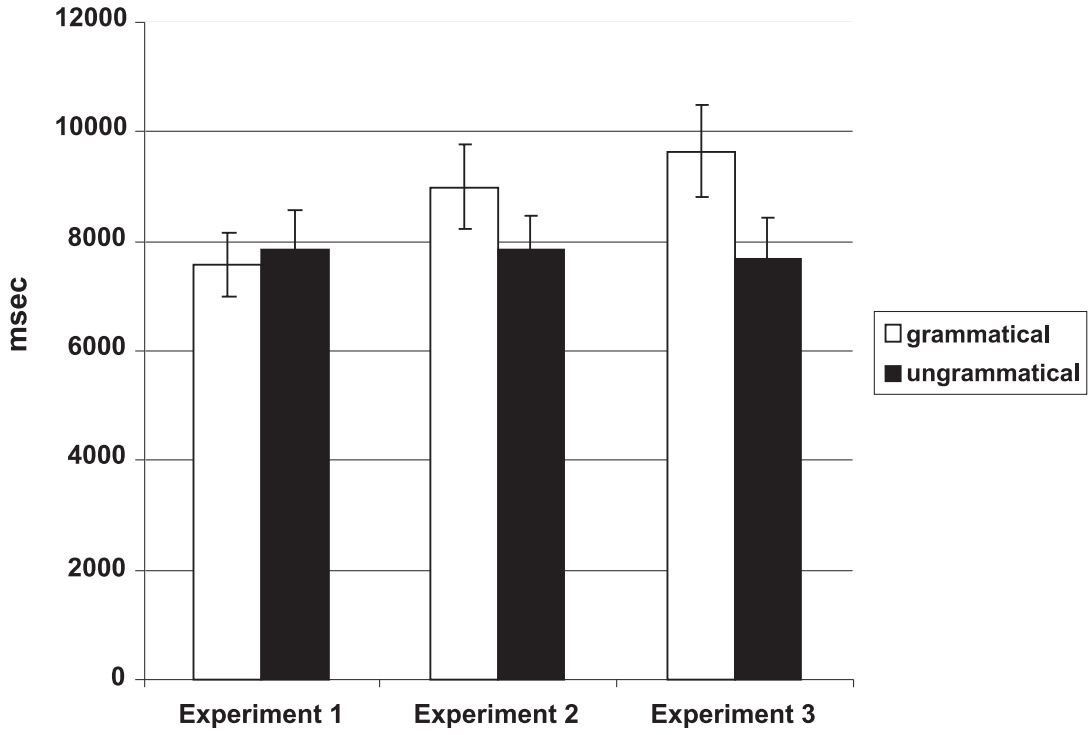

FIGURE 1 Mean listening time (msec) to grammatical and ungrammatical sentences in the three experiments (error bars = standard error of mean).

distance of two syllables. Thus, the fact that the infants did not show a preference for the grammatical sentences separated by bisyllabic adverbs in Experiment 1 cannot be due to a generally more restricted processing window for the German infants as compared to their English-learning age mates. Instead, our finding supports our hypothesis that the analyzability of the material intervening between the elements constituting a discontinuous dependency plays a crucial role for infants' ability to track the relationship.

Our conception of analyzability as outlined before is focused on the ability to assign a structure to the intervening material by taking advantage of the structural information given by functional elements. Analyzability in this sense may also be supported by the recognition of the lexical elements, that is, the nouns that appeared within the noun phrases. If this is the case, then the differences between the results in the first and the third experiment could also be due to differences between the lexical items (adverbs vs. nouns) used in the sentences. We cannot exclude the possibility that the nouns were already more familiar to the children than the adverbs and that it was the children's lexical knowledge that made the sentences with nouns easier to track than the sentences with adverbs. Because we have no information about the lexical inventories of the participants of our experiments, this possibility cannot be ruled out absolutely. At the same time the results of a frequency analysis for the nouns and adverbs used in the sentences revealed no differences in frequency of occurrence between the nouns and adverbs used in the stim-

uli. This suggests that a greater familiarity with the nouns is unlikely. According to the corpus of spoken German in the CELEX database (Baayen et al., 1991) the critical nouns in the sentences had an average frequency of 61 per million whereas the adverbs had a somewhat higher average frequency of 144 per million. This difference was not statistically significant, $t(94) = 1.18$, $p = 0.23$. The difference in the means was mainly due to the adverb *aber* 'but' with a frequency of 3,191 per million. Without this highly frequent element, the adverbs showed an average frequency of 79 per million, and a comparison of the frequency of the nouns versus adverbs showed no statistically significant difference with *aber* removed, $t(93) = 0.68$, $p = 0.49$. In addition, a frequency analysis of the words used in child-directed speech was conducted on the basis of the Caroline-Corpus from the CHILDES data base (MacWhinney, 2000). All utterances of the mother from the transcripts when Caroline was between 18- and 20-months old were included in the analysis yielding a corpus of around 15,000 word tokens. In this corpus only 11 of the adverbs and 13 of the nouns appeared. Again, no significant differences in the frequency of occurrences in the child-directed corpus was found for this subset of words (adverbs: 7.27; nouns: 7.53), $t(22) = 0.05$, $p = 0.95$. This suggests that the differences in the reactions to the sentences in Experiment 1 and Experiment 3 are not caused by frequency differences of the lexical items intervening between the dependent elements.[3]

With respect to the frequency of the verbs used in Experiment 1 and 3, a frequency analysis also revealed similar distributions. The transitive verb stems used in the sentences with an intervening noun phrase had an average frequency of 122 per million, whereas the intransitive ones used in the sentences with an intervening adverb had a somewhat lower average frequency of 45 per million. However, there was no statistically significant difference in the frequencies of the stems, $t(88) = 1.22$, $p = 0.22$. Again one item (the transitive verb *machen* 'to make', 2,432 per million) contributed overproportionally to the difference observed in the means. Without this item the two groups of verbs were even more comparable with respect to their frequency (70 per million for the transitive vs. 45 per million for the intransitive), $t(87) = 0.72$, $p = 0.46$. In the child-directed corpus only 16 of the verbs (3 that had been used in the adverb experiment, 7 that had only been used in the noun experiment, and 2 that had been used in both experiments) appeared at least in one instance. Even though there was a tendency for a higher stem frequency for the verbs used in the sentences with an intervening noun (3.97 occurrences) than for the verbs used in the sentences with an intervening adverb (1.45 occurrences) the difference was not significant, $t(19) = 0.68$, $p = 0.50$. The relatively big difference between the means was again mainly due to the verb *machen* with 125 occurrences

[3]Although it may still be the case, as pointed out by one of the reviewers, that differences in the familiarity of the determiners or of the determiner–noun versus adverb sequences play a role in infants' performance patterns.

in the corpus, which only had been used in the noun experiment. To make sure that the differences in the children's reactions to the grammatical and ungrammatical sentences were not only due to this highly frequent verb we analyzed the experimental data from Experiment 3 separately for the sentence blocks not containing the verb form *gemacht*. This subanalysis also yielded a significant advantage in looking times for the grammatical over the ungrammatical sentences (grammatical 9.6 sec, ungrammatical 7.7 sec), $t(29) = 2.24$, $p < 0.05$. According to these results it is very unlikely that the different results for Experiment 1 and 3 can be reduced to a frequency effect of the verbs used in the two experiments.

GENERAL DISCUSSION

The aim of our study was to investigate whether the morphosyntactic differences between two structurally very different languages such as English and German would affect infants' capacities to acquire and to recognize discontinuous verbal dependencies. The starting point for our studies was the finding that English-learning 18-month-olds have acquired the relation between the two verbal elements in the English progressive construction and are able to track this relation across a distance of maximally three intervening syllables, for example, *grandma is always laughing* (Santelmann & Jusczyk, 1998). For our studies with German infants, we selected the present perfect, for example, *Grossmutter hat immer gelacht* 'grandma has always laughed', a construction that parallels the English progressive in many ways, but also has crucial morphosyntactic differences from the English progressive.

Despite the fact that the German present perfect has features that could make the learning of the dependencies harder than learning the similar construction in English, our results clearly suggest that German 19-month-olds have acquired knowledge of the dependencies tested.[4] This finding can be interpreted in several ways. First, with respect to the greater distance between dependent morphemes that German infants have to cope with, our results cast doubt on the generalizability of the assumption put forward first by Newport (1988) and tested by Santelmann and Jusczyk (1998) that a small processing window may initially be advantageous to the language learning child. With respect to the discontinuous dependencies tested in our experiments, a small processing window would have rendered the acquisition of the dependencies more difficult given the input characteristics of German. This was obviously not the case. However, since we did not

[4]It may still be the case, as pointed out by one of the reviewers, that English learning children recognize these dependencies earlier than German learning children, given that the infants in Santelmann and Jusczyk's (1998) study responded to discontinuous dependencies across three syllables, whereas in our experiments the intervening material had a maximal length of two syllables.

systematically vary the distance between the dependent elements in our experiments we cannot determine whether there may be differences in the size of the processing windows of German and English children on the basis of our data. Clearly, future studies are needed to investigate the interaction between possible restrictions on the size of the processing window available to children and specific features of the target language during the process of language acquisition.

Furthermore, the lexical and morphological variability of the elements that constitute the critical dependency relation does not seem to pose a special problem for the German infants in recognizing the relationship, at least for the forms tested. On the basis of our results, we cannot exclude the idea that this relationship is established only for exactly those word forms used in the experimental stimuli, namely the third person form of the auxiliary 'have' *hat* and the regular past participle formed by combining the prefix *ge-* and the suffix *-t* with the verb stem, resulting in the pattern *ge-X-t*. This assumption may be seen in the context of the findings for the English-learning infants who seem to start out with a lexically constrained relation between *is/was–adverb–verb stem-ing* to the exclusion of *are/were–adverb–verb stem –ing* (Tincoff et al., 2000). That is, we cannot assert that German-learning infants have acquired the relation between the auxiliary and the past participle in the cases which differ from the *hat-ge-X-t* pattern, for example:

hat bezahlt 'has paid'
hat gesungen 'has sung'
ist gelaufen 'is run', that is, 'has run'.
ist gehüpft 'is jumped', that is, 'has jumped'

Again, further experiments will be needed to show whether German infants can track the dependencies over different forms of the respective paradigms and over different types of past participle formation, indicating that they have proceeded from the recognition of the formally differing instantiations of the auxiliary–past participle dependency to an abstract, functionally based representation of it.

Another explanation of our results could be that even though the distance between morphemes and the morphological variability in the input could negatively affect the acquisition of the relationship, these negative factors are outweighed by the high variability that German allows with respect to the intervening constituents. In other words, this variability by contrastively highlighting the invariant elements of the discontinuous construction, such as *A-X-B*, helps the infant to determine the structure underlying the verbal dependency relationship. This interpretation would be compatible with the results of Gomez (2002) that increasing the variability of intervening materials had a positive effect on the recognition of nonadjacent relations. Because we have no control over the natural conditions in which the children tested in our experiments have acquired their knowledge on the dependency between the auxiliary and the past participle we can only speculate

that the higher variability of the material that German allows between the dependent elements might outweigh the possible problems caused by the greater distance that is allowed to occur between the dependent elements.

The main finding of our study concerns the fact that the German infants could track the dependency relation if the intervening material was a noun phrase but not when the intervening material consisted of an adverb of the same syllabic length. We suggested that this difference is due to the fact that a structural marker, that is, the determiner, a closed class functional element introducing the noun phrase, helps the children analyze an incoming word string structurally and thereby supports the detection of the discontinuous dependency. This opens the question of what kind and what range of analyzable properties of the input affect the child's processing of the input and allow the recognition of discontinuous dependencies. For example, would any intervening element familiar to the child allow for the recognition of the dependency relation, even if its occurrence would result in an ungrammatical structure? This option seems to be unlikely given the results of Gerken and McIntosh (1993; cf. also Kedar, Casasola, & Lust, 2006; Zangl & Fernald, 2003) with 24-month-old English–learning children, which showed that sentence comprehension was interrupted by familiar but positionally incorrect elements. Nonetheless, it is a possibility that can be explored in future research.

The evidence from Experiment 3 and the findings in Höhle et al. (2004) that indicate that the infants analyze the sequence determiner + noun as a structural unit pose a further interesting question. To what extent have the infants already established a functional relation between the intervening noun phrase and the main verb of the verbal dependency, a functional relationship that may further influence the infants' capacity to track the discontinuous relationship? All the noun phrases used in the third experiment were objects, that is, elements of the subcategorization frame of the past participle main verb. In contrast the relation between a verb and an adverb is in general not constrained by subcategorization conditions. We want to suggest that this subcategorization relationship may further facilitate processing of the discontinuous dependency relation.

In fact there is evidence that infants at about the age tested are sensitive to the verb–complement relation. Hirsh-Pasek and Golinkoff (1996) have shown that 14-month-old English-learning infants analyze *kissing the ball* in *she is kissing the ball* as a unit in which *the ball* functions as the complement of *kissing*. Consequently, we may assume that the 19-month-old German-learning infants in our third experiment may have established a complement–argument relation between the noun phrase and the following verb. If so, then they may be able to process the complement-verb as a complex expression that is now adjacent to the first member of the verbal dependency, that is, the auxiliary: (auxiliary [complement-verb]). This means that the analyzability of the noun phrase leads to the formation of a complement-verb complex, and therefore brings the two elements of the verbal dependency into structural adjacency. This structural adjacency then may, in addi-

tion, facilitate the recognition of the dependency relation between the auxiliary and the past participle. To further investigate this hypothesis, the recognition of the verbal dependency in a structure constituted by an auxiliary and an intransitive verb with an intervening noun phrase that could not be analyzed as a verbal complement should be tested. The prediction would be that in these structures the verbal dependency relation should be harder to recognize than in verb-complement structures.

The option of analyzing the complement-verb relationship as a single constituent in the sentences used in Experiment 3 contrasts with the adverb condition of our first experiment. Even if the children had analyzed the intervening adverbs as belonging to a single class, they may have not been able to establish a relation between the adverb and the following verb, that is, the past participle, given that the relation between an adverb and a verb is not constrained in the same way as the relation between a verb and its complement. That is, an intervening adverb does not necessarily form a syntactic unit with the following verb, and the verb does not subcategorize for the adverb. Consequently the adjacency condition that facilitates the recognition of the dependency between the auxiliary and the past participle may not have been realized by the German-learning children. Thus, analyzability may mean in essence the replacement of a discontinuous dependency by a continuous one.

A proposal similar to ours was recently made by Newport and Aslin (2004). They found that adults' learning of nonadjacent dependencies between syllables with intervening unrelated syllables was very difficult or unsuccessful. In contrast, learning of nonadjacent dependencies between segments—either vowels or consonants—was very easy when the dependency held between one type of segment (e.g., vowels) and the intervening elements consisted in another type of segment (e.g., consonants). Newport and Aslin suggest that the learning of nonadjacent dependencies may be based on some kind of Gestalt principle under which one type of element—in their case either vowels or consonants—are physically more similar to each other and therefore are grouped perceptually together. Drawing on representations from autosegmental phonology, Newport and Aslin assume that the two types of elements involved in the Gestalt effect may be situated on two different levels of representations that makes them *adjacent* on their respective level and thus easier to compute or to be recognized as a pattern of dependent elements and thus to be learned. This means that adjacency is not defined on the surface phonetic string but rather on more abstract structural representations.

Our own results suggest that not only phonological representations but also syntactic representations can provide abstract structural representations that allow nonadjacent elements to be computed as adjacent. If we push this idea further, we may speculate that infants initially recognize discontinuous relations only when they can be reduced to local ones through the analysis of the intervening material, thus falling back on temporal contiguity as one of the universal means spoken lan-

guage has to signal a functional relationship. It would be that when adjacency fails to yield an analyzable pattern that the infant may be forced to expand his or her processing window (cf. Gomez & Gerken, 2000).

To summarize, our findings suggest that already by the age of 19 months, German children assign different structural representations to verb-complement sequences than to verb-adverb sequences. Features of these structural representations seem to affect the children's capacity to process discontinuous dependencies appearing within these structures. This is in line with previous findings on infants' and adults' language processing showing that linguistically structured material is easier to process than unstructured material (e.g., Mandel, Jusczyk, & Kemler Nelson, 1994; Marslen-Wilson & Tyler, 1980). This means that increasing linguistic knowledge may override a purely quantitative metric, for example, based on the number of syllables, for determining the processing space of the language learning child. Thus, in addition to the distance between the dependent elements and the variability of the intervening elements, we propose that the structural analyzability of the intervening material influences the recognition of functional relations between nonadjacent lexical elements. Future research will have to show how these different factors contribute to the acquisition and the processing of discontinuous dependencies and what other features might have an influence on children's recognition of these relations, which are a crucial feature of natural language.

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