

Priming Word Order in Sentence Production

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When producing a sentence, the speaker needs to place words in linear order. We hypothesized the existence of a *linearization* process, which imposes order on a constituent structure. This structure is assumed to be specified with respect to hierarchical relations between constituents but not with respect to word order. We tested this hypothesis in a primed picture description experiment. Speakers of Dutch repeated prime sentences and described target pictures. Word order of prime sentences was manipulated (e.g. “On the table is a ball” vs. “A ball is on the table”). Both alternatives could be used in the description of unrelated target pictures. In support of our hypothesis, word order was “persistent”: Speakers were more likely to use a given word order, when the prime sentence had that same word order. We argue that our results support the notion of a linearization process and reject the alternative explanation that the results should be attributed to persistent selection of a fully specified syntactic frame.

Theories of sentence production—the process by which an intention is translated into an utterance—typically distinguish separate stages of processing (Bock & Levelt, 1994; De Smedt, 1990; Dell, 1986; Garrett, 1975, 1980; Kempen & Hoenkamp, 1987; Levelt, 1989; Pick, 1913). The motivation for these different levels comes mainly from the analysis of speech error corpora (Dell, 1990; Fromkin, 1971; Garrett, 1975; Stemberger, 1982) but, as we will discuss later, also from controlled experiments. One of the processing stages so distinguished is called *grammatical encoding* (Bock & Levelt, 1994; Levelt, 1989). The task of grammatical encoding is to take the conceptual representation of the to-be-uttered sentence and to translate it into an ordered, hierarchical structure containing all constituents and words.

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How is constituent structure constructed? According to Bock and Levelt (1994), basically following Garrett (1975, 1980), grammatical encoding can be divided into two levels, called the functional level and the positional level.¹ The task of functional level processing is to select lexical items that appropriately express conceptual content. These lexical items, called lemmas (cf. Kempen & Huijbers, 1983), are not specified for phonological form, but are abstract units that contain semantic and syntactic information. A further task of functional processing is to assign grammatical functions, such as subject and direct object, to these lemmas. The functional representation drives positional processing, which also has two tasks: The construction of a constituent structure that specifies hierarchical and linear relations between constituents, and determination of inflections. The final structure is highly predictable from the functional representation but not isomorphous to it. The reason for that is that the same kind of functional relations can be expressed with a number of word orders, even in a relatively fixed word-order language such as English. An important job of positional processing is thus to place words in linear order.

According to Kempen and Hoenkamp (1987) and De Smedt (1990) this task is accomplished through a process of *linearization*, which operates on a constituent structure that is not yet specified with respect to word order. These authors constructed computational models of grammatical encoding, which explicitly assume such a linearization process.² In these models, first a constituent structure is constructed, which contains functional relations and hierarchical relations. De Smedt (1990), following Lexical Functional Grammar (e.g. Kaplan & Bresnan, 1982) called this an *f-structure*. A subsequent linearization process imposes word order on that f-structure. An important motivation for postulating a linearization process, is that it allows for *incremental* processing. A speaker does not wait until a sentence is encoded in its entirety before commencing to articulate it (Bock & Levelt, 1994; Von Kleist, 1805). Instead, production is piecemeal: As soon as one processing level has encoded a unit, another level can begin to work on it. Assuming incremental processing, a division of labour between structure building and linearization allows for very efficient processing. This is because a constituent that is constructed early on can be placed in the earliest position possible in the sentence. Placement in an early position allows subsequent phonological and articulatory encoding processes to start working immediately on that part of the sentence. Thus, under-specification of word order during constituent structure building and a subsequent linearization process allow for efficient processing and help to ensure fluent speech.

In this study, we test the hypothesis that there indeed exists such a process of linearization in sentence production. We test that hypothesis in a picture description experiment in which target pictures are preceded by prime sentences of different kinds. We assume that these prime sentences have the same functional and hierarchical relations

¹ Although that model has the same processing levels as Garrett's (1975, 1980) model, there are some important differences. According to Bock and Levelt (1994), lexical representations contain syntactic information, which drives construction of syntactic structure. They also assume incremental production (discussed later).

² These models are certainly in the spirit of the Bock and Levelt (1994) theory and focus on the process of constituent structure building.

between constituents but differ with respect to word order. If our hypothesis is correct, we expect that the linearization process can be primed, so that given a prime sentence with one word order, picture descriptions will more often have the same word order. In the remainder of this section, we will briefly review the existing evidence for the linearization process. Then we will provide a more detailed description of the rationale for our experiments.

Evidence for a Linearization Process

Experimental evidence for a linearization process is scarce. Some indirect evidence was obtained by Vigliocco and Nicol (in press). These authors elicited errors of subject–verb agreement in a constrained production experiment, using a paradigm that Bock and Miller (1991) introduced (see also Bock & Cutting, 1992; Bock & Eberhard, 1993; Eberhard, 1997; Fayol, Largy, & Lemaire, 1994; Vigliocco, Butterworth, & Garrett, 1996; Vigliocco, Butterworth, & Semenza, 1995; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996). In that paradigm, participants are presented with sentence preambles such as (1,2a,2b), containing a subject head noun (“report”) and a modifier of the subject, containing a “local noun” (“fire/ s”).

- (1) The report of the destructive fire
- (2a) The report of the destructive fires
- (2b) The report of the destructive forest fires

Participants had to repeat each preamble and then complete it to a full sentence. This naturally leads to the elicitation of a verb, and the number of wrongly inflected verbs (agreement errors) is the dependent variable. Bock and Miller (1991) showed that the number of agreement errors is highest when a head noun mismatches in number with a local noun (2a–2b). This effect of number mismatch is called an *attraction effect*. Further, Bock and Cutting (1992) showed that long preambles (2b) elicit more agreement errors than do short preambles (2a).

Vigliocco and Nicol (in press) tested the effect of a number-mismatching local noun, in a question formation variant of the subject–verb agreement paradigm. For instance, participants were presented with (3):

- (3) SAFE the flight of the helicopters

In one experiment, participants had to repeat the preamble and complete it, using the adjective. In another experiment, participants had to turn the adjective/preamble pair into a question such as “Was the flight of the helicopters safe?” An attraction effect was obtained in both experiments, even though a relatively large distance separated the verb and the local noun in the question formation version. That finding suggests that agreement is constructed with respect to a representation that is specified with respect to constituency, but not yet with respect to word order. These experiments thus support the notion of a linearization process.

Syntactic Persistence

Given the scarcity of the evidence for a linearization process, it seems desirable to obtain more direct evidence for it. The approach pursued in this study is to test whether the output of linearization—word order—is “persistent”. Is there a tendency to reuse the word order of a previously produced sentence? Persistence effects in grammatical encoding have been observed earlier, especially in the work of Bock and colleagues (Bock, 1986b, 1989; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992), which was followed *inter alia* by Branigan, Pickering, Liversedge, Stewart, and Urbach (1995) and Hartsuiker and Kolk (1998a, 1998b), and has some earlier precursors (Kempen, 1977; Levelt & Kelter, 1982; Tannenbaum & Williams, 1968; Weiner & Labov, 1983). These experiments all demonstrated some forms of repetition effect in speaking: Speakers tend to reuse recently produced words, phrases, or syntactic structures.

Bock et al. (e.g. Bock & Loebell, 1990) showed that participants in a priming experiment tended to reuse the syntactic structure of a prime sentence in a subsequent picture description. Pictures could be described with a sentence having the same structure as the prime sentence but also with a syntactic variant of that structure. The experiments showed that constituent structure is persistent—for example, following the production of prime sentence (4), the incidence of sentences such as (5a) increased, whereas the incidence of sentences such as (5b) decreased.

- (4) The cheerleader offered a seat to her friend.
- (5a) The girl is handing a bone to the dog.
- (5b) The girl is handing the dog a bone.

Such effects were reported with active and passive transitives as well as with prepositional datives (5a) and double-object datives (5b). An example of a typical sequence of events in these experiments is depicted in Figure 1.

Crucially, these effects were obtained in the absence of lexical, thematic, or prosodic correspondences between prime sentence and picture description. For instance, Bock (1989) showed that “to-dative” responses were primed equally well by “to-dative” primes and by “for-dative” primes, thus excluding the possibility that the results are an artifact of lexical priming. Furthermore, Bock and Loebell (1990) showed that priming is not an artifact of persistent thematic role assignment. For instance, a sentence with a locative complement, such as (6), which has the same phrasal configuration as a prepositional dative but different thematic roles, primes the prepositional dative response as well as does the prepositional dative itself.

- (6) The wealthy widow drove her Mercedes to the church.

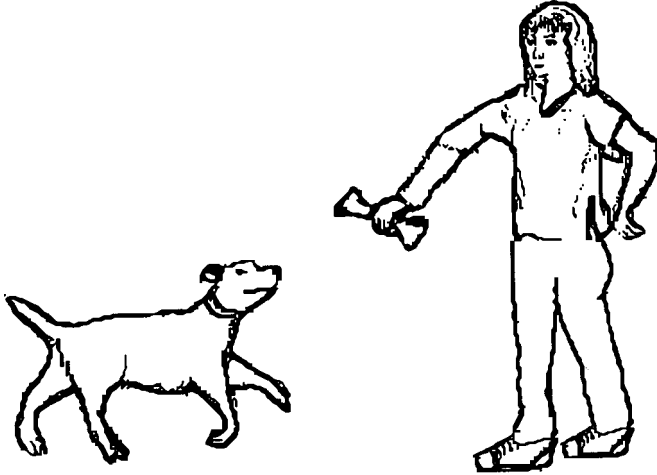
In addition, a locative sentence with a *by*-phrase, having the same phrasal configuration as a passive but different thematic roles, such as (7), primes the passive as strongly as does a passive prime.³

³ Notice, however, that all locative complements were headed by the preposition “by”, thus allowing for an explanation in terms of lexical priming.

1. *Prime sentence is presented and repeated:*

The cheerleader offered a seat to her friend

2. *Picture is presented:*



3. *Picture is described:*

A woman hands a bone to the dog

FIG. 1. Typical sequence of events in a syntactic persistence experiment (e.g. Bock, 1986b; Hartsuiker & Kolk, 1998b). In the experiment reported, each item (sentence or picture) was presented when the participant pushed a button. The item was repeated (if it was a sentence) or described (if it was a picture). After repetition or description, the participant said “yes” or “no” to indicate whether or not the item had occurred earlier in the session.

(7) The minister was praying by the broken stained glass window

Furthermore, a prime sentence with the same prosody and almost the same lexical items as a prepositional dative, but with a different constituent structure (8a) does not facilitate prepositional dative responses, whereas a prepositional dative prime (8b) does.

(8a) Susan brought a book to study.⁴

(8b) Susan brought a book to Stella.

⁴ Notice that in (8a), “to study” is a node of category S, modifying the direct object NP “a book”. In (8b) “to Stella” is an argument of the verb.

In sum, it appears that these persistence effects reflect the construction of constituent structure and cannot be attributed to conceptual, thematic, lexical, or prosodic factors. That makes the paradigm a good candidate for the investigation of a linearization process.

In the present study, we attempt to show syntactic persistence for syntactic alternatives that differ with respect to word order but not with respect to functional and hierarchical relations between constituents. Notice that some syntactic theories do not separate functional/hierarchical relations from linear relations (in these theories, a different word order implies a different structure). However, such a separation remains a plausible possibility, especially if we assume processing models that encode a sentence incrementally (we take up this issue again in the Discussion). If a persistence effect occurs, that would strongly support the hypothesis of a linearization process, because such an effect would not be attributable to other syntactic differences except word order. It is essential to notice that syntactic alternatives tested in earlier experiments (e.g. Bock, 1986b; Bock & Loebell, 1990), such as the transitive active and passive alternatives, differed from each other with respect to functional relations, hierarchical relations between constituents, and word order. In our experiment we kept the first two kinds of relations constant but manipulated word order.

Other Determinants of Word Order

Before we introduce more details about the present experiment we would like to note briefly that word order variation might be determined by many other factors, in addition to the priming effects we hope to establish. Indeed, there is a body of (psycho)linguistic literature on other determinants of word order variation. Some studies have focused on pragmatic factors, such as the “given–new” distinction (Haviland & Clark, 1974). Bock (1977) showed how for a variety of syntactic alternations, speakers had a tendency to preserve the order given–new. Similar results with respect to dative alternation were reported by Collins (1995).

Other studies focused on syntactic factors. For instance, Behagel (1932) observed that longer constituents occur more often at the end of sentences. He called this “law” the “gesetz der wachsenden glieder” (the law of growing constituents). Similar observations were made by Hawkins (1994) with respect to the placement of noun phrases (NPs) (“heavy NP-shift”). Pechmann, Uszkoreit, Engelkamp, and Zerbst (1996) reported evidence for a number of word order rules in certain constructions in German. These authors showed that although many word orders are grammatical in these constructions, some are clearly preferred (e.g. subjects tend to precede objects, and indirect objects tend to precede direct objects). Rösler, Pechmann, Streb, Röder, and Hennighausen (1998) tested the same constructions as Pechmann et al. (1996) and showed that a departure from canonical word order has repercussions for the evoked potentials emitted during on-line processing. We will return to some of these determinants of word order in the Discussion section and relate them to our linearization hypothesis.

Plan of this Study

A syntactic contrast that allows the manipulation we intend is that between two variants of the locative sentence in Dutch. These variants consist of a subject NP, a locative verb and a prepositional phrase (PP). The PP is placed in either a sentence-final position, as in (9)

or a sentence-initial position, as in (10). The syntactic structures of these sentences are shown in Figure 2.⁵

(9) Een boek ligt op de plank.
[*A book lies on the shelf.*]

(10) Op de plank ligt een boek.
[*On the shelf lies a book.*]

The construction illustrated in (9) is called the Locative State sentence (Bloom & LaHey, 1978). We dub the construction in (10) the Frontal Locative. In the remainder of this paper we will abbreviate these constructions as LS (Locative State) and FL (Frontal Locative).

Before conducting the experiment, we required 40 participants to describe experimental pictures and to supply acceptability ratings for prime sentences. None of these subjects participated in the main experiment. From the pretest it became clear that the LS is highly dominant: Few or none FLs were produced. It also became clear that one important condition of usage for the non-canonical form—the FL—is the definiteness of the elements fulfilling the thematic roles of theme and location. In particular, we observed an increase in the incidence of FLs when the prepositional object was definite (“the shelf”) and the subject was indefinite (“a book”) as in (9–10). A similar pattern of results emanated from the collection of acceptability judgments: When the distribution of definiteness was as stated previously, FLs were judged as more acceptable than they were with any of the other possible distributions. In addition, with that specific distribution FL and LS sentences were judged as equally acceptable. Thus, in order to ensure a fair number of FL responses in our experiment, we requested participants to use the distribution of definiteness as outlined above (see Method section for details).

We used the primed sentence production task developed by Bock (1986b) and exemplified in Figure 1. We presented three types of prime sentences: LS primes, FL primes, and, furthermore, “baseline” primes. The rationale for having a baseline is to obtain a frequency measure of the target structures in the absence of syntactic priming. A baseline can then help to discern more precisely the nature of the differences between the experimental conditions.

⁵ Notice that the syntactic trees depicted in Figure 2 do not conform to government and binding theory. Technically speaking, in that case both trees would have been derived, by move- α , from an underlying structure with the word order “*een boek-op de plank-liggen*”, and in which V is moved to C’ (projection of complementizer), and either the NP or the PP is moved to CP (complementizer phrase). However, with Bock, Loebell, & Morey (1992) we assume a non-transformational approach to formulating. The first reason is that Bock et al. provided evidence against the psychological reality of D-structure subjects and objects. The second is the non-locality of transformations: It would often require the construction of large portions of syntactic trees, and this seems to violate the principle of incrementality (De Smedt, 1990; Kempen & Hoenkamp, 1987; Levelt, 1989; Von Kleist, 1805).

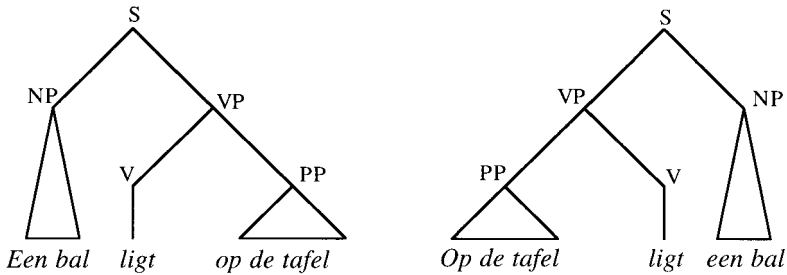


FIG. 2. Syntactic structure of the Locative State (LS) sentence "Een bal ligt op de tafel" (A ball lies on the table) and its Frontal Locative (FL) alternative. S = sentence; VP = verb phrase; NP = noun phrase; PP = prepositional phrase; V = verb.

Method

Participants

Eighty-four undergraduate students of the University of Nijmegen participated. All were native speakers of Dutch. Six participants were excluded, because they reported to have a native language other than Dutch, six reported to have a history of speech or language problems, or did not perform the task correctly (e.g. did not produce full sentences as picture descriptions). These participants were replaced by six new participants. They were paid Dfl 7.50 or obtained course credits.

Materials and Design

Experimental materials consisted of 12 prime sentence sets and 12 target pictures. Each sentence set contained three sentences: LS and FL alternatives of the same sentence and a baseline sentence. The baseline sentences were all "wh"-questions, which had a structure that was not feasible for subsequent reuse in picture description. Each sentence set was paired to a single picture. A complete list of experimental materials is provided in the Appendix.

Each picture had been shown to elicit a fair number of LS and FL responses in pretests. All of the picture material depicted a scene with a location and a theme. Next to each element, a two-word label was printed. Labels were simple noun phrases. Noun phrases next to locations contained an indefinite determiner ("een", "a"); Noun phrases next to themes contained a definite determiner ("de" or "het", "the").⁶ The set of pictures was completely balanced with respect to left/right position of theme and location. An example of an experimental picture is provided in Figure 3.

All pictures were available on computer disk. They were edited for clarity if necessary, and picture elements were provided with labels using an image enhancement software package. All sentences were recorded on analogue audio tape. They were digitized and stored on computer hard disk.

There were also filler items: 24 filler pictures and 24 filler sentences, which each occurred twice in the experiment. Filler pictures had all been shown to elicit intransitive responses in earlier experiments. All picture elements were labelled with noun phrases. There were 18 pictures with only one picture label. Of those 18, the determiner was definite in 9 cases, and indefinite in the remaining 9. Of the 6 pictures with 2 picture elements, 3 had 2 definite or 2 indefinite determiners, and 3 had 1 definite and 1 indefinite element. Filler sentences comprised a range of constructions, including

⁶ The gender system in Dutch is basically restricted to a distinction between neuter and non-neuter. The definite determiner "de" precedes non-neuter nouns, whereas "het" precedes neuter nouns.

de tafel (the table)

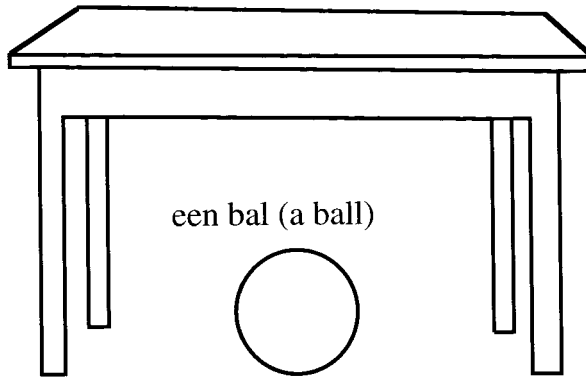


FIG. 3. Example of target picture in the present experiment.

“wh”-questions, imperatives, intransitives, and transitives with preposed objects. Furthermore, there were 10 practice sentences and pictures.

Three 120-item lists were constructed, so that in each list there was an equal number of pictures (four) in each condition of the prime factor, and so that across the lists, each picture occurred once in each condition. The lists were built up in a quasi-random fashion with the following constraints: (1) Each list started with eight fillers, followed by an experimental trial (prime and picture), followed again by eight fillers, and so on; (2) The first four experimental trials were all baseline trials; (3) There were never more than three pictures or sentences in a row. Each participant was presented with one of the three lists, and each list was presented to 28 participants. Participants were each presented with 12 locative pictures, and prime type was a within-subject factor with three levels: FL, LS, and baseline (BA).

Procedure

Participants were tested in individual sessions, lasting approximately 20 min. The procedure was similar to that depicted in Figure 1. The participants received written instructions, in which the task was explained to them as a memory task. They were instructed to repeat the sentences and describe the pictures. Following each response, they had to indicate with “yes” or “no” whether they had heard or seen the item before. The task was self-paced: Participants initiated each trial by pressing a button. Sentences were presented from computer hard disk, using a single speaker. During sentence presentation, the Dutch equivalent of “LISTEN” appeared on the screen. Following sentence presentation, the equivalent of “REPEAT” appeared.

The instruction emphasized that pictures had to be described with a single, grammatically correct Dutch sentence, containing the labels that were provided next to the picture elements. Before the actual experiment started, participants were presented with 10 practice items. The experimenter corrected any inadequate responses (incomplete sentences, wrong determiners, etc.) during practice but not during the actual experiment. The experimental sessions were recorded on audio cassette.

Scoring

The audio cassettes containing the session were transcribed. Descriptions of experimental pictures were scored for syntactic structures. Responses were divided into one of the following three categories: Locative State (LS), Frontal Locative (FL), and Other (OT). An utterance was scored as LS if the sentence started with a subject noun phrase (NP) incorporating the theme, followed by a locative verb, which was followed by a prepositional phrase (PP) incorporating the location. An utterance was scored as FL if it started with a PP incorporating the location, followed by the locative verb, followed by the subject NP. A sentence was only scored as FL or LS if an alternative in the other form was syntactically correct. The rationale for requiring the possibility of having both alternatives is that we can only assess an effect of priming when it is at least possible to produce both target structures. All responses not adhering to the criteria for LS or FL were scored as OT. These were mainly sentences containing extra modifiers such as past participles or infinitives—for example, sentences (11–12), and responses that had starter phrases such as “there is”.

- (11) Een pleister zit op de voet geplakt
(A plaster sits on the foot stuck)
[*A plaster is stuck on the foot*]
- (12) Aan de waslijn hangt een was te drogen
(On the laundry-line hangs a laundry to dry)
[*Laundry is drying on the laundry-line*]

Results

Scoring according to our criteria yielded a total of 1008 responses. There were 765 LS responses (75.9%), 160 FL responses (15.9%), and 83 OT responses (8.2%). Of the OT responses, 34.9% occurred in the BA condition, 27.7% in the LS condition, and 37.3% in the FL condition. The numbers of LS, FS, and OT responses in each prime condition are listed in Table 1.

The pattern of results listed in the table shows that there is syntactic persistence for the two tested locative alternatives in Dutch. The frequency of FL responses is highest in the condition with FL primes, followed by the condition with LS primes, followed by the BA condition. The frequency of LS responses is higher in the LS condition than in the FL condition, but, interestingly, the frequency is highest in the BA condition. Finally, the frequency of OT responses is approximately equal in all conditions.

The data were analysed with a repeated-measures two-factor analysis of variance (ANOVA), with prime type as a three-level within-subject factor (LS, FL, BA) and response type as a two-level within-subject factor (LS, FL). We conducted two ANOVAs, one with subjects as a random factor (F_1) and one with items as a random factor (F_2). We used Greenhouse-Geisser/Box's ϵ to adjust for any violations of the sphericity assumption, as recommended by Maxwell and Delaney (1990).

The OT responses were excluded, in order to prevent linear dependence (the sum of LS, FL, and OT responses is constant in each prime condition). If, however, there is an effect of prime type on the distribution of OT responses, then such an effect should be reflected in the present data as a main effect of prime type. This is because the sum of FL and LS responses have a complementary distribution to OT responses. Word order

TABLE 1
Frequencies of Occurrence of Each Type of
Response in the Prime Conditions

Prime	Type of Response					
	LS		FL		OT	
	N	%	N	%	N	%
LS	260	77	53	16	23	7
FL	230	68	75	22	31	9
BA	275	82	32	10	29	9

Note: Total number is 336 in each condition. LS stands for "locative state", FL for "frontal locative", BA for "baseline", and OT for "other".

priming should be reflected in this design as a significant interaction between response type and prime type. Finally, we determined interaction contrasts, which compared (1) the difference between the number of LS responses and the number of FL responses in the baseline prime condition with those in the mean of the two experimental conditions; (2) the difference between the number of LS responses and the number of FL responses in the FL condition with that in the LS condition.

There was no main effect of prime type, $F_1(2, 166) = 0.69; p = .499; F_2(2, 22) = 0.65; p = .497$. Thus, there were no significant differences in the total numbers of analysable responses in each prime condition. The effect of response type, however, was highly significant, $F_1(1, 83) = 255.13; p < .0005; F_2(1, 11) = 55.91; p < .0005$. This main effect should not be surprising, as there were many more LS responses than there were FL responses. Most important, there was a significant interaction between prime type and response type, $F_1(2, 166) = 11.13; p < .0005; F_2(2, 22) = 20.49; p < .0005$. Thus, in line with our hypothesis of word order priming, prime type has a significant effect on the way responses are distributed. The two interaction contrasts allowed us to specify that effect further. The first contrast compared the difference between LS and FL responses in the baseline with those in the experimental conditions. This contrast was significant, $F_1(1, 83) = 16.71; p < .0005; F_2(1, 11) = 16.80; p < .0025$. The second contrast compared the difference between the two response types in each experimental condition (FL and LS). This contrast was also significant, $F_1(1, 83) = 6.82; p = .011; F_2(1, 11) = 35.08; p < .0005$. The interpretation of these two contrasts is as follows. The first contrast shows that there are fewer FL responses and more LS responses in the baseline than in the experimental conditions. The second contrast shows that there are more FL responses and fewer LS responses in the FL condition than in the LS condition, and thus that there is significant word order priming.

Finally, we noticed that the syntactic structure used to describe target pictures was influenced by position of picture elements as well as by structure of prime sentence (cf. Flores d'Arcais, 1975). In fact, if the data are split according to this variable, a strong position effect on the total number of FL responses appears (124 when location is on the

left, 36 when location is on the right). However, in both of these item sets (each containing 50% of the materials), responses of each type were most frequent following a prime of the same type.

Discussion

Our experiment shows that there is priming for word order in locative sentences in Dutch. When a prime sentence is followed with an initial prepositional phrase, one is more likely to use the same structure in a subsequent picture description than when a prime sentence is followed with a final prepositional phrase. The latter type of sentence is more frequent when preceded by a prime of that type. The fact that the alternatives serving as prime sentences differed with respect to word order but were the same with respect to functional relations and hierarchical relations between constituents is evidence for persistence of the constituent structure linearization process.

There are two characteristics of our data that merit further elaboration. Following discussion of these characteristics, we will turn to the implications of our findings for theories of grammatical encoding. In particular, we will consider an alternative interpretation of our results. This interpretation entails the provision of evidence for persistence of constituent structure selection and the requirement that these constituent structures are specified for word order as well as for hierarchical relations between constituents. We will argue that such an interpretation runs into trouble because of the *overspecification* of the functional representation with respect to constituency. We will conclude by proposing some additional principles that guide linearization.

Long-term Priming

The first finding that merits discussion is the following. The interaction contrast, comparing the difference in the number of LS responses and FL responses in baseline and experimental conditions, was significant. In fact, there were more LS utterances (and fewer FLs) in the baseline condition than in the mean of the two experimental conditions. Why was this so? We believe that the same explanation holds as the one suggested in Hartsuiker and Kolk (1998b). In the three experiments with active and passive transitives reported there, there was a consistent finding: The number of target utterances (actives and passives) was much lower in the baseline condition than in either of the experimental conditions.

Hartsuiker and Kolk (1998b) accounted for this by assuming that in addition to short-term syntactic priming (from one prime sentence to one target picture) there is also a long-term priming effect. Repeated exposure to several priming trials with a given structure increases availability of that structure. In terms of a spreading activation model of sentence production (e.g. Dell, 1986, 1988), this increased availability can be regarded as an increase in the resting level of activation. The higher the resting level, the lower the activation that needs to be added to surpass a selection threshold. In other words, producing a prime sentence results in an increase in the activation level of the particular mental representation. That may increase the probability of producing a description with the same structure on a subsequent picture description (short-term priming). In addition,

with each priming trial there is an increase in the resting level of the relevant representation (long-term priming). Because the baseline trials were always the first trials in the experiment, they were not influenced by long-term priming.

We believe that the present result with the baseline condition can be accounted for in a similar way: In principle the locative state response is highly dominant. This is reflected by the baseline data, collected in the first four trials of the experiment. In fact, the incidence of the locative state has reached a ceiling. Long-term priming can no longer increase the availability of that structure. However, long-term priming does increase the resting level of the representation for the FL. This increases the likelihood of that structure being produced on any experimental trial and especially on trials with an FL prime. Because the overall likelihood of an FL increases, the overall likelihood of an LS decreases.

Effects of Position

We now turn to another important feature of the data: The pictures with the location on the left elicited more than three times as many FL responses as did pictures with locations on the right. Notice that FLs begin with a prepositional phrase incorporating the location. This points to left-to-right processing in either scanning the picture or reading the labels next to the picture elements. Order of mention would then, to a strong degree, be determined by the relative accessibility of the concepts to be uttered. Bock (1982) argued that variables such as (lexical) accessibility codetermine syntactic structure. Moreover, evidence for effects of lexical and conceptual accessibility was found, *inter alia*, by Bock (1977, 1986a). A counterexample is a study by Levelt and Maassen (1981), who found no effect of conceptual accessibility in the production of noun phrase conjunctions. However, it is argued by Levelt (1989) that this experiment probably tested phonological accessibility, not conceptual accessibility.

Therefore, it seems safe to assume that order of mentioning concepts is indeed determined by their accessibility. The question arises at what level of processing such conceptual accessibility effects occur. McDonald, Bock, and Kelly (1993) proposed that it is the assignment of grammatical functions that is sensitive to conceptual features. There is a tendency, for instance, to assign the role of grammatical function to animate entities. Because grammatical subjects tend to occur in the beginning of sentences, speakers prefer to start sentences with animate entities. On the other hand, quite consistent with the line of reasoning in the present experiment, Prat-Sala, Branigan, Pickering, and Shillcock (1996) provided tentative evidence for a tendency to begin utterances with animate entities, regardless of subject, in languages that allow more freedom of word order than English (e.g. Catalan and Spanish).

Effects of conceptual accessibility on word order follow in a straightforward manner from our hypothesis of a linearization process. The tendency to begin with conceptually more accessible elements would be explained as follows. Because the lemmas of the conceptually more accessible elements are retrieved earlier, assignment of grammatical functions to these lemmas has a temporal advantage. Therefore, construction of the local syntactic environment around those lemmas has a high probability of being completed earlier. Because of that, the linearization process begins earliest with these elements and places them in an initial position in the sentence.

It should be noted that similar explanations, referring to the time course of incremental sentence production, can also account for the phenomenon of “heavy-NP shift” (Haanstra, 1995; Hawkins, 1994; Stallings, MacDonald, & O’Seaghda, 1995). Speakers have the tendency to place a long complex NP in a final position in the sentence (see also Behagel, 1932). That may be accounted for by assuming that it takes longer to construct the phrase structure of a long, complex NP than that of remaining constituents. Because these remaining constituents thus have a temporal advantage, they are placed in a position farther to the left.

An Alternative Interpretation

We now turn to an alternative interpretation of the present results. Instead of persistence of a linearization process, the results could be taken as evidence for persistence of a hierarchy of phrasal nodes, which is fully specified for constituent order. One way in which positional processing could construct an ordered, hierarchical frame is by selecting it in one go. Indeed, the priming experiments reported by Bock and colleagues (Bock, 1986b, 1989; Bock & Loebell, 1990; Bock et al., 1992) seem to imply that selection of a constituent structure can be primed. Further, as mentioned in the Introduction, there are syntactic theories that consider word order variations really to be structure variations.

However, persistence of constituent structure assembly is only possible to the extent that there is a choice between alternative syntactic frames. In other words, priming that level is only possible as long as the syntactic frame is not predetermined by functional level processing. Unfortunately, Bock and Levelt’s (1994) theory seems to imply that constituent structure is largely determined by functional relations: The functional level representation is overspecified, leading to a highly predictable syntactic structure. Consider the description of an event like a man hitting a child. If during functional processing, the role of subject is assigned to “child” and the role of by-phrase object to “man”, that scene will only be described in the passive voice. As functional integration precedes constituent assembly, and as, furthermore, the theory assumes a feedforward flow of information only, there is no obvious way how, once a commitment has been made to functional relations (restricting the utterance to be, for instance, a passive), an alternative structure (an active) can be produced, even though that alternative structure may have been primed.

There is a similar situation in the case of priming of datives. Once functional integration has determined the subject, direct object, and prepositional object, the resulting phrase structure is restricted to a prepositional dative, regardless of any advantage given to a different phrase structure by priming. In sum, it seems untenable to ascribe the priming effects in the present experiment to reuse of a constituent structure specified for hierarchical relations as well as word order. Instead, we ascribe the effect to persistence of linearization.

If constituent structure priming is unlikely, what about the other syntactic persistence effects reported in the literature? Consider the results of Bock et al. (1992). These authors reported an experiment that provides evidence for a distinction between conceptual and syntactic effects on construction of constituent structure. In a syntactic persistence experiment with active and passive transitives, they showed additive effects of constituent

structure on the one hand, and a conceptual feature (i.e. animacy) of subject and object on the other hand. The effect of animacy was such that, if a prime sentence had an animate subject and an inanimate object, there was a tendency to repeat that assignment in a picture description. According to Bock et al., this tendency to repeat the assignment of animacy to subject and object results from functional processing, and the tendency to repeat syntactic structure results from positional processing. However, they admit that there is another possibility: that the animacy effects occur at an earlier level (that of conceptualizing) and that priming of constituent structure is located at the stage of functional integration. That would solve the problem of overspecification to which we have alluded: Priming cannot take place at the level of constituent structure building, because that process is predetermined by functional integration. A more likely locus for priming effects is the process of functional integration itself.

There are two objections that one can raise against this latter hypothesis. First, it might be argued that a similar problem of overspecification applies to the conceptual representation, which serves as input for functional integration. We do not think that this is the case. The reason is that in order for the speaker and listener to know the communality of different constructions that express the same state of affairs, there must be a processing level at which these different constructions share a common representation. With Bock et al. (1992) we assume that this communality lies in the conceptual representation. Therefore, a single conceptual representation can be expressed with different kinds of constituent structure. This is not to say that we deny the role of a semantic/pragmatic component in the decision to produce, for instance, a passive and not an active. However, we conceive of these higher level cues as “gentle forces”: They may bias the system in one direction or another, but they do not predetermine the outcome. In other words, it seems plausible that the conceptual representation is underspecified with respect to eventual syntactic structure. On the other hand, the functional representation is overspecified with respect to syntactic structure.

Second, another possible objection to the localization of structural priming effects at the level of functional integration follows from the results of Bock and Loebell (1990), mentioned in the Introduction: A locative such as (6), repeated here, primes a prepositional dative, even though thematic role assignment is different (the last noun phrase has the role of recipient in a dative and the role of location in a locative).

(6) The wealthy widow drove her Mercedes to the church

If structure priming is localized at the functional level, why is a priming effect obtained with locatives such as (6)? As mentioned in Footnote 3, it is possible that these results can be accounted for in terms of lexical priming. Furthermore, it is important to distinguish thematic role assignment from functional relation assignment. It may be the case that thematic roles are important for functional integration, and that locatives and datives differ with respect to this aspect of functional integration. However, that does not preclude the possibility that datives and locatives share other aspects of functional integration that are more important for the occurrence of a priming effect. For instance, if we assume, with Bock et al. (1992, p. 166), that functional assignment involves subcategorization properties of the selected verb form, then both locative and dative verbs would specify

the need to assign a function like “object of prepositional phrase”. Thus, the shared subcategorization properties may well be the representation that is primed.

Conclusion

In sum, the syntactic persistence experiments reported in the literature may be taken to show priming of function assignment. Moreover, the alternative interpretation that constituent structure is primed runs into trouble because the functional representation is overspecified with respect to constituent structure. On the other hand, constituent structure as we envisage it is underspecified with respect to word order. Therefore, the results of the present experiment can best be taken to show priming of constituent structure linearization. This conclusion is also supported by the effect of position, mentioned before: Because picture elements on the left side of the picture are available earlier, their linguistic encoding is available sooner to the linearization process. Therefore, they are placed in an earlier linear position and hence are articulated earlier.

Given our conclusion—that constituent structure is underspecified with respect to linear order—the process of linearization seems a good candidate for the explanation of a number of effects. For instance, although a language may have free word order, some word orders are more canonical than others (see also Pechmann et al., 1996). Therefore, it is likely that in a language with predominantly the word order subject–verb–object (SVO-language) there is a bias to place grammatical subjects in first position. Such a bias could be implemented during linearization. Furthermore, an “instruction to topicalize” (De Smedt, 1990) or the instruction to form a question (Vigliocco & Nicol, in press) may be implemented at that stage. If linearization then is conceived as an interplay of “gentle forces”, such as accessibility, canonicity of word order, pragmatic constraints, and the need to ensure fluency of speech, it seems a likely candidate indeed for a process that is sensitive to priming.

REFERENCES

- Behagel, O. (1932). *Deutsche Syntax: Band IV. Wortstellung, Periodenbau* [German syntax: Part IV. Word order. Sentence structure]. Heidelberg: Winters.
- Bloom, L., & Lahey, M. (1978). *Language development and language disorders*. New York: John Wiley & Sons.
- Bock, J.K. (1977). The effect of pragmatic presupposition on syntactic structure in question answering. *Journal of Verbal Learning and Verbal Behavior*, *16*, 723–734.
- Bock, J.K. (1982). Toward a cognitive psychology of syntax: information processing contributions to sentence formulation. *Psychological Review*, *89*, 1–47.
- Bock, J.K. (1986a). Meaning, sound, and syntax: Lexical priming in sentence production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*, 575–586.
- Bock, J.K. (1986b). Syntactic persistence in language production. *Cognitive Psychology*, *18*, 355–387.
- Bock, J.K. (1989). Closed-class immanence in sentence production. *Cognition*, *31*, 163–186.
- Bock, J.K., & Cutting, J.C. (1992). Regulating mental energy: Performance units in language production. *Journal of Memory and Language*, *31*, 99–127.
- Bock, J.K., & Eberhard, K.M. (1993). Meaning sound and syntax in English number agreement. *Language and Cognitive Processes*, *8*, 57–99.

- Bock, J.K., & Levelt, W.J. (1994). Language production. Grammatical encoding. In M.A. Gernsbacher (Ed.), *Handbook of Psycholinguistics* (pp. 945–984). San Diego: Academic Press.
- Bock, J.K., & Loebell, H. (1990). Framing sentences. *Cognition*, 35, 1–39.
- Bock, J.K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological Review*, 99, 150–171.
- Bock, J.K., & Miller, C.A. (1991). Broken agreement. *Cognitive Psychology*, 23, 45–93.
- Branigan, H.P., Pickering, M.J., Liversedge, S.P., Stewart, A.J., & Urbach, T.P. (1995). Syntactic priming: Investigating the mental representation of language. *Journal of Psycholinguistic Research*, 24, 489–506.
- Collins, P. (1995). The indirect object construction in English: An informational approach. *Linguistics*, 33, 35–49.
- De Smedt, K.J. (1990). IPF: An incremental parallel formulator. In R. Dale, C. Mellish, & M. Zock (Eds.), *Current research in natural language generation* (pp. 167–192). London: Academic Press.
- Dell, G.S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review*, 93, 283–321.
- Dell, G.S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist model. *Journal of Memory and Language*, 27, 124–142.
- Dell, G.S. (1990). Effects of frequency and vocabulary type on phonological speech errors. *Language and Cognitive Processes*, 5, 313–349.
- Eberhard, K.M. (1997). The marked effect of number on subject–verb agreement. *Journal of Memory and Language*, 36, 147–164.
- Fayol, M., Largy, P., & Lemaire, P. (1994). When cognitive overload enhances subject–verb agreement errors. A study in French written language. *Quarterly Journal of Experimental Psychology*, 47, 437–464.
- Flores D'Arcais, G.B. (1975). Some perceptual determinants of sentence construction. In G.B. Flores D'Arcais (Ed.), *Studies in perception: Festschrift for Fabio Metelli* (pp. 344–373). Milano: Aldo Martello-Giunti Editore.
- Fromkin, V.A. (1971). The non-anomalous nature of anomalous utterances. *Language*, 47, 27–52. (Reprinted in *Speech errors as linguistic evidence*, pp. 215–242, by V.A. Fromkin (Ed.), 1973, The Hague: Mouton)
- Garrett, M.F. (1975). The analysis of sentence production. In G.H. Bower (Ed.), *The psychology of learning and motivation* (pp. 133–177). New York: Academic Press.
- Garrett, M.F. (1980). Levels of processing in sentence production. In B. Butterworth (Ed.), *Language production, Volume 1: Speech and talk* (pp. 177–220). London: Academic Press.
- Haanstra, J.-A. (1995, December). *Heaviness influences in the processing of sentences with a coordination*. Poster presented at the First Conference on Architectures and Mechanisms of Language Processing, Edinburgh, 1995.
- Hartsuiker, R.J., & Kolk, H.H.J. (1998a). Syntactic facilitation in agrammatical sentence production. *Brain and Language*, 221–254.
- Hartsuiker, R.J., & Kolk, H.H.J. (1998b). Syntactic persistence in Dutch. *Language and Speech*, 143–184.
- Haviland, S.B.E., & Clark, H.H. (1974). What's new? Acquiring new information as a process in comprehension. *Journal of Verbal Learning and Verbal Behavior*, 13, 512–521.
- Hawkins, J.A. (1994). *A performance theory of order and constituency*. Cambridge, MA: Cambridge University Press.
- Kaplan, R., & Bresnan, J. (1982). Lexical-functional grammar: A formal system for grammatical representation. In J. Bresnan (Ed.), *The mental representation of grammatical relations*. Cambridge, MA: MIT Press.
- Kempen, G. (1977). Conceptualizing and formulating in sentence production. In S. Rosenbaum (Ed.), *Sentence production: Developments in research and theory*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.
- Kempen, G., & Hoenkamp, E. (1987). An incremental procedural grammar for sentence formulation. *Cognitive Science*, 11, 201–258.
- Kempen, G., & Huijbers, P. (1983). The lexicalization process in sentence production and naming: Indirect election of words. *Cognition*, 14, 185–209.

- Levelt, W.J.M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.
- Levelt, W.J.M., & Kelter, S. (1982). Surface form and memory in question answering. *Cognitive Psychology*, 14, 78–106.
- Levelt, W.J.M., & Maassen, B. (1981). Lexical search and order of mention in sentence production. In W. Klein & W.J.M. Levelt (Eds.), *Crossing the boundaries in linguistics. Studies presented to Manfred Bierwisch* (pp. 221–252). Dordrecht: Reidel.
- Maxwell, S.E., & Delaney, H.D. (1990). *Designing experiments and analyzing data: A model comparison perspective*. Pacific Grove, Ca: Brooks/ Cole.
- McDonald, J.L., Bock, J.K., & Kelly, M.H. (1993). Word and world order: semantic, phonological, and metrical determinants of serial position. *Cognitive Psychology*, 25, 188–230.
- Pechmann, T., Uszkoreit, H., Engelkamp, J., & Zerbst, D. (1996). Wortstellung im deutschen Mittelfeld. Linguistische Theorie und psycholinguistische Evidenz [Word order in the German middle field. Linguistic theory and psycholinguistic evidence]. In C. Habel, S. Kanngiesser, & G. Rickheit (Eds.), *Perspektiven der kognitiven Linguistik. Modelle und Methoden [Perspectives of cognitive linguistics. Models and methods]*. Opladen: Westdeutscher Verlag.
- Pick, A. (1913). *Die agrammatischen Sprachstörungen*. Berlin: Springer.
- Prat-Sala, M., Branigan, H.P., Pickering, M.J., Shillcock, R.C. (1996). Is word order influenced by conceptual accessibility? Poster presented at the 9th CUNY Conference on Sentence Processing, New York.
- Rösler, F., Pechmann, T., Streb, J., Röder, B., & Hennighausen, E. (1998). Parsing of sentences in a language with varying word order: Word-by-word variation of processing demands are revealed by event-related brain potentials. *Journal of Memory and Language*, 38, 150–176.
- Stallings, L.M., MacDonald, M.C., & O'Seaghda, P.G. (1995, March). Phrase order constraints in heavy-NP shift. Poster presented at the eighth annual CUNY Conference on Sentence Processing, Tucson.
- Stemberger, J.P. (1982). Syntactic errors in speech. *Journal of Psycholinguistic Research*, 11, 313–345.
- Tannenbaum, P.H., & Williams, F. (1968). Generation of active and passive sentences as a function of subject or object focus. *Journal of Verbal Learning and Verbal Behavior*, 7, 246–250.
- Vigliocco, G., & Nicol, J. (in press). Separating hierarchical relations and word order in language production. Is proximity concord syntactic or linear? *Cognition*.
- Vigliocco, G., Butterworth, B., & Garrett, M.F. (1996). Subject–verb agreement in Spanish and English: Differences in the role of conceptual constraints. *Cognition*, 61, 261–298.
- Vigliocco, G., Butterworth, B., & Semenza, C. (1995). Constructing subject–verb agreement in speech: The role of semantic and morphological factors. *Journal of Memory and Language*, 34, 186–215.
- Vigliocco, G., Hartsuiker, R.J., Jarema, G., & Kolk, H.H.J. (1996). One or more labels on the bottles? Notional concord in Dutch and French. *Language and Cognitive Processes*, 11, 407–442.
- Von Kleist, H. (1805). Über die allmähliche Verfertigung der Gedanken beim Reden [On the progressive elaboration of thought while speaking]. In H. Sembdner (Ed.), *Sämtliche Werke und Briefe*. Darmstadt: Wissenschaftliche Buchgesellschaft.
- Weiner, E.J., & Labov, W. (1983). Constraints on the agentless passive. *Journal of Linguistics*, 19, 29–58.

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APPENDIX: Experimental Sentence Sets and Pictures

- | | | | |
|---|--|---|---|
| <p>1. Een doek ligt op het aanrecht
Welke flessen kan ik meenemen?
<i>Een hond zit naast het hok</i></p> | <p>(a cloth lies on the sink)
(which bottles can I take?)
<i>[a dog sits besides the kennel]</i></p> | <p>7. Een kunstwerk hangt aan de muur
Waarom staan die mensen daar?
<i>Een kop en schotel staat op de tafel</i></p> | <p>(a work of art hangs on the wall)
(why stand those people there?)
<i>(a cup and saucer stand on the table)</i></p> |
| <p>2. Een bal ligt onder de auto
Waar kun je die planten kopen?
<i>Een schilderij staat op de tafel</i></p> | <p>(a ball lies under the car)
(where can you those plants buy?)
<i>[a painting stands on the table]</i></p> | <p>8. Een kwast ligt op de verfpot
Waarom doe jij zo vervelend?
<i>Een poes zit onder de tafel</i></p> | <p>(a bush lies on the paint pot)
(why do you so annoying?)
<i>(a cat sits under the table)</i></p> |
| <p>3. Een beker staat op het dienblad
Wat is de reden van zijn bezoek?
<i>Een was hangt aan de waslijn</i></p> | <p>(a cup stands on the tray)
(what is the reason of his visit?)
<i>[a laundry hangs on the laundry line]</i></p> | <p>9. Een kussen ligt op de bank
Welke oen heeft dat gedaan?
<i>Een boom staat voor de kerk</i></p> | <p>(a pillow lies on the couch)
(which fool has that done?)
<i>(a tree stands before the church)</i></p> |
| <p>4. Een knikker ligt onder de kast
Wie is die man?

<i>Een tuinslang ligt op de boomstronk</i></p> | <p>(a marble lies under the cupboard)
(who is that man?)

<i>[a garden hose lies on the tree stump]</i></p> | <p>10. Een struik staat naast de deur
Wie kan er vandaag nog komen helpen?
<i>Een hond zit in het hok</i></p> | <p>(a bush stands besides the door)
(who can there today yet come help?)
<i>(a dog sits in the kennel)</i></p> |
| <p>5. Een lamp hangt boven de tafel
Waar is de vergadering?
<i>Een boek staat op de plank</i></p> | <p>(a lamp hangs above the table)
(where is the meeting?)
<i>[a book stands on the shelf]</i></p> | <p>11. Een fiets staat tegen de muur
Waarop is dit gebaseerd?
<i>Een bal ligt onder de tafel</i></p> | <p>(a bicycle stands against the wall)
(what on is this based?)
<i>(a ball lies under the table)</i></p> |
| <p>6. Een handdoek ligt in de wasmand
Waarbij vind je deze kleur passen?
<i>Een pleister zit op de voet</i></p> | <p>(a towel lies in the laundry-basket)
(where by find you this colour fit?)
<i>[a plaster sits on the foot]</i></p> | <p>12. Een dweil ligt op de grond
Wie gaat er mee?
<i>Een appel ligt in de kom</i></p> | <p>(a floor cloth lies on the floor)
(who goes there along?)
<i>(an apple lies in the bowl)</i></p> |

Note: prime sentence in the LS-form, baseline sentence, and LS-target picture description in italics. Sentences are followed by word-by-word literal English translation. Translations of compound “wh”-words, e.g. “waarop”, meaning “on what”, are provided morpheme-by-morpheme—that is, “what on”.