# Gesture Structure Affects Syntactic Structure in Speech

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## Abstract

Different functions have been proposed for the hand gestures speakers spontaneously produce while speaking. The Information Packaging Hypothesis (Kita, 2000) states that gestures can structure rich spatio-motoric information into packages suitable for speaking. It therefore predicts that how information is divided over different gestures affects how it is divided over different processing units in speech: clauses. We indeed found that if participants were asked to express the manner and path of a motion in one gesture, they were also more likely to conflate this information into one clause in speech, whereas if they were asked to produce separate gestures, they were more likely to express manner and path in separate clauses too. These results support the view that there are speaker-internal motivations for gesture production. They confirm predictions made by the Information Packaging Hypothesis, which the Lexical Retrieval Hypothesis and the Image Activation Hypothesis do not make.

**Keywords:** Gesture; Speech; Production; Motion Event

## Introduction

When speaking, most people tend to produce hand gestures that are closely synchronized with their speech semantically (e.g. McNeill, 2005), temporally (e.g. Chui, 2005), and structurally (e.g. Kita & Özyürek, 2003). Because of this careful coordination, it is generally assumed that the processes of speech and gesture production are somehow related. Yet what is the exact role of gesture production in relation to speech production?

### Gesture and Speech Production

In this paper, we focus on representational hand gestures (McNeill, 1992). Representational gestures either depict action, motion or shape ("iconic gestures") or indicate a location or direction ("deictic gesture"). Much evidence has been gathered in support of a theory that (representational) gestures, like speech, are part of a speaker's communicative effort (Kendon, 2004). In line with this view, Growth Point Theory (McNeill, 2005; McNeill & Duncan, 2010) starts from the observation that gesture and speech co-express idea units, each using a different form of semiosis. While gesture employs a global/synthetic form of representation, speech is expressed in an analytic/ combinatoric form. It is assumed that gesture and speech production share a common origin: the growth point. From this origin, a bimodal utterance develops from the interplay of imagistic and linguistic processing. Thus, in this view, gesture and speech are two outcomes of a single process.

In addition to the line of thought that gestures are intended communicatively, it has also been proposed that there are speaker-internal motivations for gesture production. Some propose that gesture production facilitates cognitive processes in general, by lightening cognitive load (Goldin-Meadow, Nusbaum, Kelly & Wagner, 2001). Others propose that gesture production facilitates a specific process in speech production. In this article, we focus on the latter class of proposals. There are three prominent proposals in the literature: The Lexical Retrieval Hypothesis, the Image Activation Hypothesis, and the Information Packaging Hypothesis.

The Lexical Retrieval Hypothesis (LRH) states that gestures facilitate the retrieval of lexical items from the mental lexicon (Krauss, Chen, & Gottesman, 2000). In this view, gesture production is based on spatial imagery in working memory. Rather than there being an interplay between the processes of gesture and speech production, the execution of a gesture is thought to activate spatio-dynamic features, which in turn activate conceptual information. Through cross-modal priming, this aids the retrieval of lexical items. Thus, gesture production precedes speech formulation entirely.

The Image Activation Hypothesis (IAH) states that gesturing serves to keep an image (Freedman, 1977) or certain spatial features (De Ruiter, 1998) activated while they are encoded by the process of speech formulation.

The Information Packaging Hypothesis (Kita, 2000) critically differs from the Lexical Retrieval Hypothesis and the Image Activation Hypothesis in its assumptions on the for-speaker motivations of gesture production, and on the interplay between gesture and speech production. Rather than simply activating information or maintaining the activation of spatial information, gesture production is thought to structure information, and to package it into units that are suitable for the speech formulation process.

Like Growth Point Theory, the Information Packaging Hypothesis (IPH) assumes that different forms of processing underlie gesture and speech. It is proposed that gesture is based on spatio-motoric processing and speech on analytic processing. The IPH assumes that "[s]patio-motoric thinking, which underlies representational gestures, helps speaking by providing an alternative informational

organization that is not readily accessible to analytic thinking, the default way of organizing information in speaking" (Kita, 2000, p. 163). Furthermore, it assumes that "[s]patio-motoric thinking and analytic thinking have ready access to different sets of informational organizations" (Kita, 2000, p. 163). The representations in these two modes of thinking are thought to be coordinated online during language production, such that they tend to converge.

The Information Packaging Hypothesis is implemented in the Interface Model (Kita & Özyürek, 2003), which adds gesture production components to Levelt's (1989) model of speech production. In the Interface model, what needs to be expressed is determined in the communication planner. This module informs the action generator, where gestural contents are determined, as well as the message generator, where the preverbal message is determined. Importantly, the action and the message generator are bi-directionally linked to each other, allowing for gesture and speech to coordinate their contents during language production. Lastly, the message generator is also linked bi-directionally to the formulator, which converts a preverbal message into an utterance, through accessing the mental lexicon and retrieving and processing morphological, syntactic and phonological information. This way, the formulator can pass on information to the action generator, via the message generator. Thus, the *bidirectional* link between the action and message generator allows for gesture and speech production to be coordinated semantically and structurally. It is assumed that the processes of speech and gesture generation constantly exchange information, which is transformed from one format into another, such that the content of both modules tends to converge.

What is the evidence for this convergence of information packaging in speech and gesture? The evidence for the speech-to-gesture influence comes from studies of motion event descriptions (Kita, 2000; Kita & Özyürek, 2003; Özyürek, Kita, Allen, Furman, & Brown, 2005). It was found that whether speakers used a single or multiple clauses to verbally describe the manner and path of a motion tended to match whether they expressed manner and path in a single or in separate gestures. For example, "he rolled down the hill" would likely be accompanied by a gesture in which the hand describes circular motions as it is moved down diagonally, while "he rolled, as he went down the hill" would be more likely to be accompanied by one gesture illustrating the rolling and another gesture illustrating the downward path. In one study on English speakers (Kita, et al., 2007), different clausal structures in speech were elicited by varying whether a manner was incidentally or causally related to the path of a motion in the stimulus animations. Different clause structures lead to the predicted different patterns of packaging of manner and path in gestures.

The evidence for the gesture-to-speech influence comes from studies in which the availability of gestures was manipulated (Alibali & Kita, 2010; Alibali, Spencer, Knox, & Kita, 2011). It was found that the availability of gestures changed the type of information encoded in speech. More specifically, when gestures are produced, speakers tended to encode spatial information that gestures readily had access to. To date, there is no study that manipulated gesture structure (as opposed to gesture availability) to examine its influence on speech production.

## Present Study

We will test the prediction made by the IPH (but not by the LRH and IAH), that the information structure underlying gesture production can influence the information structure underlying speech. In doing so, we will use the task of describing motion events, as in the study described above (Kita, et al., 2007). Yet how can we measure the analytic representations underlying speech production?

Bock and Cutting (1992) propose that syntactic processing units comprise of (finite) clauses. Using a procedure to elicit verb agreement errors, they found that these errors occurred more frequently when the head noun and its verb were separated by a phrase (e.g. "The claim about the stolen babies was rejected", p. 104) than when they were separated by a relative clause (e.g. "The claim that wolves were stealing babies was rejected", p. 104). Assuming a hierarchical processing structure, they explain this as that the more information is introduced within a single processing unit, the more sources of interference there are between similar, concurrently active elements. In this example, when the head noun and the local noun are part of a single clause, their numbers are more likely to interfere than when they are part of separate clauses. Thus, within a clause, elements are more likely to interfere than across clauses. This supports the notion that clauses are the units of syntactic processing. Following Bock and Cutting (1992), we will assume finite clauses to be indicative of the processing units underlying speech.

We instructed participants to either conflate the manner and path of a motion into a single gesture (Conflated condition), or to produce one gesture for the manner and a separate gesture for the path of the motion (Separate condition) and observed the syntactic packaging of manner and path in speech. Since the IPH assumes that the processing units underlying speech and gesture are coordinated, it predicts this manipulation will affect the clausal structure of speech, such that conflated gestures tend to go with single, conflated clauses, whereas separate gestures tend to go with separate clauses for manner and path.

The Image Activation Hypothesis may not make specific predictions as to the difference between the conflated vs. separate gesture condition. Both the conflated gesture and separate gesture condition should equally boost the activation of the imagery of manner and path. More crucially, the hypothesis does not propose any mechanism as to how linguistic expressions are influenced by gesture

production, aside from the assumption that more strongly activated imagery leads to better quality descriptions.

The Lexical Retrieval Hypothesis may predict an effect of gesture production on speech production. Yet this effect is different from the effect predicted by the IPH. Rather than the clausal structure of speech being affected by the way speakers gesture, it may predict that speakers who use different gestures would activate different lemmas and would thus use different words.

# Method

## Participants

Twenty-one native Dutch first-year students (4 male) from Tilburg University participated in our study as part of their curriculum. They were aged between 18 and 24 years old ($M = 21.24$, $SD = 1.61$). Four participants were left-handed. The number of male and left-handed participants was equal in the two conditions.

## Material

The ten stimulus clips that our participants described were from a set of animated cartoons known as 'the Tomato Man movies' (Özyürek, Kita, & Allen, 2001). Each clip consisted of an initial entry event, followed by a target event in which one of the two figures completes a motion along a certain path and in a certain manner, and finally a closing event (see Figure 1).
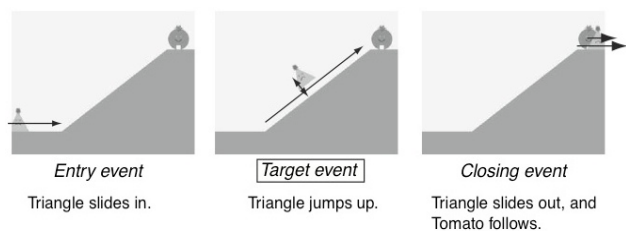


| Entry event | Target event | Closing event |
| Triangle slides in. | Triangle jumps up. | Triangle slides out, and Tomato follows. |

Figure 1: Example of a stimulus clip, taken from (Kita, et al., 2007).

## Procedure

Participants came to the lab and were randomly assigned to one of the two gesture conditions. They first received a written instruction, after which they were allowed to pose clarification questions. The instruction explained that the participant was to watch animated cartoons in which a cartoon figure sometimes conducted a motion involving both a certain manner and a certain path of movement. In the Conflated condition, participants were asked to produce a hand gesture with their description of such motions, such that 'the gesture illustrates both the path and manner of movement at the same time'. In the Separate condition, participants were requested to produce two different gestures with their description of the motion, with 'one

gesture illustrating the path, while the other gesture shows the manner of movement'. Note that participants were asked to *gesture* differently only. Otherwise, the instructions were exactly the same in both conditions.

Participants were seated next to a table with a laptop on it, which showed a Powerpoint presentation. Upon pressing a button, an animated cartoon played twice, after which the participant was to describe it to the experimenter, who was seated across from the participant. Behind the experimenter was a camera, capturing the participant. The first clip was a practice clip. If needed, the experimenter gave additional instructions on how to do the task, by asking specific questions (e.g. "And how exactly did the figure go around the tree?") or by describing how the gestures produced by the participants differed from the gestures requested. The participant then proceeded to watch and describe the ten stimulus clips. Afterward, the participant filled out a short questionnaire, which asked for participants' native language and whether they were left or right handed. Lastly, they filled out a consent form. All participants permitted their data to be used for research and educational purposes.

## Coding and Analysis

All recordings were analyzed using Elan (Max Planck Institute for Psycholinguistics; Wittenburg, Brugman, Russel, Klassmann, & Sloetjes, 2006). For each description of a target event, speech was transcribed into finite clauses and gestures were coded. We used finite verbs to decide on clause boundaries. Each clause contained one conjugated verb. Hence, the first two examples in Table 1 (next page) were both coded as a single clause. Few utterances contained a praedicativum, as in (1). *Al springend* is linked both to the verb and to the noun. Its status is therefore not entirely clear. It can be thought of as an adjective, a verb or an adverb (Jansen & Lentz, 2002). Because of this and since these cases were few, we excluded them from our analyses.

(1) "Al  springend            gaat hij omhoog."
   while in a jumping manner  goes he  up.
   "(While) jumping he goes up."

For each clause and each gesture, it was determined whether it contained information on manner, on path, or on both. Verbal descriptions in which manner and path were solely expressed in a single clause were coded as *conflated*. Descriptions in which there were separate clauses for manner and path were coded as *separate*, even if the description also contained a clause in which the two were conflated. Descriptions in which either manner or path was described in a separate clause, yet not both, and in which there was a conflated clause as well were coded as *mixed*. Table 1 provides some of participants' utterances and our coding. Gestural descriptions were coded analogously, for whether manner and path were conflated into a single gesture, expressed in separate gestures or a mixture of both.

Table 1: Examples of utterances and our coding. Coded clause boundaries are indicated by forward slashes.

| Utterance: | Label: |
|---|---|
| "het rode rondje draait dan zo omhoog" /the red circle (+diminuative) turns then like this upwards/ the red circle then *twists upwards* like this | conflated |
| "en hij gaat zo springend omhoog" /and he goes like this in a jumping manner upwards/ and he *goes jumping upwards* like this | conflated |
| "en die draait terwijl die naar boven gaat" /and that (pronoun feminine/masculine) turns/ while that to up goes/ and he *turns* as he *goes up* | separate: (manner, path) |
| "en de driehoek gaat omhoog en dat doet ie door uh te springen" /and the triangle goes up/ and that does he by uh to jump/ and the triangle *goes up* and that he does by uh *jumping* | separate: (path, manner) |
| "de appel die rolt en hij rolt van links naar rechts omhoog" /the apple that rolls/ and he rolls from left to right upwards/ the apple *rolls* and it *rolls upwards* from left to right | mixed: (manner, conflated) |

Occasionally, participants failed to describe both the manner and the path of a motion in gesture and speech (8 cases). Also, participants sometimes failed to comply with the instructions, only producing separate gestures for manner and path in the Conflated condition (3 cases), or only producing a conflated gesture in the Separate condition (24 cases). These cases were discarded from our analyses. The more frequent problems in the Separate condition may indicate that conflated gestures (along with conflated speech) are more common among Dutch speakers, similarly to English speakers (Kita & Özyürek, 2003). The remaining dataset contained 175 descriptions (verbal and gestural) by 21 participants. To ensure fair comparison between participants and between conditions, despite an unequal number of descriptions, we computed the proportion of verbal expressions of a certain type (conflated, separate, mixed) for each participant, rather than using the raw counts. The means of both conditions were compared using independent-samples T-tests. When Levene's test for equality of variances was significant, we report the adjusted statistics.

## Results

Participants produced greater proportions of verbal descriptions in which manner and path were conflated into a single clause when they were asked to produce a single conflated gesture for manner and path ($M = .88$, $SD = .18$),

than when they were asked to express manner and path in two separate gestures ($M = .19$, $SD = .31$), $t(19) = 6.26$, $p < .001$. The reverse pattern was found for descriptions in which manner and path were expressed in separate clauses (see Table 2). Similar results were obtained when descriptions on which participants failed to comply with the instruction were included. We did not find any effects of gender, or left or right-handedness.

## Discussion

Our results show that the way people gesture influences the way they speak. When asked to divide manner and path information over two gestures, participants were more likely to also use two clauses for manner and path. These results are in line with the Information Packaging Hypothesis (Kita, 2000). Being required to separate manner and path into two gestures forced speakers to think about the event in a certain way spatially. That is, it requires them to separately focus on the path of the motion and the manner of the motion sequentially, as each unit of information is the base of one unit in gesture. This differs critically from the conflated condition, in which participants were asked to conflate manner and path into a single gesture, which calls for spatially processing the motion as a whole, that is, a single unit of information. The Information Packaging Hypothesis predicts that the analytic processing units underlying speech tend to converge with the spatio-motoric processing units

Table 2: The effects of gesture condition (Conflated vs. Separate) on the mean proportions (SD) of verbal descriptions in which manner and path were expressed in a single clause (conflated), separate clauses (separate) or a combination (mixed).

| Verbal descriptions | Conflated gesture (N=10) | Separate gestures (N=11) | Statistics |
|---|---|---|---|
| proportion conflated | .88 (.18) | .19 (.31) | $t(19) = 6.25$, $p < .001$ |
| proportion separate | .09 (.11) | .63 (.31) | $t(12.7) = 5.46$, $p < .001$ |
| proportion mixed | .03 (.07) | .18 (.24) | $t(19) = 1.85$, $p = .08$ |

underlying gesture. We have taken clauses to be a measure of the analytic processing units (Bock & Cutting, 1992). When gesture production forced participants to spatially process the motion as a whole, manner and path were more frequently conflated into a single clause, reflecting one analytic processing unit. Yet when gesture forced participants to process the manner and the path of the motion separately, they more frequently expressed manner and path in two separate clauses, reflecting two units in analytic processing. This supports the prediction made by the Information Packaging Hypothesis, that the processing units underlying speech can be adapted to the processing units underlying gesture.

Our results also support the Interface Model of gesture and speech production (Kita & Özyürek, 2003). Specifically, they confirm that the link between the action generator and the message generator is bidirectional in nature. Earlier work had already shown that the constraints a language imposes on what information can be linguistically expressed within a clause affect gesture production (Kita & Özyürek, 2003) and that the structure of speech could affect the structure of gesture (Kita, et al., 2007; Özyürek, et al., 2005). Our current study shows that when gesture formulation is constrained, this affects speech formulation as well, exactly as the model would predict.

Since gesture is generally assumed to be less conventionalized than speech, it may not be as straightforward to see in what kind of naturalistic situations gesture would impose constraints on speech formulation. However, there is a growing body of evidence that speakers adapt their gestures to one another (Holler & Wilkin, 2011; Kimbara, 2008; Mol, Krahmer, Maes, & Swerts, 2012; Parrill & Kimbara, 2006). When a gesture shape or a structure in gesture is imitated from another speaker, this may in turn influence the speech formulation process, potentially causing speech to converge across interlocutors as a result. Also, there can be cultural and pragmatic constraints on gesture (Enfield, Kita, & De Ruiter, 2007; Kita & Essegbey, 2001). More importantly though than gesture imposing constraints on how information can be expressed, it can open up new possibilities of organizing information, by supporting spatio-motoric thinking (Chu & Kita, 2008; Kita, 2000). Our results confirm that speech production can benefit from gesture this way. This supports theories in which gesture results from speaker-internal motivations.

Can the current findings on clause structure be accounted for by the Lexical Retrieval Hypothesis? The Lexical Retrieval Hypothesis may be supported if the manipulation of gestures caused different choices of manner verbs in the two conditions, which in turn lead to different clause structures. Though, in principle, any Dutch manner verb can be used in both clausal structures, we examined the manner verbs in the two conditions. We included all inflections of manner verbs, such as in (2), as well as manner adverbs, as in (3).

(2) hij  *rolt*  zo  omhoog
he  rolls  like this  upwards
"he rolls up like this"

(3) hij gaat  *rollend*  van  de helling  af
he goes  in a rolling manner  from  the hill  off
"he goes rolling off the hill"

The numbers of manner (ad)verbs used in the two conditions were highly correlated, $R(11) = .90$, $p < .001$, see Table 3. This indicates that the compositions of (ad)verbs used in the two conditions were very similar. Thus, there is no support for the idea that gesture affected clause structures via different choices of manner (ad)verbs.

Can the current findings be accounted for by the Image Activation Hypothesis? According to this hypothesis, gestures boost the activation level of the imagery that is intended to be communicated. This hypothesis does not specify the relationship between clause structures and imagery; thus, gesture's effect on clause structure cannot be accounted for.

## Conclusion

Our results demonstrate that gesture production can influence speech production. Specifically, the way information was divided over individual gestures affected the way information was divided into clauses. This supports the Information Packaging Hypothesis (Kita, 2000), in which gesture production serves to organize rich spatio-motoric information into packages suitable for speaking, and the spatio-motoric processing units underlying gesture production are coordinated with the analytic processing units underlying speech production. Therefore, these results also support the view that there are speaker-internal motivations for gesture production.

Table 3: Manner (ad)verbs used in each condition.

| Lemma: | Translation: | Number of occurrences: | |
|---|---|---|---|
| | | Conflated | Separate |
| draaien | turn | 34 | 34 |
| springen | jump | 13 | 23 |
| rollen | roll | 12 | 16 |
| stuiteren | bounce | 11 | 3 |
| cirkelen | circle | 8 | 0 |
| huppen/hoppen | hop | 5 | 6 |
| twisten | twist | 0 | 1 |
| tuimelen | tumble | 0 | 3 |
| koprollen | rollover | 0 | 1 |
| kantelen | topple | 0 | 1 |
| buitelen | tumble | 0 | 1 |
| Total: | | 83 | 89 |

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