

# **Mapping Intransitive Verbs to Self-Propelled Actions**

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## **I. Introduction:**

As adult speakers, we know as a rule of thumb, that nouns are generally paired up with object kinds, adjectives with properties, and verbs with events. These relations, although by no means exhaustive or deterministic, are of particular interest of acquisitionists, because proper expectations about these relations can be greatly facilitative for learning novel word meanings. What we are interested in is young learners' expectations about the link between certain grammatical categories and conceptual categories.

Infants have been shown to develop expectations about the link between a word's grammatical category and its likely meaning during the second year of life (Waxman & Markow, 1995; Waxman & Booth, 2001), and their knowledge that verbs label event categories are acquired by 21-months (Bernal et al, 2007). However, given previous studies that have shown infants' sensitivity to the distributional features of the verb category by 15-months (Peterson, 2006; Mintz, 2006), it is surprising that the link between verbs and events is acquired only at 21 month. This study, as part of a larger project that looks at the development of the particular link between verbs and events of English-learning infants, aims to serve as an initial probe into this issue by focusing on the mapping between intransitive verbs and self-propelled actions.

## **II. Word-Learning Problem Revisited:**

Before moving on, I would like to stress the importance of studying this grammatical-conceptual category link in acquisition by revisiting the word-learning problem.

The word-learning problem, one might think, is simply a two-way mapping between a sound and a concept (assuming segmentation has been accomplished). But this configuration is missing an important component: How is the concept that is mapped to the sound evoked? In other words, from the observed world, which concept is extracted and applied to the sound? To see the point, imagine a scenario where you see a penguin moving in a spiral motion and hear someone say 'Look, it's doking!'. What do you think [doukiŋ] means? As a mature English speaker, you may say that it means "spinning", or alternatively, "moving", "dancing", etc., but you would probably not consider meanings like "penguin", "nose", "cute", or even "I saw a penguin yesterday", etc.. Why not these meanings, which are perfect descriptions of the scenario?

Saying that learning a novel word is to map a sound to a concept presupposes that there *is* a concept there to be mapped onto the sound. However, from the example above, we have seen that the same piece of world can be perceived in many different ways, thus many different concepts being evoked. Therefore, before a learner could map a sound to a concept, this concept, out of many available, has to be singled out. And this step is not at all trivial: from a learner's perspective, the number of hypotheses that are compatible with the data is large, and in principle infinitely many; this will result in a learnability problem, because few data point is going to distinguish those hypotheses. So, the real challenge in a word-learning task is not to map a concept to a sound, but rather, to know which concept, among many available in the world, to apply to the sound.

How do the learners come to know which concept to apply to a sound? In other words, how are the infinitely many possible meanings reduced to a much smaller subset? One hypothesis is: if the learner has some expectation about what kind of meaning a certain grammatical category may take, the number of hypotheses they consider is going to be significantly reduced. Applying to the example above, if the learner is a) able to identify that the novel word belongs to the verb category from the distributional cues, and b) knows that verbs refer to events as a general heuristic, then those non-event concepts like "penguin" and "nose" will not be evoked upon hearing the utterance "it's doking".

We are interested in the second component here, namely, the development of the verb-event link. Let's first see what we have already known from the literature.

### III. Literature Review:

The development of the verb-event link invites a two-fold question (Figure 1): First is this link's role as precursors of other learning processes; in this regard, we want to ask when this link is first established; Second is about what prerequisites are needed to establish this link; in this regard, we ask if the establishment of this link is dependent on the noun-kind link.



- Figure 1 -

As for the first question, namely, when the verb-event link is first established, we know from Bernal et al. (2007) that this verb-event link is in place at 23 month, for French-speaking children. They used an intermodal preferential pointing paradigm. They divided 23m-old French-speaking infants up in two conditions: in

the experimental condition, infants were shown an event (flower rotating) and taught a novel verb, which was introduced in a verb frame "It's pooning!"; in the control condition, infants were also shown the same event but was taught a novel noun, which was introduced in a nominal frame "It's a poon!". In test, both groups were asked to choose from two pictures the one containing the correct reference of the novel word, one was the familiar event (flower rotating), the other a novel event (flower jumping), both with the same object as the agent (flower). They found that the infants in the experimental group who were taught a novel verb, pointed more towards the correct answer, the familiar action; whereas those in the control condition who were taught a novel noun, showed a novelty preference. These results show that 23m-olds can exploit the syntactic context of a verb and link it to an event concept.

From this study we know that French-speaking 23m-olds have the verb-event link in place. A prerequisite for this link is categorization of verbs as a grammatical category. When could infants categorize verbs? Mintz (2006) showed that learners were sensitive to the distributional properties of verbs as early as 12 month. He used a head-turn preference paradigm. Infants were familiarized to four novel words, two in verb frames (e.g. *to deeg it*), and two in noun frames (e.g. *the gorp*); in test, they heard some grammatical sentences with the novel verb still in verb frames, novel noun still in noun frames, and some ungrammatical sentences with the novel verb now in noun frames (e.g. *a deeg of*) and novel noun in verb frames (e.g. *I gorp you*). The strings in test were completely novel, but they were not novel in terms of categorization. They found longer listening time to ungrammatical sentences than grammatical sentences.

This result suggests that children's knowledge of the verb category may be in place early, which establishes a prerequisite for the verb-event link. Thus, it warrants further investigation that whether the verb-event link is established earlier than 23 month, for English-speaking children.

As for the second question, namely, if the verb-event link depends on the establishment of other category links, some studies of Sandy Waxman are worth mentioning. She found that infants start off with a rather broad expectation that words refer to any commonalities in general (Waxman & Booth, 2003); and at 13 month, their expectation about noun meanings are more finely tuned to pick out a common object kind (Waxman & Markow, 1995); at 21month, infants establish the link between adjectives and properties (Waxman & Markow, 1998). This picture, however, is missing the piece of the verb-event link, and we want to fill in this gap by adding some evidence on children's development of this link as well as studying possible relations between the verb-event link and other category links - the noun-kind link, for instance.

#### **IV. Current Study:**

##### **(1) Questions & Hypotheses:**

Given what we know in the literature, the current study aims to fill two gaps: one in terms of the timeline of verb learning, the other is in terms of the relation of verb-event link to other category links. To fill the first gap, we investigate English-speaking 14m- and 18m-old infants to find the earliest age of the verb-event link. To fill the second gap, we examine the effect of vocabulary size on infants' ability to learn novel verb meanings – since infants' early vocabulary mainly consists of nouns and thus is indicative of their noun knowledge, looking at how verb learning ability varies as a function of their noun knowledge will be informative of the relationship between the verb-event link and the noun-kind link.







About the first question, we have two hypotheses: Hyp1a says infants at 14m and/or 18m have the verb-event link in place; Hyp1b (null hypothesis) says infants at 14m and/or 18m do not have this link in place yet. About the second questions, there are also two hypotheses: Hyp2a says the establishment of this link is dependent on the noun-kind link, and richer noun knowledge leads to better verb learning; Hyp2b (null hypothesis) says the establishment of this link is independent of the noun-kind link, and verb learning is independent of noun knowledge.

##### **(2) Method:**

This study uses the Habituation-Switch Paradigm (Werker et al., 1998). Briefly speaking, this paradigm shows infants something repeatedly over and over again until they get bored and then presents something new, usually with some subtle change; and if infants notice the subtle change, they would be interested again; if not, they would be more bored. Their boredom is measured by their looking time to the stimuli – longer looking time indicates higher interest and thus lower boredom. This paradigm normally consists of two stages, Habituation Phase and Test Phase; and there are two test conditions, the Switch Condition where a new thing is presented and the Same Condition (as a control) where the same thing is continued. Asymmetrical looking pattern between conditions are expected to be evidence against the null hypothesis (namely, infants fail to notice the change).

In our particular study, during Habituation, we present infants two video-audio pairs: one is a penguin-spinning video paired with the utterance 'it's doking', and the other is a penguin-cartwheeling video paired with the utterance 'it's pratching'. An experimenter codes the infant's look online by pressing a button when he/she is looking lifting the finger off the button when he/she is looking away, and the computer keeps track of the looking time. We play the aforementioned two pairs repeatedly in a random order until the infant gets bored, which is indicated by average look time dropping to 65% of that in the first habituation block (one block consists of three trials). At this point, the computer transitions from Habituation to Test Phase. Infants are divided up into two groups, one in the Switch Condition, and the other in the Same Condition (as control). If the infant is in the Same condition,

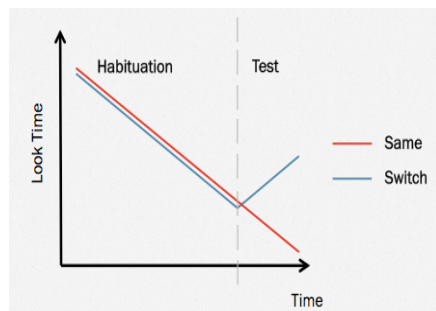
he/she will be shown the same two pairs as in Habituation; and if he/she is in the Switch condition, he/she will be shown two new pairs derived by switching the video-audio pairings - the penguin-spinning video is paired with the 'it's pratching' audio and the penguin-cartwheeling video is paired with the 'it's doking' audio. (Figure 2)

	Video		Audio
Habit		spinning	'It's doking'
		cartwheeling	'It's pratching'
Test-Same		spinning	'It's doking'
		cartwheeling	'It's pratching'
Test-Switch		spinning	'It's pratching'
		cartwheeling	'It's doking'

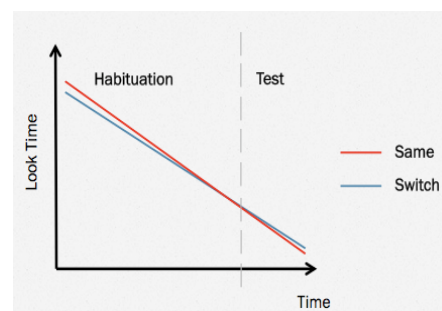
- Figure 2 -

### (3) Predictions:

Hyp1a, which says infants know the verb-event link would predict an asymmetry in look pattern between conditions – looking time drops during habituation, and in Switch Condition, we will see an increase in looking time during Test, but no such bounce-back in Same Condition (Figure 3a); Hyp1b, which says infants do not know this link yet, however, would predict no such asymmetry (Figure 3b).



- Figure 3a -



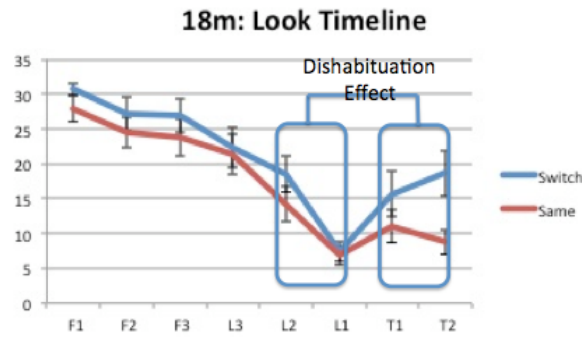
- Figure 3b -

Hyp2a, which says the establishment of verb-event link depends on noun knowledge, would predict an asymmetry between the performance of high-vocab and low-vocab infants; Hyp2b, which says the establishment of verb-event link is independent of noun knowledge, on the other hand, would predict no significant difference between the performance of high-vocab and low-vocab infants.

### (4) Results:

We found that 18m-olds behaved just as Hyp1a predicts. All infants were first habituated, indicated by the dropping attention in the Habituation Phase, but only those in Switch Condition showed an increase in looking time during Test:

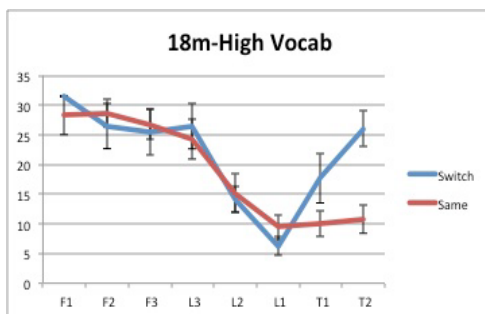
Difference in average looking time during Test between conditions reaches significance ( $p=0.014$  for the second test trial only,  $p=0.04$  for the two test trials combined). We call the attention bounce-back observed in Switch (as illustrated by the steep slope in the blue line) *dishabituation effect*, measured by the difference between the average test look time and the average look time of the last two habituation trials. (Figure 4)



- Figure 4 -

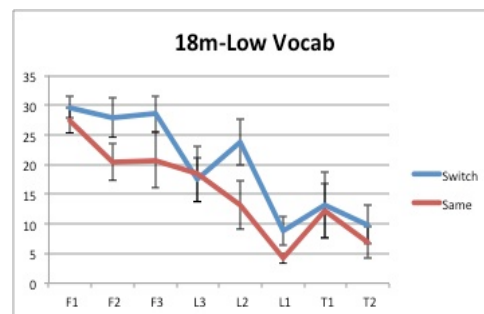
The x-axis is the timeline - the first three habituation trials (F1, F2, F3), followed by the last three habituation trials (L3, L2, L1), followed by the two test trials (T1, T2); the y-axis is looking time (the maximal time per trial is 32 seconds);  $N=23$ ,  $N(\text{Same})=12$ ,  $N(\text{Switch})=11$ .

What is more interesting is, when we split 18m-olds up by median vocabulary (median vocabulary: 63 for Same group, 68 for Switch group; vocabulary measured by MacArthur CDI), we found that only high-vocab infants showed the *dishabituation effect* (Figure 5a), but not low-vocab infants (Figure 5b): Difference in the size of dishabituation effect between conditions reaches significance for the high-vocab group ( $p=0.0005$ ) but not the low-vocab group ( $p=0.345$ )



- Figure 5a -

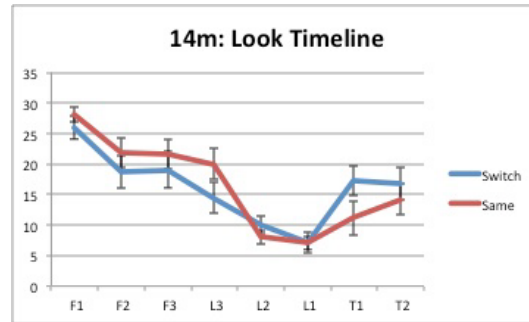
$N=12$ ,  $N(\text{Same})=6$ ,  $N(\text{Switch})=6$



- Figure 5b -

$N=11$ ,  $N(\text{Same})=6$ ,  $N(\text{Switch})=5$

All 14m-olds were habituated, but infants in both conditions dishabituated. The *dishabituation effect* is numerically but not statistically larger for Switch than for Same (Figure 6). When split up by median vocabulary, there was no significant asymmetry found between high-vocab and low-vocab groups.



- Figure 6 -

### (5) Discussion:

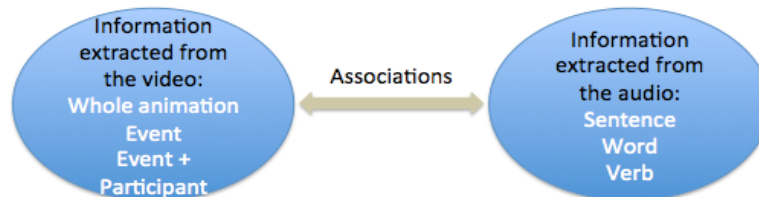
The results for 14m-olds seem to support Hyp1b, namely, 14m-olds do not have the mapping between verb and event yet. However, in addition to this possibility, there are also other alternative accounts: a) 14m-olds are unable to categorize novel word as verb - they fail to recognize the novel word 'doke' and 'pratch' as belonging to the verb category; this can either be due to their lack of knowledge of the entire verb category, or due to their inability to use the 'is -ing' dependency for verb categorization; b) 14m-olds are unable to sort subcategories of motion events - in other words, instead of mapping the novel verb to a specific motion, they tend to do the mapping on a superordinate level, namely, considering 'spinning' and 'cartwheeling' as instances of 'moving'; if this is the case, they will not be surprised at the switch, because both motions fall into the category 'moving'.

18m-olds' data, on the other hand, are consistent with an established verb-event link (Hyp1a). This is so far the earliest evidence of possible knowledge of this link in English. Given the gap between an early sensitivity to the distributional properties of verbs reported in Mintz (2006) and a relatively late establishment of verb-event link reported by Bernal et al. (2007), the result of current study more closely connects these observations. In addition, the result that high-vocab but not low-vocab 18m-olds showed the dishabituation effect is consistent with Hyp2a, indicating a possible relation between acquisition of the semantic features of verbs and knowledge of nouns. It is still unclear, however, what is the nature of this relation – acquisition of verb meaning may depends on noun knowledge for purely syntactic reason, or as an artifact of some non-linguistic inference mechanism (See Section V. for further discussion).

### V. Future Direction:

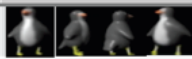





However appealing the results are, the current study cannot provide any conclusive answer to the question when infants first establish the verb-event link, but can only get us started in this big inquiry. Thus we have to be cautious in interpreting the results. 18m-olds' performance in this task is also consistent with strategies other than knowledge of the verb-event link. There are many different types of



information that subjects can extract from the video and the audio, resulting in many different ways of association between them (Figure 7). For example, they may simply map the entire animation to the sentence as a whole; or they may map the verb to the ‘event + participant’ as a unit; or alternatively, instead of having the verb-event link, they may think that words from different grammatical categories all map onto event; etc..



- Figure 7 -

To examine this issue more closely, we are conducting another experiment with similar designs in our lab. This experiment differs from the previous one in that we introduce a novel word from the noun category in addition to a novel word from the verb category. The two video-audio pairings in the Habituation Phase are: the penguin-spinning event paired with a noun-frame utterance 'it's a doke', and the penguin-cartwheeling event paired with a verb-frame utterance 'it's pratching'. This manipulation gives rise to two different types of switches: the first type is what we call a *Consistent Switch* in which the switch of video-audio pairing does not affect the reference of the novel noun; the second type is what we call an *Inconsistent Switch*, in which the novel verb was used to refer to the spinning event but now switched to pair up with the cartwheeling event. (Figure 8)

	Video	Audio
Habit	 spinning	'It's a doke'
	 cartwheeling	'It's pratching'
Test-Same	 spinning	'It's a doke'
	 cartwheeling	'It's pratching'
Test-Switch	 spinning	'It's pratching'
	 cartwheeling	'It's a doke'

 Inconsistent Switch  
 Consistent Switch

- Figure 8 -

In this new design, we will compare the dishabituation effect in different types of switch conditions. There are 4 different hypotheses based on possible associations between the video and audio that the subjects might make: Hyp1 says that if infants have both the verb-event link and the noun-kind link, they will show a larger dishabituation effect for consistent than inconsistent switch; Hyp2 says that if



infants have only the noun-kind link, but their knowledge of what conceptual category a verb maps onto is still not finely-tuned - they think that verb is mapped onto the 'event + participant' as a whole unit, then this would also predict a larger dishabituation effect for consistent than inconsistent switch; Hyp3 says if infants think that any word can label event, then there will be an equal dishabituation effect for both types of switch, because 'a doke' will also be considered as reference to an event, and the event obviously changed; Hyp4 says if infants use a low-level association that maps the entire video onto the entire audio, then there will also be an equal dishabituation effect for both types of switch, because in both types of switches, the video-audio mapping is changed.

This new design aims at telling apart the first two hypotheses from the last two, but it cannot distinguish Hyp1 from Hyp2 or Hyp3 from Hyp4. After this new experiment, further studies are still needed to tease apart these hypotheses.

In addition to carrying out several follow-up experiments along this line, there is another question we would like to pursue in the future. This is about the vocabulary effect we observed in 18m-olds' data. 18m-olds' data are consistent with the hypotheses that richer noun knowledge leads to better verb learning. However, the reason why verb learning depends on noun knowledge is unclear. One possible reason is the that verb learning depends on having knowledge of NPs that can serve as arguments of the verb, which is the main spirit of the Syntactic Bootstrapping Theory (Gleitman, 1990; Naigles, 1990); another possible reason, however, is that infants are simply using some kind of inference mechanism - for example, kids with high vocabulary are likely to know that nouns pair up with object kinds and adjectives with properties; what is left over is events and verbs, so they set up a link between them. We think teasing apart these two reasons will definitely be an interesting question to pursue in the future.

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