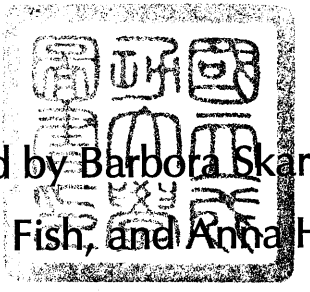
PROCEEDINGS OF
THE 26TH ANNUAL

Boston University Conference on Language Development

VOLUME 1



edited by Barbora Skarabela,
Sarah Fish, and Anna H.-J. Do

Cascadilla Press
Somerville, MA 2002

Printed in the United States of America

ISSN 1080-692X
ISBN 1-57473-072-X (2 volume set, paperback)
ISBN 1-57473-172-6 (2 volume set, library binding)

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The Robustness of Non-English Sequences in Created Gesture Systems

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1. Order is Important in Language Learning and Language Creation

One of the most robust features of human language is consistent word order. Although languages across the globe vary in the degree to which a particular order is obligatory, all languages have a basic order (Greenberg, 1963; Hawkins, 1983; but see Mithun, 1992). Word order is important not only as a general feature of adult language, but also for children learning language. Children consistently order words to express relations between elements in their earliest multi-word productions (Brown, 1973). Even when exposed to languages that permit wide variability in word order, children display consistent orders within their own developing sentences. For example, deaf children learning American Sign Language (ASL) from their deaf parents use consistent order as a syntactic device for marking role early in development despite the fact that adult ASL permits a variety of orders (Hoffmeister, 1978; Newport & Ashbrook, 1977; Newport & Meier, 1985). Similarly, adults acquire ordering information quickly and consistently when learning either a first (Newport, 1990) or second (Johnson & Newport, 1989) language late in life. For example, adults who vary in the age at which they first begin to learn English as a second language show differences in their judgments of many rules of English grammar. However, they display *no* differences in their knowledge of basic word order rules, all having essentially mastered the ordering constructions (Johnson & Newport, 1989).

Consistent word ordering also emerges in unconventional communication situations. As an example, children whose hearing losses prevent them from acquiring a spoken language and whose hearing parents have not yet exposed them to a sign language communicate nevertheless – using gesture. The gestural "home sign" systems that these children create are characterized by a number of linguistic properties, including gesture order (Goldin-Meadow & Feldman, 1977; Goldin-Meadow & Mylander, 1998).

Adults, when asked in experimental settings to describe short videotaped scenes using their hands and not their mouths, also produce gestures in a consistent order. Interestingly, for English-speaking adults, this order does *not* follow canonical English word order (Goldin-Meadow, McNeill, & Singleton, 1996). The scenes these adults were asked to describe involved objects or people moving across space in relation to a second, stationary object. One example pictured a girl jumping into a hoop. A typical verbal description of this scene in

 BUCLD 26 Proceedings, ed. Barbora Skarabela et al., 278-289. Somerville, MA: Cascadilla Press.

English is "the girl jumps into the hoop." However, the English-speaking adults in this study consistently produced their gestures in a different order – "hoop-girl-jump." The adults gestured the stationary object (S) before the moving object (M), which in turn preceded the action (A). This SMA order was preserved regardless of the communication situation — whether or not the adults produced the gestures with feedback from a listener; whether or not they shared common ground with the listener; or whether or not they switched roles with the listener so that they had an opportunity to both receive and produce gestures (Gershkoff-Stowe & Goldin-Meadow, 2002). The robustness of the SMA order led Gershkoff-Stowe and Goldin-Meadow (2002) to hypothesize that SMA may be a default way of sequencing the semantic elements in a crossing-space event.

The purpose of the present study is to probe the robustness of order in gesture systems created by adults under a variety of experimental circumstances. In Study 1, we extend the range of events that adults are asked to describe in gesture. In addition to viewing objects crossing space or moving in place in relation to other objects (scenes that typically evoke *intransitive* sentences), the adults also view objects acting on other objects (scenes that typically evoke *transitive* sentences). In Study 2, we ask whether non-English ordering arises in created gesture systems even if the events are presented, not as visual scenes as in Study 1, but as written sentences that follow canonical English word order.

2. Study 1: Exploring the SMA Order with Events that Elicit Transitive Sentences

In previous work (Goldin-Meadow et al., 1996; Gershkoff-Stowe & Goldin-Meadow, 2002), we asked adults to describe a subset of the stimuli from the Verbs of Motion Production (VMP) test designed by Supalla and colleagues (2002) to measure knowledge of motion verbs and classifiers in ASL. The VMP test is composed of short video scenes in which animated toys appear to move through space. In the current research, we videotaped real people and objects, half moving in relation to another object or person (stimuli designed to elicit *intransitive* sentences) and half acting on an object or person (stimuli designed to elicit *transitive* sentences).

2.1. Participants, Stimuli and Procedures

Nine hearing adults were paid to participate in this study. All were native English speakers and none had knowledge of ASL or any other conventional sign language. All had exposure to another spoken language (e.g., Chinese, French, German, Italian, Korean, Spanish) and five described themselves as fair to fluent speakers of at least one other language. However, all of the adults used English almost exclusively in their daily lives. The mean age of the adults was 22.9 years (range 19-29). All were students or staff at the University of Chicago. All were recruited through postings at various campus locations.

The items portrayed in the video stimuli were people and objects drawn from categories commonly represented in the gesture systems of deaf children of hearing parents (Goldin-Meadow, Mylander & Butcher, 1995) and ASL (Wilbur, 1987). The supercategories were animate objects, inanimate objects, and vehicles. Within each supercategory, two subcategories and four exemplars for each subcategory were depicted, as shown in Table 1. Scenes were filmed against simple and unadorned backdrops (e.g., plain white walls, unmarked concrete walls) to maximize the saliency of the objects and minimize visual distractions. The scenes were short, ranging from 4 to 8 seconds.

Table 1: Object categories

Supercategory	**Subcategory**	**Exemplars**
Animate	People (2-legged)	3 women, 1 man
	Animals (4-legged)	3 dogs, 1 cat
Inanimate	Straight	door, yardstick, pencil, stick
	Round	donut, orange, ball, record
Vehicles	2-wheeled	3 bicycles, 1 motorcycle
	4-wheeled	2 cars, 1 minivan, 1 SUV

The stimuli included 46 scenes, 23 actions *on* an object (called *transitive* events) and 23 actions *by* an object (called *intransitive* events). To facilitate comparisons between intransitive and transitive events, all scenes contained two objects — a moving object (M) crossing space or moving in place in relation to a stationary object (S) in the intransitive scenes, and a moving object (M) acting on a stationary object (S) in the transitive scenes. All of the objects appeared in both transitive and intransitive events and, across the videotaped events, assumed most of the possible roles (i.e., moving and stationary objects in transitive and intransitive events).

Adults were shown the short video segments presented digitally on a computer screen, and were given the following instructions: "Describe what you see without speaking, using only gesture. You should gesture so that your gestures would be understandable to someone watching the videotape later. You may take as much time as you like to think about what you want to gesture before you begin. You may gesture however you like, but you cannot get out of the chair and you cannot use any props." Stimulus order was random with the constraint that no more than three scenes of the same type (intransitive, transitive) could appear in succession. The entire session was videotaped

2.2. Coding

Videotapes were analyzed for the production of gesture strings ("sentences") based on the order and the meaning of the gestures. Any movement of the hands and body that represented or mimed elements of the scenes was considered to be a gesture. Movements excluded from the analysis

include functional actions, such as adjusting one's glasses or hair, scratching one's nose, etc.

The meaning of a gesture was determined in the context of the three elements occurring in the scene (moving object, stationary object, action). If a gesture captured some aspect of an element in the scene, it was coded as representing that element. In some instances, adults would use their hands to represent actions and objects in space. For example, the index and middle fingers, tips pointed downward, would be wiggled to represent walking, or the same two fingers held motionless would be used to represent a person. In other cases, adults used their own bodies to represent an action or an object. For example, some adults bounced up and down in their chairs to represent jumping or mimed an overhand throw to represent a ball. If the meaning of a gesture was unclear, it and the string of which it was a part were coded as Uninterpretable (6% of 764 gesture strings).

Gestures were often combined into strings. Gestures were considered to belong to different strings when they were separated by pauses of more than one second, or by a relaxation or withdrawal of the hands. Gestures were considered to belong to the same string when there was a continuous flow of movement between them. When a series of unbroken gestures referred to the same object or action, they were classified together for the purposes of determining gesture order. Thus, if an adult gestured WOMAN in two different ways with no break between the gestures and a break at the end, the gestures were coded as a single string containing 1 semantic element. In contrast, if the adult produced a string-ending pause between the two gestures, each gesture was counted as a single string containing 1 semantic element. Descriptions of a single videotaped event typically contained several strings. When the gestures in a string were produced simultaneously thereby eliminating ordering information, those strings were coded as Uninterpretable (4% of 764 gesture strings).

2.3. Results

Before turning to the ordering results, we first describe general characteristics of the data. The adults produced the same proportion of strings containing 1, 2, 3, or 4+ semantic elements whether describing events eliciting transitive strings or events eliciting intransitive strings ($X^2(4)=3.47$,ns). Strings containing only 1 semantic element do not bear on our ordering questions and thus will not be considered in the following analyses. Moreover, strings containing 4 or more semantic elements were infrequent, making it difficult to discern any ordering patterns; they too will be omitted here. Thus, the following analyses focus on the strings containing 2 semantic elements (N=164 strings, 74 intransitive and 90 transitive) and 3 semantic elements (N=136 strings, 68 intransitive and 68 transitive).

Turning first to gesture strings containing two semantic elements (Figure 1), we find that we have replicated findings from previous research on events eliciting intransitive sentences, and extended the findings to events eliciting

transitive sentences. Gestures for moving objects preceded gestures for actions (MA) in the intransitive ($t(8)=9.54$, $p<.01$, Bonferroni correction) and transitive strings ($t(8)=5.07$, $p<.01$). Gestures for stationary objects also preceded gestures for actions (SA), reliably in the transitive strings ($t(8)=6.23$, $p<.01$) and showing a trend in the intransitive strings ($t(8)=3.20$, $p<.10$). The number of strings containing gestures for both moving and stationary objects was small for scenes eliciting both intransitive and transitive strings. We therefore turn to strings containing three semantic elements (M, S, and A) to determine the ordering of moving and stationary objects.

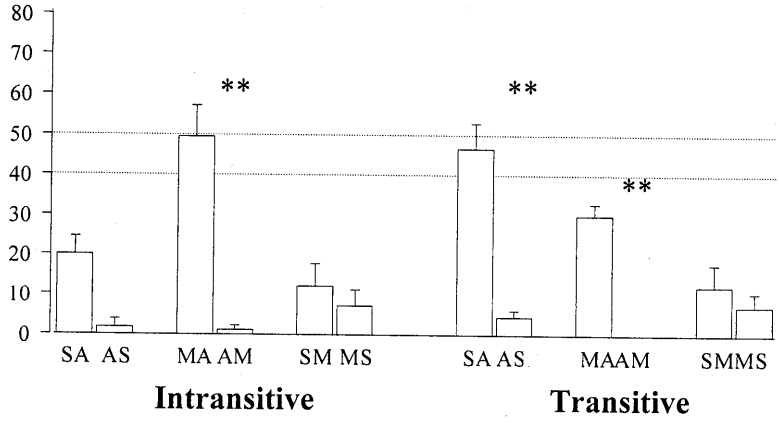

Figure 1. Mean Proportion of Intransitive and Transitive Gesture Strings Containing 2 Semantic Elements in Study 1 (video task). S=Stationary object, M=Moving object, A=Action, ** $p<.01$.

Figure 2 presents the data for gesture strings containing three semantic elements. As in previous work, gestures for stationary objects preceded gestures for moving objects, which preceded gestures for actions (SMA). The SMA order was more common than all of the other orders combined for both intransitive strings ($t(8)=3.93$, $p<.05$) and transitive strings ($t(8)=4.57$, $p<.05$). This pattern occurred not only at the group level, but at the individual level as well: SMA was the preferred order for both types of events for 8 of the 9 gesturers in the study.

Note that SMA is a non-canonical order in English in both transitive and intransitive sentences. When describing the scene in which a man ate a donut, the adults gestured DONUT-MAN-EAT, rather than the MAS order more typical of English, "man eats donut." Similarly, when describing a ball rolling past a motorcycle, the adults gestured MOTORCYCLE-BALL-ROLL, rather than the MAS order more typical of English, "ball rolls past motorcycle."

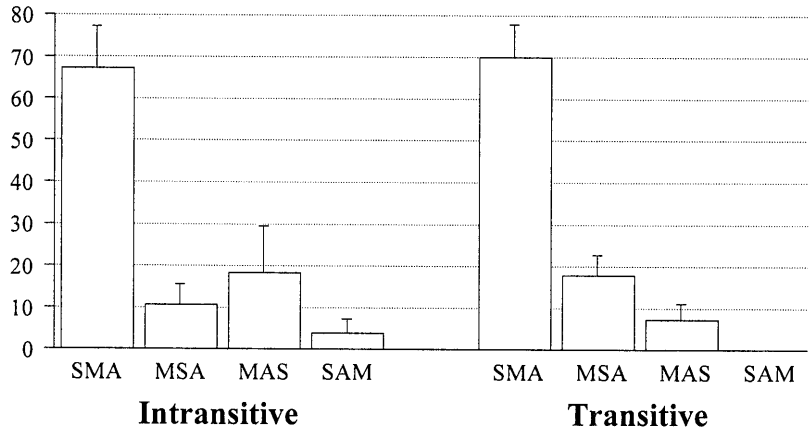

Figure 2. Mean Proportion of Intransitive and Transitive Gesture Strings Containing 3 Semantic Elements in Study 1 (video task). S=Stationary object, M=Moving object, A=Action. Because only 2 Action-first strings occurred in the corpus, Action-first orders are omitted from the figure. SMA order occurs more frequently than all other orders combined for both intransitive and transitive scenes.

We have found that, when called upon to use their hands to communicate, English-speakers adopt a non-English SMA gesture order to convey the relation between elements in a scene. Our goal in Study 2 was to determine whether the non-English SMA order is inevitable in adult-created gestures. Rather than present the scenes visually as we did in Study 1, in Study 2 we gave adults written English sentences and asked them to "translate" those sentences into gesture. We assumed that the English sentences would encourage the adults to incorporate English word order into their gesture strings.

3. Study 2: Is the SMA Order Robust in the Face of Written Stimuli in English Word Order?

3.1. Participants, Stimuli, Procedures, and Coding

Nine hearing adults who did not participate in Study 1 were paid to participate in Study 2. All had exposure to other spoken languages (e.g., Chinese, French, Hebrew, Korean, Spanish) and seven described themselves as fair to fluent speakers of at least one other language. However, English was the language all of the adults used in their daily lives. The mean age of the adults was 31.8 years (range 19-50).

Written stimuli were based on the video scenes used in Study 1. A pilot group of English-speaking adults (n=11) was shown each of the video scenes and asked to compose a written sentence to describe the scene. Sentences for each scene were compared. The sentences used in Study 2 were the sentences

produced by a majority of the adults in the pilot study. Object names were standardized across the sentences (e.g., a bicycle was referred to as "bicycle" in all of the sentences, never as "bike"). The sentences are shown in Appendix A.

The procedure was modeled after Study 1. However, instead of watching a video, adults were presented with an easel supporting an 8 1/2 x 11 inch sheet of paper listing a single sentence. The adults were told to "describe what you read without speaking, using only gesture." The remaining instructions were identical to those used in Study 1. Coding was done as in Study 1.

3.2. Results

Figure 3 presents the gesture strings containing two semantic elements that the adults produced in response to the written stimuli (N=168 strings, 77 intransitive and 91 transitive). As in Study 1, gestures for moving objects preceded gestures for actions (MA) in both intransitive ($t(8)=8.25$, $p<.01$) and transitive ($t(8)=4.58$, $p<.01$) strings. But the MA order does not violate typical English word order (e.g., *bicycle* falls; *bicycle* crushes record). Importantly, gestures for stationary objects were *not* ordered consistently with respect to gestures for actions; that is, SA occurred as often as AS in both intransitive ($t(8)=0.58$, ns) and transitive ($t(8)=0.67$, ns) strings. Strings containing both moving objects and stationary objects continued to be infrequent.

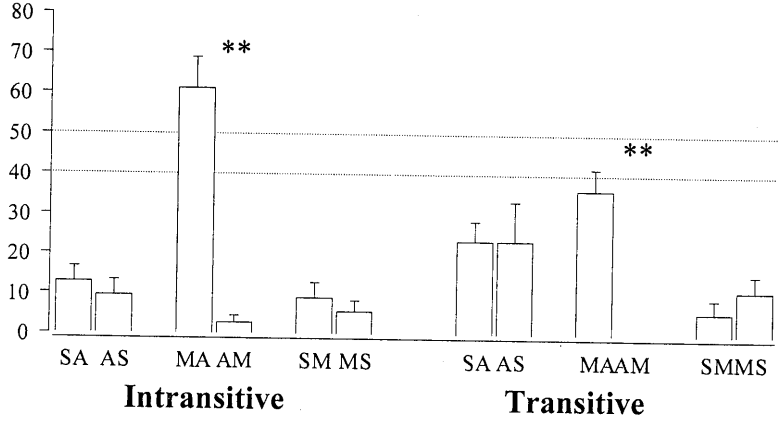

Figure 3. Mean Proportion of Intransitive and Transitive Gesture Stings Containing 2 Semantic Elements in Study 2 (text task). S=Stationary object, M=Moving object, A=Action, **p<.01.

Figure 4 presents the gesture strings containing three semantic elements that the adults produced in response to the written stimuli (N=153 strings, 76 intransitive and 77 transitive). In contrast to the consistent orders found in Study 1, little consistency was found in these data. The SMA order was not the most common order in either intransitive ($t(8)=2.11$, ns) or transitive ($t(8)=1.25$, ns)

strings. In fact, no single order predominated and several new orders — two Action-final orders (SMA and MSA) and an order reminiscent of canonical English word order (MAS) — appeared for the first time in the gesturers' repertoires.

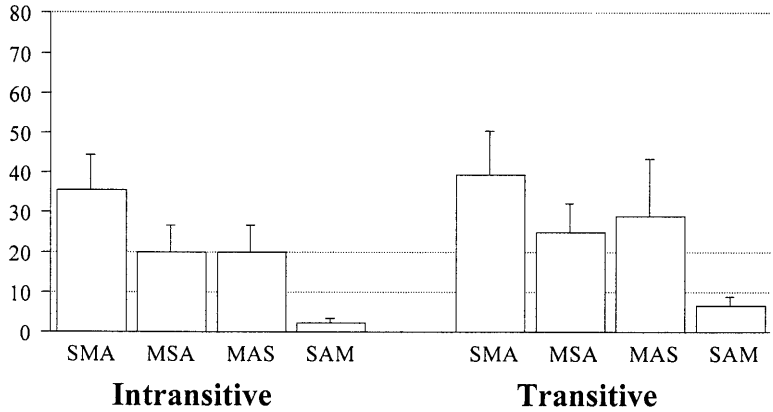

Figure 4. Mean Proportion of Intransitive and Transitive Gesture Strings Containing Three Semantic Elements in Study 2 (text task). S=Stationary object, M=Moving object, A=Action.

4. An Analysis of Individual Patterns in Studies 1 and 2

The shift away from the SMA order which occurred when the stimuli were presented as written text (Figure 4) could reflect a complete lack of consistency; that is, the individual adults may no longer have been consistent within themselves. Alternatively, each individual adult may have followed a consistent order, but there may have been no consistency across adults. To explore these possibilities, we examined the pattern for each individual in Study 2 and, for comparison, each individual in Study 1. Table 2 presents the most prevalent ordering pattern for each adult in the two studies. In the video task (Study 1), 8 of the 9 adults followed an SMA order in their intransitive and transitive strings (the 9th adult produced only 1 relevant instance). In contrast, in the text task (Study 2), only 1 of the 9 adults followed an SMA order in intransitive and transitive strings, 3 followed the English MAS pattern in both types of strings, and the remaining 5 used a combination of A-final, M-first, SMA, and MSA patterns across their intransitive and transitive strings. Thus, the adults in Study 2 were consistent within themselves but displayed no consistency as a group.

When presented with the visual stimuli in Study 1, adult after adult not only produced gestures according to a consistent ordering pattern, but all of the adults followed the same ordering pattern (SMA). There seems to be a default order that adults follow when asked to create gestures to describe scenes that are

Table 2. Most prevalent individual pattern for each adult in gesture strings containing 3 semantic elements. The label for the pattern is followed by the percentage of strings that followed the pattern and by the total number of strings produced by that adult (in parentheses).

Study 1 Video Task	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
Intransitive Patterns	**SMA** 86% (7)	**SMA** 100% (15)	**SMA** 92% (13)	**SMA** 80% (5)	**SMA** 67% (6)	**SMA** 67% (6)	**SMA** 67% (6)	**SMA** 44% (9)	--- (1)
Transitive Patterns	**SMA** 100% (6)	**SMA** 75% (12)	**SMA** 60% (5)	**SMA** 64% (11)	**SMA** 71% (7)	**SMA** 100% (4)	**SMA** 36% (14)	**SMA** (56% (9)	--- (0)

Study 2 Text Task	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**
Intransitive Patterns	**SMA** 67% (9)	**A-final** 73% (8)	**A-final** 100% (2)	**MSA** 38% (13)	**MSA** 80% (10)	**M-first** 66% (9)	**English** 100% (7)	**English** 90% (10)	**English** 63% (8)
Transitive Patterns	**SMA** 100% (6)	**SMA** 71% (7)	**MSA** 50% (6)	**MSA** 50% (6)	**MSA** 57% (7)	**MSA** 50% (10)	**English** 100%(10)	**English** 94% (16)	**English** 56% (9)

visually presented. Interestingly, no such default was found when we asked adults to create gestures to describe scenes presented in written English text (Study 2). We had originally assumed that asking adults to translate English sentences into gesture would encourage those adults to follow English word order in their created gestures. And it may have — but the English MAS order

did not dominate and seemed to be in competition with the default SMA order. The result, for some adults, seemed to be a compromise — new orders that were neither SMA nor MAS. In a sense, the surprising outcome is that text presentation which gave the adults a standard, and familiar, model to copy did *not* result in a dominant order across all gesturers, whereas visual presentation did.

5. Discussion

These studies provide further evidence for the robustness and limitations of the SMA order in created gesture systems. The findings from Study 2 make it clear that the SMA order is not inevitable in the manual modality — most of the adults did *not* rely on SMA when they created gestures following stimuli presented as written text. Thus, the adults in Study 1 did not follow an SMA order just because they were using gesture.

Where did the SMA order come from? The SMA order was implemented when adults were asked to describe a scene, either a moving object crossing space or moving in place in relation to a stationary object or a moving object acting on a stationary object. Placing a gesture for the action at the end of a string seems to be a sensible strategy since it allows the gesturer to introduce the two stable objects in the scene before describing the relation between those objects. And placing the stationary object before the moving object makes sense since the object that does not move essentially sets the scene for the object that does.

This ad hoc explanation is bolstered from findings from non-communicative situations. Eye-tracking data from Griffin and Bock (2000) suggest that, when adults are asked to scan a picture of an event that elicits transitive sentences, they look first at the object playing the patient role if their goal is to identify the person or thing acted upon, but also if they are given no instructions at all (it is only when asked to describe the event in English that the adults look first at the object playing the agent role) — the stationary patient is noticed first. Similarly for intransitive events, when adults are asked to stack transparent pictures of objects that participated in a crossing-space event, they first stack the picture of the stationary object, then the picture of the moving object, and finally the picture of the action (Gershkoff-Stowe & Goldin-Meadow, 2002). Thus, the SMA ordering pattern is *not* limited to communicative situations, nor to the manual modality.

Taken together, these results suggest that the SMA order may emerge from a general underlying cognitive structure, tied neither to language nor to communication. But if SMA is so robust, why do so few languages use it? Slobin (1977) has proposed that a number of factors shape languages — pressures to be clear, processible, quick and easy, and expressive. Not all of these pressures operate on languages in the same way. So while a language may experience pressures to be clear and easy to process — and might select an SMA ordering to accomplish this task — pressures to be quick and easy or expressive

may, at the same time, push that language toward a different order. SMA may be the order that languages adopt in their earliest stages when being clear and easy to process has the highest priority.

Appendix A: Stimuli sentences for Study 2.

Intransitive Sentences

A bicycle falls over next to a woman.
A bicycle moves toward a minivan.
A bicycle moves toward a stick.
A car moves towards a bicycle.
A cat walks past a yardstick.
A dog lies down in front of a car.
A dog stands in front of a bicycle.
A dog walks past an SUV.
A dog walks to and sits beside a woman.
A donut rolls in front of a man.
A door closes next to a bicycle.
A man sleeps next to a pencil.
A minivan moves past a dog.
A minivan moves toward a man.
A stick waves in front of an SUV.
A tennis ball rolls past a motorcycle.
A woman jumps up and down next to a record.
A woman jumps up and down next to an orange.
A woman spins around next to another woman.
A yardstick falls over next to a donut.
A yardstick waves in front of a dog.
An orange rolls over a yardstick.
An SUV moves toward a tennis ball.

Transitive Sentences

A bicycle bumps into a car.
A bicycle bumps into a dog.
A bicycle bumps into a woman.
A bicycle crushes a record.
A car bumps into a woman.
A car squishes a donut.
A cat licks a woman.
A dog pulls on a stick.
A door hits a woman.
A man eats a donut.
A man pushes a minivan.
A minivan bumps into a bicycle.
A stick hits a record.
A stick hits the handlebars of a bicycle.
A tennis ball hits a car.
A woman kisses a man on the cheek.
A woman lifts a bicycle.
A woman pets a cat.
A woman rides a stationary bicycle.
A woman tosses an orange up and down.
A yardstick hits the hood of a car.
An orange breaks a yardstick.
An orange hits a woman's head.

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