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Verb Learning in 14- and 18-Month-Old English-Learning Infants

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ABSTRACT
The present study investigates English-learning infants' early understanding of the link between the grammatical category *verb* and the conceptual category *event*, and their ability to recruit morphosyntactic information online to learn novel verb meanings. We report two experiments using an infant-controlled Habituation-Switch Paradigm. In Experiment 1, we habituated 14- and 18-month-old infants with two scenes each labeled by a novel intransitive verb embedded in the frame "is ___ing": a penguin-spinning scene paired with "it's *dok*ing", a penguin-cartwheeling scene paired with "it's *pratch*ing". At test, infants in both age groups dishabituated when the scene-sentence pairings got switched (e.g., penguin-spinning—"it's *pratch*ing"). This finding is consistent with two explanations: (1) infants were able to link verbs to event concepts (as opposed to other concepts, e.g., objects) and (2) infants were simply tracking the surface-level mapping between scenes and sentences, and it was scene-sentence mismatch that elicited dishabituation, not their knowledge of verb-event link. In Experiment 2, we investigated these two possibilities, and found that 14-month-olds were sensitive to any type of mismatch, whereas 18-month-olds dishabituated only to a mismatch that involved a change in *word meaning*. Together, these results provide evidence that 18-month-old English-learning infants are able to learn novel verbs by recruiting morphosyntactic cues for verb categorization and use the verb-event link to constrain their search space of possible verb meanings.

Introduction

Successful word learning requires forming a link between the phonological form of a word and the concept that it picks out. Our fundamental problem is that the extralinguistic context of language use provides unboundedly many possible meanings for any particular word form (Quine, 1960). In principle, a novel word could refer to any aspect of the world, including an object at the basic ("rabbit") or superordinate level ("animal"), a part of an object ("head"), a property of the object ("furry"), an action ("running"), or some combination of these features ("furry + head"; "furry + running"). Given the vast array of candidate meanings, learners must be constrained in the meanings they consider for a novel word and the information they take to be relevant for selecting among these. One possible constraint may come from the language itself (Brown, 1957; Gleitman, 1990), in particular, from the partial correspondences between grammatical categories and conceptual categories (Brown, 1957; Grimshaw, 1981; Pinker, 1989; Waxman & Booth, 2001; Waxman, Lidz, Braun, & Lavin, 2009). Because object kinds tend to be labeled by count nouns, and events tend to be labeled by verbs, for example, such correspondences can serve as a good heuristic for learners to constrain their search space of possible word meanings. For instance, if learners expect event categories to be expressed in the grammatical category *verb*, then upon categorizing a word as a *verb*, they will be able to infer with some certainty that this word

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picks out an event concept, avoiding the need to consider meanings from other conceptual categories like *object* or *property*.[1] The present study investigates the emergence of the verb-event link at early stages of English-learning infants' lexical acquisition with the primary goal of mapping the early developmental trajectory of infants' use of this correspondence.

Infants produce their first words at the end of their first year and rapidly develop a lexicon with a preponderance of words referring to object categories (e.g., Bates et al., 1994; Fenson et al., 1994; Gentner, 1982). In contrast, it is not until their second birthday that children start to produce a sizeable number of verbs, using them systematically to refer to actions, mental states and relations (for reviews, see Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005; Waxman & Lidz, 2006). In terms of comprehension, current literature also reveals an asymmetry between nouns and verbs. It has been shown that labeling with a novel noun facilitates object categorization compared to no labeling for infants around 12- to 13-months of age (Waxman & Markow, 1995); at 14 months, nouns are treated differently from adjectives in that nouns pick out object categories but not object properties, whereas adjectives highlight both commonalties (Waxman & Booth, 2001); and early success in novel noun-learning tasks has been consistently and robustly documented (e.g., Echols & Marti, 2004; Fennell, 2006; Prudent, Hirsh-Pasek, Golinkoff, & Hennon, 2006; Trehub & Shenfield, 2007). Infants' knowledge of the verb-event correspondence and their ability to utilize it in novel verb learning tasks, however, seems to be more protracted and results from experimental work about its developmental are mixed and less clear (e.g., Bernal, Lidz, Millotte, & Christophe, 2007; Echols & Marti, 2004; Imai, Haryu, & Okada, 2005; Imai et al., 2008; Kobayashi, Mugitani, & Amano, 2006; Oshima-Takane, Ariyama, Kobayashi, Katerelos, & Poulin-Dubois, 2011; Oshima-Takane, Satin, & Tint, 2008; Waxman et al., 2009).

Imai and colleagues demonstrated that 3-year-old Japanese-learning children successfully learned a novel noun taught in a noun context (e.g., "*X* ga aru (There is an *X*)") and mapped it to a new action performed by the familiar object, but failed to map a novel verb taught in a verb context (e.g., "*X*-teru! (There is *X*ing!)") to the familiar action performed by a new object (Imai et al., 2005). Also see Imai et al. (2008) for a replication of these results in Japanese, and similar findings in English and Mandarin.

On the contrary to this failure with preschoolers, several previous studies showed success of verb learning in young toddlers. Waxman et al. (2009), using the Preferential Looking Paradigm, demonstrated that 24-month-old English-learning toddlers were able to map novel verbs to event categories: toddlers presented with dynamic scenes (e.g., a man waving a balloon) and descriptive sentences involving a novel verb (e.g., "the man is *larp*ing a balloon") successfully mapped the verb (e.g., "larp") to the event (e.g., waving), but not the object (e.g., balloon). Bernal et al. (2007) found similar results with 23-month-old French-learning toddlers: using a pointing task, they showed that toddlers familiarized with scenes (e.g., a flower rotating) and accompanying sentences involving a novel verb (e.g. "it's *poun*ing") mapped the verb (e.g., "poune") to the event (e.g. rotating) rather than the object (e.g., flower). In a more recent work, Oshima-Takane et al. (2011) used the Habituation-Switch Paradigm to test younger children: they habituated 20-month-old Japanese-learning toddlers with two different scenes (e.g., Scene A—an animal bouncing; Scene B—a vehicle jumping), each described by a sentence with a novel verb (e.g., Scene A—"*Moke*-shi-te(i)ru-yo (it's *moke*-ing)"; Scene B—"*Seta*-shi-te(i)ru-yo (it's *seta*-ing)"), and they found that toddlers dishabituated when there was a mismatch between the action and the verb (e.g., bouncing labeled by "seta"). This result suggests that children may have established the verb-event link as early as 20 months of age. Also see Oshima-Takane et al. (2008) for similar findings with 20-month-old English- and French-speaking toddlers.

Kobayashi et al. (2006) reported that younger children—Japanese-learning 14- and 18-month-olds (but not 12-month-olds)—were able to learn the association of novel intransitive verbs and events. However, in that study, novel words were presented in isolation (e.g., /boome/ paired with a

[1]Of course, some event concepts are expressed as nouns (e.g., earthquake, rehearsal), but a learning bias need not be a deterministic rule (cf. Grimshaw, 1981; Macnamara, 1982).

rotating motion, and /seppu/ paired with a wiggling motion), rather than in syntactic frames. Therefore, no grammatical categorization was involved, rendering this weaker evidence for children's using the grammatical category of a novel word to infer its conceptual category. To our knowledge, there is only one study that documented knowledge of the verb-event link in children younger than 20 months. Echols and Marti (2004), using a preferential looking task with 18-month-old English-learning infants, showed a significant interaction between labeling condition (noun vs. verb) and looking choice (familiar object new action vs. familiar action new object), suggesting different ways of labeling (e.g., noun: "that's a *gep*"; verb: "it's *gep*ping") made a difference in infants' looking choice. Beyond this, there is not much other evidence for infants' verb-event knowledge at this young age; replication and extension are urgently needed.

Taken together, the picture of early knowledge of the verb-event link and its deployment in learning novel verbs is quite unclear and elusive. Current literature seems to suggest that the ability to use the grammatical category *verb* to infer its conceptual category *event* may be established around the end of the second year, but evidence prior to that is less clear and less robust. Here we aim to improve our understanding of the early developmental trajectory of the verb-event link. For the correspondence between the grammatical category *verb* and the conceptual category *event* to form, it requires certain conceptual and linguistic underpinnings that support categorizations of *verb* and *event*. When are these underpinnings in place? We review the relevant literature below.

For the conceptual underpinnings, research on event concept development has provided evidence that by the end of the first year, infants have the conceptual foundations to support a range of verb meanings, including verbs encoding moving trajectories (e.g., *fall*), causal results (e.g., *open*), intentional actions (e.g., *get*), transactions (e.g., *give*), as well as psychological states (e.g., *see*) (Buresh, Wilson-Brune, & Woodward, 2006). Infants demonstrate sensitivity to fundamental event relations such as agency and goal-directedness very early in development: as early as 3 months of age, infants are able to detect an actor's goal (Sommerville, Woodward, & Needham, 2005); 5-month-olds attribute goals to human agents as well as to non-human agents with animacy features like self–propulsion (Luo & Baillargeon, 2005); and by 12 months of age, infants are able to interpret and draw inferences about goal-directed behaviors of rational agents (Gergely & Csibra, 2003; Gergely, Nádasdy, Csibra, & Bíró, 1995), and are able to predict the ending of a rational goal-directed motion event based on its beginning (Wagner & Carey, 2005). In addition, there is evidence that young infants are aware of certain types of events. For example, knowledge of containment events is seen as early as 2.5 months: Hespos and Baillargeon (2001) found that 2.5- and 3.5-month-olds recognized an object could be lowered inside a container with an open but not a closed top. Infants' sensitivity to causal relations in events have also been shown to develop early: Leslie and Keeble (1987) found that reversal of a causal event elicited more interest than the reversal of a non-causal event in 7-month-olds; Casasola and Cohen (2000) found 14-month-olds were able to distinguish pushing and pulling events that only differ in the causal relations among participants.

Regarding the linguistic underpinnings, we know three things. First, analyses of child-directed speech corpora have identified various morphosyntactic cues to grammatical categories in speech to children (Cartwright & Brent, 1997; Maratsos & Chalkley, 1980; Mintz, 2003, 2006; Mintz, Newport, & Bever, 2002; Redington, Crater, & Finch, 1998). For example, frequent frames like "the __ is" or "you __ it" are good cues to nouns and verbs, respectively (Mintz, 2003). Second, evidence from behavioral studies has shown that young children are sensitive to these cues; for example, Santelmann and Jusczyk (1998) showed that 18-month-old English-learning infants could distinguish a well-formed morphosyntactic dependency of verbs—the "is __ing" dependency, from an ungrammatical ("can __ ing") dependency. Third, young children were shown to be able to utilize these cues for novel word categorization (Bernal, Dehaene-Lambertz, Millotte, & Christophe, 2010; Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004; Mintz, 2006; Peterson-Hicks, 2006) (also see Shi, 2014 for a review). Evidence for children's early categorization of *verbs* comes from both neurological measures and behavioral studies. Bernal et al. (2010) observed an early left-lateralized (ELAN) brain response[2] in 24-month-old French toddlers when

[2]ELAN is an ERP response that most often occurs when linguistic stimuli violate word-category or phrase structure rules.

hearing a noun incorrectly inserted in a verb position (or vice versa). In addition, two behavioral studies using Head-Turn Preference Procedure (Jusczyk & Aslin, 1995) demonstrated verb categorization in younger children. Peterson-Hicks (2006) showed that 15-month-old infants familiarized with novel words in frequent verb frames (e.g. "can *pell*", "will *pell*") listened longer to those words presented in ungrammatical test frames (e.g. "her *pell*", "my *pell*") than those presented in grammatical test frames; importantly, the grammatical frames at test were different from the frames used in familiarization (e.g., infants familiarized with "can *pell*" were tested with "will *pell*"). This suggested that infants this age were able to use preceding auxiliaries to categorize a novel word into the verb category. Mintz (2006) reported that even younger infants were able to do so: 12-month-olds familiarized with novel words in frequent verb frames (e.g. "can *gorp*", "to *gorp*"), listened longer to those words presented in ungrammatical test frames (e.g. "the *gorp*", "a *gorp*") than those presented in novel grammatical test frames (e.g. "to *gorp*" for those who heard "can *gorp*" during familiarization, and "can *gorp*" for those who heard "to *gorp*").

In summary, our synthesis of previous findings is this: on one hand, the verb-event link is seen established and deployed in verb learning towards the end of the second year across a few different languages, and evidence before that is sparse or unclear; on the other hand, the underpinnings that support its establishment seem to be ready as early as the end of the first year of life. What happens during this 8- to 12-month gap? The present study takes as its primary goal to more accurately map the development trajectory of the verb-event link, by zooming in on the window between 12 and 20 months; specifically, we look at 14- and 18-month-old English-learning infants. A secondary aim of the present study is to provide evidence that young English-learning infants are not only sensitive to morphological cues to verbs (Lidz, Omaki, & Orita, 2012; Santelmann & Jusczyk, 1998), and are able to use the cues for novel verb categorization (Mintz, 2006; Peterson-Hicks, 2006), but also are able to utilize this categorization in learning novel verb meanings. The morphosyntactic cue used in the current study is the "is __ing" frame.

In two experiments using the Habituation-Switch Paradigm (Casasola & Cohen, 2000; Werker, Cohen, Lloyd, Casasola, & Stager, 1998; Younger & Cohen, 1986), we examined 14- and 18-month-old English-learning infants' ability to extract morphosyntactic information to categorize novel verbs and identify the event concepts these verbs pick out. In Experiment 1, we habituated infants with two events of an animated animal performing self-propelled actions (a penguin spinning event, and a penguin cartwheeling event), each labeled with a different novel verb embedded in intransitive "is __ing" frames ("it's *dok*ing", and "it's *pratch*ing"), and tested them on a new event-verb combination (e.g., spinning labeled with "doke" at habituation was labeled with "pratch" at test). In this task, successful acquisition of the novel verbs' meanings would require (a) the ability to use the morphosyntactic information to categorize the novel words as verbs and (b) the knowledge that verbs pick out event categories. These would lead infants to form the hypothesis that the verb "doke" picks out the spinning event and "pratch" the cartwheeling event, and consequently, they would be surprised to see a familiar event labeled with a different verb, reflected in a recovery of attention at test. However, strategies other than having the verb-event knowledge may also lead to a recovery of attention at test; Experiment 2 addresses one such alternative.

Note that in our task, successful learning only requires *identifying* the event that falls under the concept labeled by the verb (e.g., identify that "doke" picks out the spinning event, from a penguin spinning scenario), but does not require *extending* the verb to the full range of events that fall under that concept (e.g., extend "doke" to apply to other instances of spinning, with different agents). While we recognize that both the identifying and the extending components would provide evidence for richer verb knowledge, in the current study, we only focus on the first component. We made this design choice because infants may be able to identify the target event but not view that event under a concept that extends in a way that matches adult intuitions. For example, they may link the verb to a narrower event concept than the one we had in mind. This is a possible outcome given that verbs differ in how broadly they extend (e.g., "fly" applies to both birds and airplanes, but "swim" applies to fish but not submarines), and that learners may be conservative about the extension of an unknown verb. Infants' performance in a design that strips off the extending component will allow us to see a clean picture of their ability to use the morphosyntacitc cues to verb-hood as evidence that the novel word labels an event. We leave examination of the "extending" component to future work.

Experiment 1

Method

Participants

Forty-two English-speaking infants (21 boys, 21 girls) with a mean age of 14;02 (range: 13;19–14;16) and 34 English-speaking infants (17 boys, 17 girls) with a mean age of 18;00 months (range: 17;15–18;16) participated in this experiment. Eighteen additional infants (9 from the 14-month group, 9 from the 18-month group) were tested but excluded from the final sample because of experimental error (1), being unable to finish the experiment (7), and failure to habituate (10). All infants were recruited through the Infant and Child Studies Consortium Database at University of Maryland College Park.

Stimuli

The experimental stimuli included (1) main visual and linguistic stimuli used for habituation and test phases, (2) visual and linguistic stimuli used for pre- and post-test phases, and (3) an attention-getter visual stimulus.

The main visual stimuli were computer-animated objects engaged in different self-propelled actions—a penguin engaged in a spinning action and a cartwheeling action. The animal penguin, and the spinning-like and the cartwheeling-like actions were chosen because infants were not likely to have labels for them.[3] Each event lasted 15 s and was repeated up to two times per trial, giving a maximum trial length of approximately 30 s. These visual stimuli were paired with sentences containing intransitive novel verbs labeling the events, with the pronoun "it" referring to the animal. The sentences were all in present progressive tense/aspect. For example, "it's *dok*ing!" and "it's *pratch*ing!". During the 15-s event, the linguistic stimuli were played six times, in slightly different frames—"Look, it's *dok*ing", "Wow, it's *dok*ing", "Yay, it's *dok*ing", "Do you see it *dok*ing"—with each utterance lasting about 2–3 s.

The stimuli used at the beginning (pre-test) and end of the experiment (post-test) were a flower bouncing event and the sentence "it's *sneb*bing!" paired with the event. The duration of this event was the same as other events (i.e., 15 s), and was also played up to two times in its trial (i.e., 30 s maximum). The attention-getter stimulus was a video of a butterfly perched on a leaf.

Apparatus

The experiment was run in the Habit version 1.0. program (Cohen, Atkinson, & Chaput, 2004). The stimuli were played on a Samsung wall-mounted 51-in. plasma television, with built-in speakers, located 66 in. away from the chair (or highchair) where the infants were seated. A Sony EVI-D100 video camera was placed directly above the TV monitor. The camera was connected to a color TFT LCD monitor to allow the experimenter to observe the infant's eye fixation to the screen from a different room, and conduct online coding. Additionally, the video of the child, with a picture-in-picture display of what was on the TV screen, was captured on an iMac computer using QuickTime.

Design

This study used the Habituation-Switch Paradigm (Casasola & Cohen, 2000; Fennell & Werker, 2003; Werker et al., 1998; Younger & Cohen, 1986), the basic design logic of which is this: infants are habituated to two pairs of stimuli (e.g. word A to object A, word B to object B), and are "tested on their ability to detect a switch in the pairing" (Fennell & Werker, 2003) (e.g., word A to object B). With this paradigm, the current study tested infants' ability to learn novel verbs from pairs of events and sentences, by first presenting some event-sentence pairs repeatedly over and over again, and when the infant reaches a pre-set habituation criterion, a new event-sentence combination was introduced; we measured the amount of attention recovery upon getting the novel combination.

[3]While "spin" and "cartwheel" are not on the CDI, "penguin" is; and our CDI search confirmed this––only three of our participants (across both experiments) reportedly had produced the word "penguin".

Table 1a. Stimuli used in Experiment 1 (see Table 1b for how they were ordered).

Stimuli Number	Video	Audio
0	flower jumping	*it's snebbing*
1	penguin cartwheeling	*it's pratching*
2	penguin spinning	*it's doking*
3	penguin cartwheeling	*it's doking*
4	penguin spinning	*it's pratching*

Table 1b. Stimuli in different condition-order assignments in Experiment 1 (see Table 1a for the stimuli descriptions, in correspondence to the numberings).

	Same A	Same B	Switch A	Switch B
Pre-test		0		
Habituation		1 & 2 randomized by block of three trials		
Test trial #1	1	2	3	4
Test trial #2	2	1	4	3
Post-test		0		

The experiment consisted of the following phases––a pre-test phase, a habituation phase, a test phase, and a post-test phase. The task began with one pre-test trial, where a flower bouncing event paired with "it's *sneb*bing" was shown. Then, during the habituation phase, infants were presented trials of event-sentence pairs[4] until they reached a pre-set *criterion of habituation* or the preset maximum of 12 trials, whichever came first. In this experiment, the criterion of habituation (following Werker, Fennell, Corcoran, & Stager, 2002) was when an infant's average looking time during any block dropped to less than 65% of average looking time of the most-attended block (i.e., the block that has the longest total looking time); any three consecutive trials made a block. Therefore, the total number of habituation trials each infant received was different. These trials were randomized by blocks of three, to avoid the same event-sentence pair occurring more than two times in a row. Infants who did not meet the criterion of habituation were excluded from the sample of analysis, classified as exclusion due to *failure to habituate*. When infants reached the criterion of habituation or when the 12 trials were all played, the habituation phase was stopped and the test phase began.

At test, all infants were presented a fixed number of 2 trials. These two trials were either familiar event-sentence combinations from habituation (*Same condition*), or novel combinations (*Switch condition*). Half of the infants were assigned to the Same condition and the other half to the Switch condition. Condition was designed to be a between-subjects factor rather than within, because the latter may introduce noise of its own: in a within-subjects design, the two test trials are either Same followed by Switch, or Switch followed by Same; in the latter case, the Same trial, by virtue of following the Switch trial, becomes a "switch" trial (switching from Switch to Same), which will possibly elicit more attention for reasons other than the one of interest. A between-subjects design allows us to avoid this problem. Each condition had two orders (*Order A* and *Order B*), differing in the order of the two test trials. Following the test trials, one post-test trial (same as pre-test) was presented to control for fatigue. See Table 1a and 1b for a summary of the design.

Procedure and coding

The procedure began with obtaining the parent(s)' informed consent and collecting the MacArthur Communicative Development Inventory (MCDI) (Fenson et al., 1994) data.[5] When the infant was ready, he/she was led to the test room where the TV monitor and the digital camera were located.

[4]We did not counterbalance the label-event pairings in Experiment 1 (so it's always "doke" paired with spinning and "pratch" paired with cartwheeling during habituation), because there was no reason to expect that this pairing would matter; we counterbalanced them in Experiment 2 to make sure that that was true.

[5]We collect MCDI data as part of the regular procedure in the lab; for the current study, we did not predict an effect of vocabulary, so any vocabulary analyses would be post-hoc. We discuss vocabulary analyses in the "General Discussion" section.

The parent came to the test room with the infant and stayed with him/her during the entire process. The infant sat either in the parent's lap or in a highchair in front of the monitor. We took precautions to ensure that the parent could not influence the child's behavior, by explicitly instructing the parent not to direct the infant's attention in any way, and by asking the parent to wear a visor (to block sight) in cases where she chose to hold the infants on her lap.

The experimenter began the experiment in the control room next door, by setting up the computer to display the attention-getter stimulus. Once the infant looked at the attention-getter, the experimenter pressed the space bar on the computer to begin the first trial, such that the attention-getter on the screen was replaced by the pre-test trial. For each trial, the experimenter pressed a key on the computer when the infant attended to the screen, held the key for as long as the attention was maintained, and released it as soon as the infant looked away. A minimum of 2-s attention was required for it to be registered as a look––that is, if the child did not continuously attend to the stimulus for a minimum of 2 s, the program would not count this look toward its calculation. If the infant looked away for more than 2 continuous seconds during a trial, the trial ended; if not, the trial continued to its end. At the end of each trial, the attention-getter came back on the screen to recapture the infant's attention, and stayed on the screen until the start of next trial. This is a standard adopted by most other studies using this paradigm (e.g., Casasola & Cohen, 2000). The experimenter was not able to hear the audio, and so was unaware of what phase of the experiment the child was in.

Inter-coder reliability was obtained by comparing online coding (as described above) and offline-coding from a second coder on 10% randomly selected infants' recordings from the sample. The Pearson-product moment correlations of the online and offline codings ranged from 0.986–0.999, with a mean of 0.997.

Measurement

The dependent variable for analysis was *looking time*, i.e., the amount of time spent on looking at the visual stimuli during a selected window. We used looking time to test for two things: (a) successful *habituation* (controlled for fatigue) and (b) *dishabituation* at test. To test for habituation, we compared average looking time of the first and last habituation blocks to see if there was a decrease in attention over the habituation trials. To control for fatigue, if infants' attention recovered upon seeing the post-test trial––indexed by a significant increase in average looking time from the last habituation block to post-test, we took that to mean habituation without fatigue. We also compared pre-test and post-test, but did not use this comparison to determine fatigue, because a consistent relation between the two was not established by previous studies––some studies showed that attention in post-test recovered to the same level as in pre-test (e.g., Fennell & Werker, 2003), whereas some showed that post-test attention was no less than 25% of pre-test attention (e.g., Oshima-Takane et al., 2011). To test for dishabituation, we compared average looking time of the last two habituation trials[6] with that of the two test trials; and we took significant increase of looking time from habituation to test as indicator of dishabituation. We chose to use the last two habituation trials, rather than the last three which made a block, because we wanted to compare the same number of trials in habituation and test.

Predictions and results

We predicted all infants to be habituated during the habituation phase, indicated by decreased attention from the first habituation block to the last. For infants in the Same condition, we predicted them to remain habituated––that is, to exhibit relatively short looking times at test. For those in the Switch condition, we predicted dishabituation, if they learned the association between the events and the novel verbs; this would be reflected by an increase in looking time from the last two habituation trials to the test trials. Since our method predicted a single direction of difference in all cases, we

[6]Previous studies adopted different baselines. Some studies used mean of the last four habituation trials as the baseline for comparison (Oshima-Takane et al., 2011); and others, had an additional trial following habituation, which played the same event-verb combination, and used looking time of that trial as baseline (e.g., Oshima-Takane et al., 2011).

used a one-tailed t-test in our planned comparisons. We adopted a significance level of 0.05 for all statistical analyses performed in this article.

(i) **Habituation controlled for fatigue**. Looking time data from the habituation phase were first entered into a three-way mixed ANOVA with *age group* (14- vs. 18-month-olds) and *condition* (Same vs. Switch) as between-participants factors, and with *trial block* (first habituation block vs. last habituation block) as a within-participants factor. This analysis revealed a main effect of age group, $F(1, 72) = 12.46$, $p < 0.001$;[7] and a main effect of trial block, $F(1, 72) = 371.30$, $p < 0.001$. There was no main effect of condition, suggesting that the two conditions did not make a difference during the habituation phase.

Due to the main effect of age, separate analyses for the two age groups were conducted. Analyses revealed that participants from both age groups were successfully habituated, indicated by a decrease in attention from the first block to the last block. For 14-month-olds, there was a main effect of trial block, $F(1, 40) = 127.47$, $p < 0.001$; and planned comparison between the first and last habituation block, using one-tailed t-test, revealed that mean looking time of the last block ($M = 12.02$ s, $SD = 5.00$ s) was significantly less than that of the first block ($M = 21.45$ s, $SD = 7.55$ s), $t(41) = 11.43$, $p < 0.001$. For 18-month-olds, there was also a main effect of trial block, $F(1, 32) = 395.56$, $p < 0.001$; and planned t-tested revealed that the mean looking time of the last habituation block ($M = 15.51$ s, $SD = 3.66$ s) was significantly less than that of the first block ($M = 26.4$ s, $SD = 15.35$ s), $t(33) = 19.99$, $p < 0.001$.

To make sure this habituation was not due to fatigue, we compared the post-test trial and the last habituation block, as planned, using one-tailed t-test. We found that for 14-month-olds, the mean looking time of the post-test ($M = 16.77$ s, $SD = 10.35$ s) was significantly greater than that of the last block ($M = 12.02$ s, $SD = 5.00$ s), $t(41) = 2.89$, $p < 0.01$. This showed that infants' attention recovered from habituation upon seeing the perceptually distinct post-test trial, suggesting they were not fatigued. Similarly, for 18-month-olds, post-test attention ($M = 22.15$ s, $SD = 9.47$ s) was also significantly greater than that of the last habituation block ($M = 15.51$ s, $SD = 3.66$ s), $t(33) = 4.43$, $p < 0.001$.

We also compared post-test to pre-test, and found that for both age groups, attention in post-test did not recover to the level of pre-test. Instead, infants generally lost some attention in post-test: 14-month-olds lost about 25% attention in post-test ($M = 16.77$ s, $SD = 10.35$ s) compared to pre-test ($M = 21.97$ s, $SD = 9.80$ s), $t(41) = 2.63$, $p < 0.01$, one-tailed; and 18-month-olds lost about 15% attention in post-test ($M = 22.15$ s, $SD = 19.47$ s) compared to pre-test ($M = 26.31$ s, $SD = 9.47$ s), $t(33) = 2.15$, $p = 0.02$, one-tailed.

The above results are illustrated in Figure 1a and 1b. Table 2a summarizes the mean number of habituation trials per condition per age group, which was quite uniform.

(ii) **Dishabituation analysis**. Having determined that infants were successfully habituated, we then conducted the main set of analyses on their performance at test. Data were first entered into a three-way mixed ANOVA with *age group* (14- vs. 18-month-olds) and *condition* (Same vs. Switch) as between-participants factors, and with *trial block* (last two habituation trials vs. two test trials) as a within-participants factor. This analysis revealed a main effect of condition, $F(1, 72) = 9.64$, $p < 0.01$; a main effect of trial block, $F(1, 72) = 18.00$, $p < 0.001$; but no main effect of age group, $F(1, 72) = 2.53$, $p = 0.12$. There was a significant interaction between condition and trial block, $F(1, 72) = 7.61$, $p < 0.01$. Specifically, for the Same condition, attention during test ($M = 11.49$ s, $SD = 7.72$ s) was not significantly different from attention in the last two habituation trials ($M = 10.00$ s, $SD = 5.27$ s), $t(37) = -1.13$, $p = 0.13$, one-tailed; for the Switch condition, however, attention during test ($M = 17.74$ s, $SD = 7.83$ s) was significantly greater than that in the last two habituation trials ($M = 10.73$ s, $SD = 14.91$ s), $t(37) = -4.64$, $p < 0.001$, one-

[7]The significance level for all statistical tests performed in this paper was 0.05; we also indicate probabilities lower than this level.

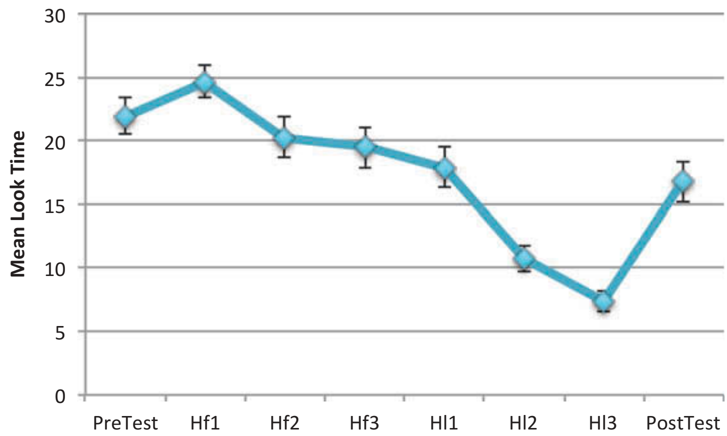

Figure 1a. 14-month-olds' habituation timeline in Experiment 1 (Hf1-3: first, second, and third habituation trial; Hl1-3: third-to-last, second-to-last, and last habituation trial; error bars are standard errors).

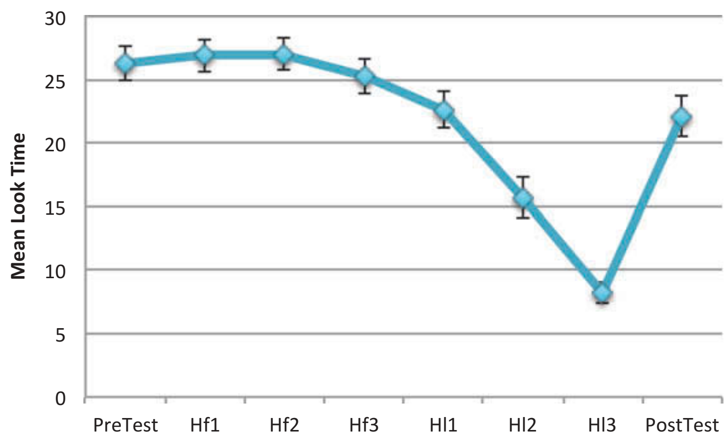

Figure 1b. 18-month-olds' habituation timeline in Experiment 1 (Hf1-3: first, second, and third habituation trial; Hl1-3: third-to-last, second-to-last, and last habituation trial; error bars are standard errors).

Table 2a. Mean number of habituation trials per condition per age group in Experiment 1.

	Same	Switch
14 m	7.81 (*SD* = 2.54 s)	7.76 (*SD* = 2.95 s)
18 m	7.47 (*SD* = 1.87 s)	7.47 (*SD* = 2.50 s)

tailed. These results suggested the following: first, 14- and 18-month-olds did not demonstrate different performance patterns; second, infants in this experiment dishabituated to the test stimuli only in the Switch condition, but not in the Same condition.

Although there was no significant age effect, it does not mean both age groups (equally) strongly showed the effect. To have a better idea of the developmental picture, we still analyzed the data separated for the two age groups. Data from each age group were entered a two-way mixed ANOVA with *trial block* (last two habituation trials vs. two test trials) as within-subject factor and *condition* (Same vs. Switch) as between-subject factors. For 14-month-old infants, there was a main effect of condition, $F(1, 40) = 6.15$, $p = 0.02$; a main effect of trial block, $F(1, 40) = 15.83$, $p < 0.01$; and a significant interaction between condition and trial block, $F(1, 40) = 7.41$, $p < 0.01$. Specifically, for the Same condition, attention during test ($M = 10.82$ s, $SD = 7.29$ s) was not significantly different from the last two habituation trials ($M = 9.17$ s, $SD = 5.06$ s): $t(20) = -0.86$, $p = 0.20$, one-tailed; but for the Switch condition, attention during test ($M = 17.78$ s, $SD = 7.29$ s) was significantly greater than that of the last two habituation trials ($M = 8.97$ s, $SD = 4.49$ s), $t(20) = -4.88$, $p < 0.001$. For 18-month-old infants, there was a marginally significant effect of condition, $F(1, 32) = 3.77$, $p = 0.06$; and a marginally significant effect of trial block, $F(1, 32) = 3.89$, $p = 0.06$. There was no interaction between condition and trial block, $F(1, 32) = 1.30$, $p = 0.26$. A closer look into each condition revealed the following: for the Same condition, attention during test ($M = 12.31$ s, $SD = 8.47$ s) was not significantly different from that during the last two habituation trials ($M = 11.03$ s, $SD = 5.49$ s), $t(16) = -0.7112$, $p = 0.24$, one-tailed; but for the Switch condition, attention during test ($M = 17.69$ s, $SD = 8.69$ s) was significantly greater than that during the last two habituation trials ($M = 12.89$ s, $SD = 4.64$ s), $t(16) = -1.92$, $p = 0.04$, one-tailed. See Figure 2a and 2b for illustrations of the results.

Discussion

The results of Experiment 1 showed that infants in the two conditions performed differently. First, they did not dishabituate in the Same condition. Second, in the Switch condition, 14-month-olds clearly dishabituated, and 18-month-olds demonstrated a marginally significant effect of trial block, with attention increased from the last two habituation trials to the test trials. This asymmetry between conditions was consistent with the hypothesis that infants were able to recruit morphosyntactic cues online to categorize novel verbs and map novel verbs to event concepts. However, the results are also consistent with an alternative explanation: infants were using some strategy that did not require syntactic analysis or categorization to succeed in the task. Such a strategy would allow infants to track mismatches of any kind, triggering recovery of attention in the Switch condition. For example, if infants represented the audio as a whole (as opposed to analyzing it into syntactic units), and represented the video as a whole (as opposed to analyzing it into an event and a participant), and tracked the connection between them––i.e., establishing an audio-video link, instead of a verb-event link; once the original connection was broken (e.g., audio A was originally linked to video A, but now linked to video B), there was a recovery of attention. Therefore, this strategy might have led to the same overall pattern observed in Experiment 1. This possibility is especially likely for 14-month-olds, given the findings of Santelmann and Jusczyk (1998) that 15-month-olds are not yet aware of the "is __ing" dependency and that this was the morphological cue we used to indicate that the novel word was a verb in the current experiment. Experiment 2 was designed to address this possibility.

To disentangle the general-purpose mismatch-detecting strategy from true linguistic categorization based on the verb-event link, there needs to be a condition where the audio-video connection gets switched, but the word-concept mapping remains the same. If infants show no recovery of attention in this condition, then this would suggest they were not using mismatch-detecting strategy in Experiment 1. In Experiment 2, we added such a condition.

Experiment 2

Method

Participants

Forty-three English-speaking infants (21 boys, 22 girls) with a mean age of 14;05 months (range: 13;12–14;20) and Forty-one English-speaking infants (20 boys, 21 girls) with a mean age of 18;1 months (range: 17;12–18;19) participated in this experiment. Twenty-five additional infants

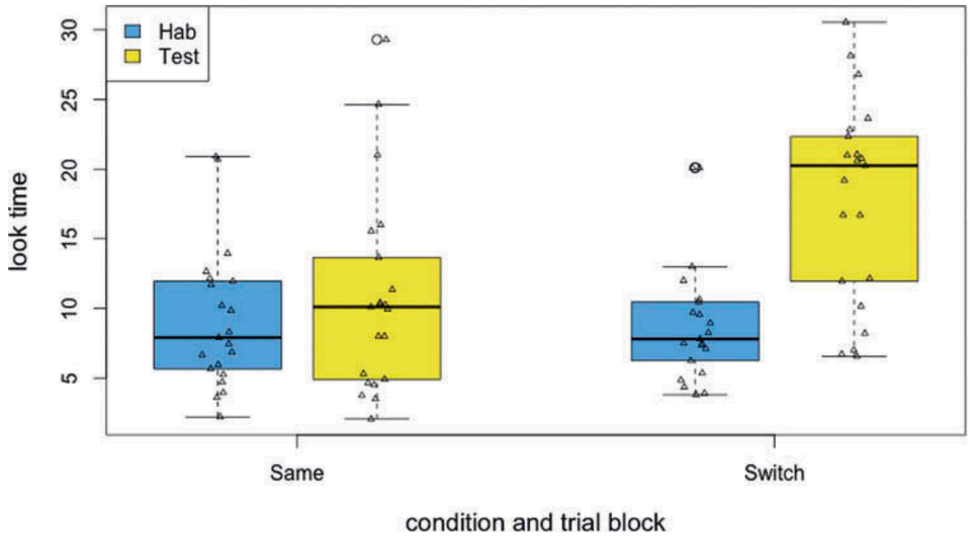

Figure 2a. 14-month-olds's looking time across trial blocks in different conditions in Experiment 1 (triangles are individual participants' data points).

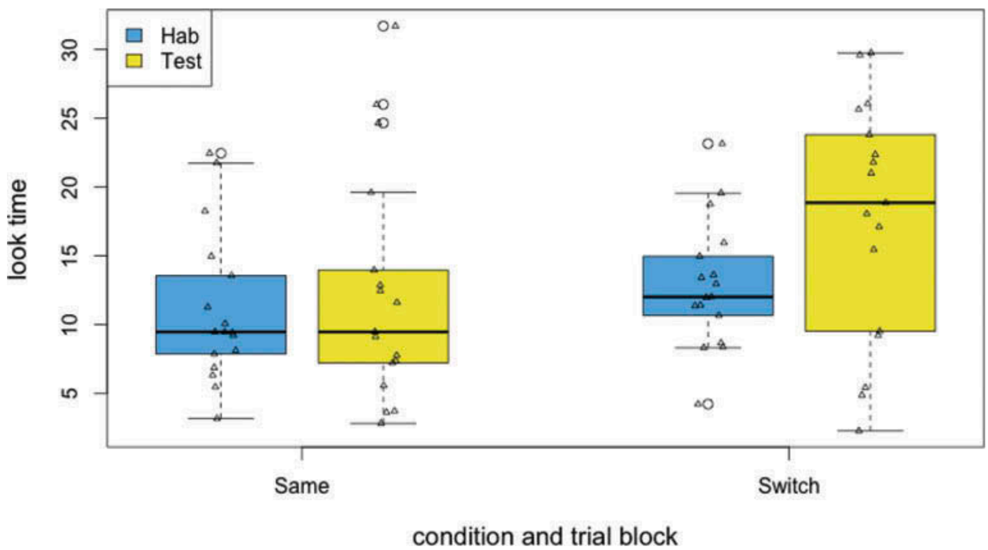

Figure 2b. 18-month-olds's looking time across trial blocks in different conditions in Experiment 1 (triangles are individual participants' data points).

(11 from the 14-month group, 14 from the 18-month group) were tested but excluded from the final sample because of experimental error (3), being unable to finish the experiment (6), parental interference (1), and failure to habituate (15). All infants were recruited through the Infant and Child Studies Consortium at University of Maryland College Park.

Stimuli

The visual stimuli were same as those used in Experiment 1. The linguistic stimuli paired with these visual stimuli were sentences containing an intransitive novel verb labeling the action (e.g., "it's *dok*ing"), and sentences containing a novel noun labeling the animal performing the action (e.g., "it's a *pratch*"). The pairing between the visual stimuli and linguistic stimuli were counterbalanced such that one group of infants heard the verb "doke" label the spinning event and the noun "pratch" labeling the penguin, while the other group heard the verb "pratch" label the spinning event and "doke" labeling the penguin. The same attention-getter and post-test stimuli were used as those in Experiment 1.

Apparatus

The experimental set-up and apparatus were the same as those used in Experiment 1.

Design

A major change in Experiment 2 was the introduction of a third condition such that there were three conditions at test——the *Same condition*, where a familiar audio-video combination from habituation was presented; the *Switch-Noun condition*, where the audio with a novel noun was paired with a different event but the same object; and the *Switch-Verb condition*, where the audio with a novel verb was paired with a different event but the same object. These two types of switch conditions were designed to tease apart the general-purpose mismatch-detecting strategy from true linguistic knowledge, because both conditions involve a switch in the pairing between the video and the audio, but only the Switch-Verb condition involves a change in word meaning (since the novel verb is used to label a different event). Infants were randomly assigned to one of the three conditions. See Tables 3a and 3b for an example illustrating the design in Experiment 2.

On top of this major difference in design, Experiment 2 also differed from Experiment 1 in a few other aspects. First, Experiment 2 did not have a pre-test phase, for two reasons: (a) we found in Experiment 1 that infants' attention during post-test did not recover to the same level as pre-test, and previous studies did not establish a consistent ratio (between post-test and pre-test looking time) to be used as a threshold to determine fatigue (see "Measurement" section); and more importantly, (b) the presence of pre-test stimuli might make the post-test stimuli less novel to infants, making it hard to say if the decreased attention in post-test was due to fatigue or less interest in a familiar stimuli. Second, the two test trials in Experiment 1 were different (e.g., one trial had the spinning event paired with "it's *pratch*ing", and the other had the cartwheeling event paired with "it's *dok*ing"), whereas those in Experiment 2 were the same (e.g., both trials had the spinning event paired with "it's *pratch*ing" in the Switch-Verb condition; both trials had the spinning event paired with "it's a doke" in the Switch-Noun condition). This was because the two ways of switching in Experiment 2 were different in nature—one maintained the meaning of the novel word (Switch-Noun), the other changed the meaning (Switch-Verb), and thus mixing them would have resulted in a different design.

Procedure and coding

The procedure was the same as Experiment 1, except for absence of pre-test phase. Inter-coder reliability was obtained by comparing online coding (as described above) and offline-coding from a second coder on 10% randomly selected infants' recordings from the sample. The Pearson-product moment correlations of the online and offline codings ranged from 0.993–0.999, with a mean of 0.997.

Measurement

As in Experiment 1, we used *looking time* as dependent variable to test for habituation and dishabituation.

Predictions and results

We predicted all infants to be habituated during the habituation phase. For infants in the Same condition, we predicted them to remain habituated at test. For those in the Switch-Verb condition, we predicted them to dishabituate at test. For those in the Switch-Noun condition, however, our predictions would depend on whether infants were using a general-purpose mismatch-detecting strategy, or were truly analyzing the linguistic stimuli into meaningful units and knew the verb-event and noun-object links––if the former, we would predict them to dishabituate at test; if the latter, we would predict them to remain habituated; in either case, we predict a single direction of difference between the mean looking time during test and that during the last two habituation trials. We therefore used a one-tailed *t*-test for all our analyses.

(i) **Habituation controlled for fatigue**. Similar analyses as in Experiment 1 were conducted, and main findings were summarized as following. First, the three-way mixed ANOVA revealed a main effect of trial block, F(1, 78) = 324.510, $p < 0.001$. There was no main effect of condition––F(2, 78) = 0.54, $p = 0.58$, no main effect of age––F(1, 78) = 1.29, $p = 0.14$, suggesting that both age groups had a similar pattern of habituation across conditions. A closer look into the main effect of trial block revealed that mean looking time of the last block (M = 12.94 s, SD = 4.24 s) was significantly less than that of the first block (M = 21.36 s, SD = 6.74 s), t(83) = 18.18, $p < 0.001$. These results suggested infants were successfully habituated. Second, we compared the post-test trial and the last habituation block and confirmed that habituation was not due to fatigue: the mean looking time of the post-test (M = 18.65 s, SD = 9.10 s) was significantly greater than that of the last block (M = 12.94 s, SD = 4.24 s), t(83) = 5.95, $p < 0.001$.

We did not separately analyze the data by age group due to no main effect of age; but we illustrate 14- and 18-month-olds' habituation results separately in Figure 3a and 3b; and Table 2b summarizes the mean number of habituation trials per condition per age group, where not much variation was seen.

(ii) **Dishabituation analysis**. The three-way mixed ANOVA––with *age group* (14- vs. 18-month-olds) and *condition* (Same vs. Switch-Noun vs. Switch-Verb) as between-participant factors, and with *trial block* (last two habituation trials vs. two test trials) as a within-participant factor––revealed a main effect of condition, F(1, 78) = 3.94, $p = 0.02$; a main effect of trial block, F(1, 78) = 8.46, $p < 0.01$; no main effect of age, F(1, 78) = 0.28, $p = 0.60$; a significant interaction between condition and trial block, F(2, 78) = 24.33, $p < 0.001$; and a significant interaction between age group, condition, and trial block, F(2, 78) = 3.61, $p = 0.03$. This three-way interaction invited us to look closer into the two age groups to see how their performance patterns differed. Therefore, data were then analyzed separately for the two age groups, each with a two-way mixed ANOVA with *trial block* (last two habituation trials vs. two test trials) as a within-participant factor and *condition* (Same vs. Switch-Noun vs. Switch-Verb) as a between-participant factor.

For 14-month-olds, there was a main effect of trial block, F(1, 40) = 7.50, $p < 0.01$; and a significant interaction of condition and trial block, F(2, 40) = 14.43, $p < 0.001$. Specifically, for the Same condition, attention during test (M = 8.63 s, SD = 4.33 s) was significantly less than that of the last two habituation trials (M = 13.07 s, SD = 6.43 s), t(14) = 3.00, $p < 0.01$, one-tailed; for Switch-Verb condition, test (M = 15.5 s, SD = 8.13 s) has a longer looking time than habituation (M = 9.37 s, SD = 4.98 s), t(13) = −3.11, $p < 0.01$, one-tailed; and for Switch-Noun condition, attention during test (M = 14.77 s, SD = 5.57 s) was significantly greater than that habituation (M = 8.01 s, SD = 2.23 s), t (13) = −4.35, $p < 0.001$, one-tailed. These suggested that 14-month-old infants dishabituated to test stimuli in both the Switch-Noun and Switch-Verb conditions, but not in the Same condition. See Figure 4a for illustration.

For 18-month-olds, there was a main effect of condition, F(2, 38) = 5.305, $p < 0.01$; and a significant interaction between condition and trial block, F(2, 38) = 13.376, $p < 0.001$. Specifically, for the Same condition, attention during test (M = 7.72 s, SD = 3.41 s) was significantly less than that during the last two habituation trials (M = 11.02 s, SD = 4.81 s), t(12) = 3.56, $p < 0.01$, one-tailed; for Switch-Verb condition, test (M = 16.78 s, SD = 5.74 s) had a significantly longer looking time than habituation (M = 12.01 s, SD = 2.28 s), t(13) = −3.78, $p = 0.001$; and for the Switch-Noun condition,

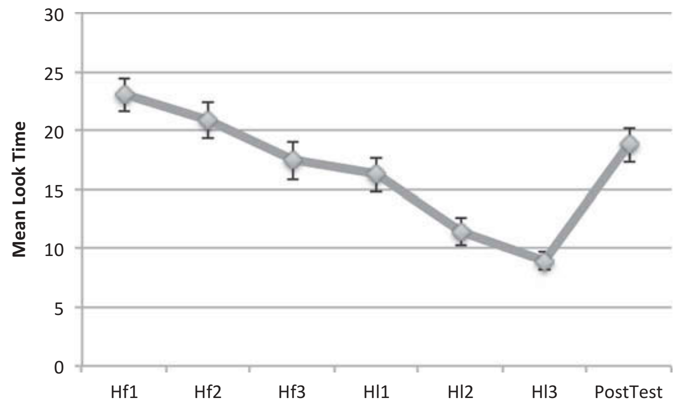

Figure 3a. 14-month-olds' habituation timeline in Experiment 2 (Hf1-3: first, second, and third habituation trial; Hl1-3: third-to-last, second-to-last, and last habituation trial; error bars are standard errors).

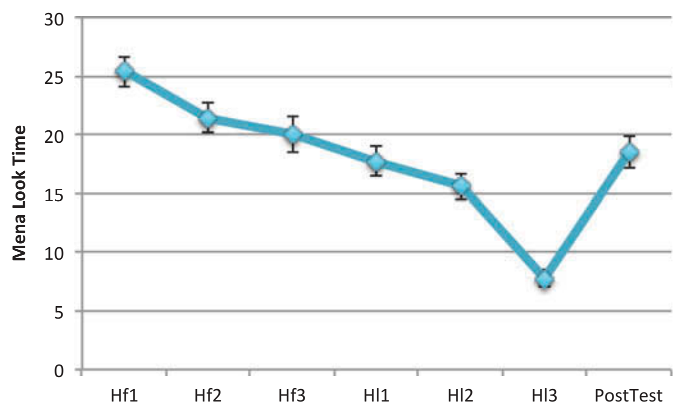

Figure 3b. 18-month-olds' habituation timeline in Experiment 2 (Hf1-3: first, second, and third habituation trial; Hl1-3: third-to-last, second-to-last, and last habituation trial; error bars are standard errors).

Table 2b. Mean number of habituation trials per condition per age group in Experiment 2.

	Same	Switch-Noun	Switch-Verb
14 m	7.8 (*SD* = 2.40)	7.21 (*SD* = 2.52)	7.21 (*SD* = 1.67)
18 m	7.46 (*SD* = 1.85)	8 (*SD* = 2.45)	7.79 (*SD* = 2.08)

attention during test (M = 12.33 s, SD = 5.32 s) was not significantly different than that of habituation (M = 11.98 s, SD = 4.41 s), $t(13) = -0.33$, $p = 0.37$, one-tailed. These suggested that 18-month-olds dishabituated to test stimuli only in Switch-Verb condition, but not in Switch-Noun or Same condition. See Figure 4b for illustration.

Discussion

The results of Experiment 2 showed that 14-month-olds dishabituated to both types of switch, whereas 18-month-olds only dishabituated to the type of switch that had a change in word meaning (i.e., Switch-Verb). These findings suggest that the two age groups may have used different strategies in completing our switch tasks. While 18-month-olds may be analyzing the linguistic stimuli into meaningful units, recruiting morphosyntactic cues online to categorize novel words (i.e., use "is __ing" dependency to

Table 3a. Stimuli used in Experiment 2 (see Table 3b for how they were ordered).

Stimuli Number	Video	Audio
0	flower jumping	it's snebbing
1	penguin cartwheeling	it's pratching
2	penguin spinning	It's a doke
3	penguin cartwheeling	It's a pratch
4	penguin spinning	It's doking
5	penguin cartwheeling	It's a doke
6	penguine spinning	it's pratching
7	penguin cartwheeling	It's doking
8	penguin spinning	It's a pratch

Table 3b. Stimuli in different condition-order assignments in Experiment 2 (see Table 2a for the stimuli descriptions, in correspondence to the numberings).

Condition Order	Same A	Same B	Same C	Same D	Switch-Noun A	Switch-Verb A	Switch-Verb B	Switch-Noun B
Habituation	1 & 2	1 & 2	3 & 4	3 & 4	1 & 2	1 & 2	3 & 4	3 & 4
Test trial #1	1	2	3	4	5	6	7	8
Test trial #2	1	2	3	4	5	6	7	8
Post-test	0	0	0	0	0	0	0	0

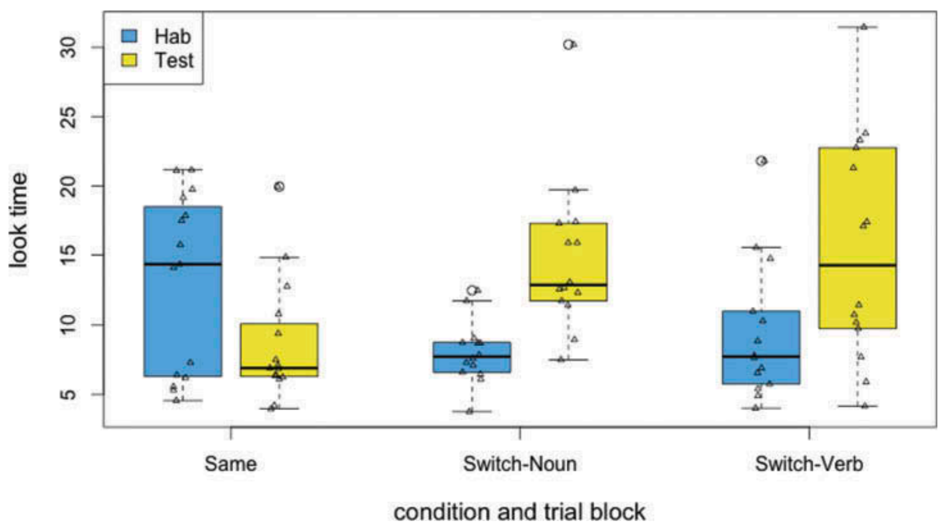

Figure 4a. 14-month-olds's looking time across trial blocks in different conditions in Experiment 2 (triangles are individual participants' data points).

categorize verbs), and mapping novel words onto their corresponding event categories (i.e., verb-event, noun-object), their 4-month younger peers may have simply attended to the surface-level connection between the video and audio stimuli. For the 14-month-olds, therefore, whenever there was a change in the connection between the video and audio stimuli (i.e., Switch-Noun and Switch-Verb conditions), their attention was recaptured. Eighteen-month-olds, however, *only* re-attended to the stimuli when there was a change in terms of word meaning (i.e., Switch-Verb condition).

General discussion

The present study, with two experiments using the Habituation-Switch Paradigm, demonstrated that English-learning 18-month-old infants were able to rapidly learn the meanings of novel verbs from

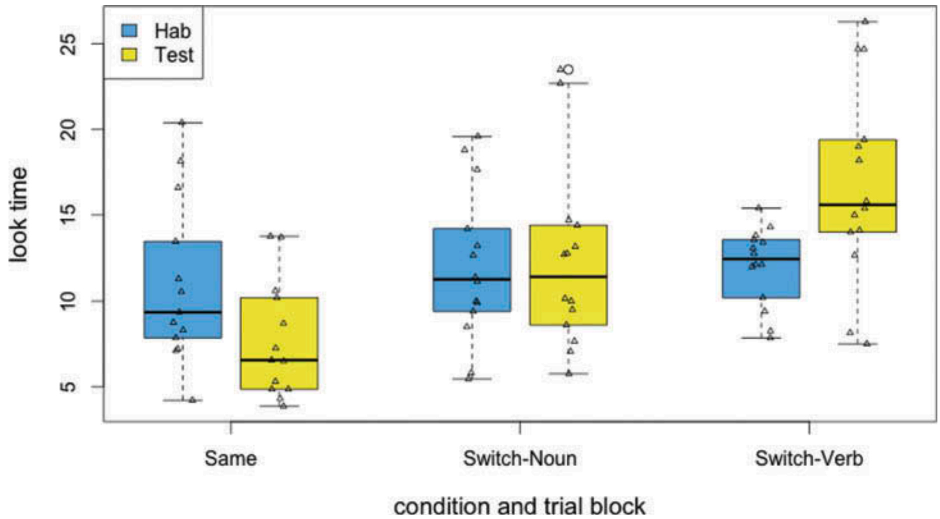

Figure 4b. 18-month-olds's looking time across trial blocks in different conditions in Experiment 2 (triangles are individual participants' data points).

presentations of simple motion events performed by an animated agent, paired with novel intransitive verbs embedded in "is __ing" frames. To successfully learn verb meanings in this task, infants needed to have the knowledge that verbs label events, and to be able to deploy their knowledge, in at least two respects: first, they should be aware of the frequent frame "is __ing" as a context for verbs to occur in, and they should be able to recruit this morphosyntactic information online to categorize a novel word as a verb; and second, they should be aware of the link between the grammatical category *verb* and the conceptual category *event*, and be able to use this general relation to quickly learn the specific links presented in the task. Our findings suggested that English-learning infants demonstrated such abilities by 18 months of age, but younger infants did not show evidence of having developed these abilities. These findings extend Kobayashi et al. (2006)'s finding with Japanese-learning infants to English; and importantly, with novel words taught in syntactic frames (rather than in isolation), the current findings were able to show young infants' abilities to categorize novel nouns and verbs using morphosyntacitc cues. To our knowledge, prior to the current finding, the only piece of evidence for English-learning infants' ability to categorize novel verbs and map newly categorized verbs to event concepts was from Echols and Marti (2004)'s preferential looking task. Our results extend and strengthen the earlier work by showing the same results in a different experimental paradigm. We will discuss the implications of our findings on early lexical development below.

Word learning is an impressive ability because the context of use provides indefinitely many possible meanings for any given word form. This indeterminacy problem of word meanings is particularly severe in the real world (i.e., outside of the lab), where in addition to the general problem of inducing a concept from finite observations, the observational context is typically cluttered with multiple people, objects and events. Solving this problem, therefore, calls for a learning procedure that is constrained in the range of hypotheses that learners consider as possible meanings for a novel word. One such constraint may come from correspondences between form and meaning, for example, the mapping between the grammatical category *verb* and the conceptual category *event*. Having the verb-event link in place early in development can aid learning novel verb meanings by restricting the conceptual categories that provide candidate verb meanings. Laboratory studies testing the availability of this hypothetical tool, as well as its development onset, would shed light on how young learners overcome one aspect of the word learning challenge.

This tool is indeed available to young learners. Regarding *when* it becomes available, prior literature suggests that young children can deploy this tool in learning novel verbs late in the second year (e.g., Bernal et al., 2007; Oshima-Takane et al., 2011, 2008; Waxman et al., 2009). However, as discussed above, the linguistic and conceptual underpinnings that support the establishment of the verb-event link are already in place by the end of first year (Buresh et al., 2006; Casasola & Cohen, 2000; Gergely & Csibra, 2003; Gergely et al., 1995; Hespos & Baillargeon, 2001; Leslie & Keeble, 1987; Luo & Baillargeon, 2005; Mintz, 2006; Sommerville et al., 2005; Wagner & Carey, 2005). The current study therefore examined the developmental trajectory during the second year, and provided evidence that this verb-learning tool becomes available by at least 18 months of age for English-learning infants. In addition, our findings also augments the literature by showing that 18-month-olds are not only sensitive to morphosyntacitc cues to the *verb* category (Santelmann & Jusczyk, 1998) and are able to use them for novel verb categorization (Mintz, 2006; Peterson-Hicks, 2006), but also are able to deploy this morphosyntacitc-based categorization in learning novel verb meanings in real time.

But even with the developmental trajectory more accurately mapped out, we are still faced with a developmental question: what specifically develops between 14 and 18 months? To think about this question, it may be useful to distinguish three pieces of knowledge: (1) identifying the surface cues to category-hood––for example, knowing that a word appearing in a "you __ it" frame belongs to a different grammatical category than a word appearing in a "the __ is" frame;[8] (2) assigning the label of that category––for example, the category for words occurring in "you __ it" is V, and the category for words occurring in the "the __ is" is N; and (3) knowing the likely semantic consequences of the labels––for example, Vs are likely to name event concepts, and Ns are likely to name object concepts.

An important subtlety is that identifying a category of words based on shared distribution (i.e., 1) is not identical to knowing the label for that category (i.e., 2). The former means mere grouping of words into the same bin (i.e., simply, these words belong together) based on distributional similarity, whereas the latter means knowing what grammatical feature is responsible for the distributional similarity. In virtually all grammatical theories (Bresnan, 1982; Chomsky, 1981; Gazdar, Klein, Pullum, & Sag, 1985), grammatical categories do more than simply label surface distributional contexts. For example, words that are nouns serve as the head of phrases that can bear Case (1a), but cannot assign case to their objects (1b-c); verbs, on the other hand, can assign Case (2a), but cannot head phrases that bear Case (2b).

(1) a. The train arrived.
b. *The arrival the train
c. the arrival of the train
(2) a. I saw the arrival.
b. *I saw the arrive.

These features of grammatical categories explain a wide range of further facts, ranging from properties of passives and other movement constructions (Burzio, 1986) to facts about anaphoric dependencies (Chomsky, 1981; Merchant, 2001). And, as emphasized by Pinker (1984), some of the properties that distinguish nouns from verbs fall outside the likely experience of child learners. For example, it is possible to create a wh-movement dependency into the complement of a verb, but not into the complement of a noun (Ross, 1967):

(3) a. who did you claim that she met __
b. *who did you make the claim that she met __

[8]Note that the frequent frames (e.g., "you ___ it") are different from the full distributional contexts words occur in, but might be a good bootstrap to the actual distributions, without being a significant part of it.

Thus, the properties of the grammatical categories are far richer than the surface distributional facts that enable us to identify which words fall into which categories.

Now, identifying the surface cues to grammatical categories is surely data dependent, as these cues vary from language to language. A wide range of evidence now exists showing that such cues are both available in speech to children and detectable by children (Christodoulopoulos, Roth, & Fisher, 2016; Gutman, Dautriche, Crabbé, & Christophe, 2015; Mintz, 2003, 2006; Shi, 2014). What is not clear is how these categories come to have labels and hence to have the full range of grammatical properties that distinguish them, including their link to meaning.

One possibility, initially due to Pinker (1984), and pursued more recently by Gutman et al. (2015) and Christodoulopoulos et al. (2016), is that the semantic properties can be observed directly for some critical subset of items and it is on the basis of this subset that the entire class comes to have the relevant semantic property. And on Pinker's semantic bootstrapping hypothesis, this semantic property is innately linked to the relevant abstract syntactic properties such that the learner need not observe all of these properties in order to acquire them.

Yet another possibility is that the innate categories N, V, and A lead to expectations about their distributions which would enable learners to label the categories appropriately. For example, if learners antecedently expected sentences to consist of NPs and VPs, they might predict that Vs occur about once per clause on average, that Ns occur more than once per clause on average (given that Vs can take multiple NP arguments) and that As occur less than once per clause (given they are optional modifiers of NPs). These distributional expectations would allow learners to infer both the richer semantic and abstract syntactic properties of the grammatical categories.

A third possibility, pursued in usage-based theories (e.g., Ambridge, Pine, & Lieven, 2014; Lieven, Behrens, Speares, & Tomasello, 2003; Tomasello, 2000, 2003), is that the abstract syntactic properties do not exist, that the grammatical categories are merely labels for detectable surface distributions, and that the semantic properties of the grammatical categories can be learned through exemplar-based categorization procedures (Ambridge et al., 2014).

Distinguishing these three possibilities (and others) falls beyond the scope of this paper, but they help to identify what might be developing between 14 and 18 months of age. On both the semantic bootstrapping and exemplar-based models, learning the labels requires noticing a link between the semantic and distributional features of the verb category. On the expectation-driven view, the learner in this time period is connecting up the surface distributional categories with frequency distributions over those categories.

The current study remains agnostic about this issue. Our results do not directly argue for any of these accounts, but showing that the verb-event link is in place early in development may place more constraints on the usage-based accounts: if the verb-event link is in place by (or even earlier than) 18 months, then a usage-based learner must have acquired a sufficient number of verbs demonstrating this link (i.e., the relation between *verb* and *event* categories) prior to this age in order to license the inference to verbs in general. Not knowing how many is "sufficient", the question remains unanswerable. Evidence about vocabulary development in the literature does not seem to provide adequate evidence either: we only know that by the end of the second year, children start to produce a sizeable number of verbs (Bates et al., 1994; Caselli et al., 1995; Fenson et al., 1994; Gentner, 1982; Gleitman et al., 2005), but we know very little about when children begin to build their receptive verb vocabulary. The current study was not designed to probe the role of vocabulary in the development of the verb category; however, with the MCDI data collected, we were able to conduct some post-hoc vocabulary analyses. We first observed that the 18-month-olds had a larger vocabulary on average than the 14-month-olds ($p < 0.001$), and a larger verb size too ($p < 0.001$); but this does not really help us understand more about the development of the verb-event link beyond the observation that older children have larger vocabularies and may have performed the task in a different way than the younger children. We also conducted correlation analyses to see if there was any correlation between vocabulary size (total vocabulary, as well as verb size) and performance in the tasks (i.e., dishabituation) within each age group and each condition; however, we did not see any such correlation (all p values for Pearson's R correlation greater than 0.13, with one exception[9]). Therefore, at least in our sample, 14- and 18-month-olds infants' ability in using the verb-event link to learn novel verbs did not seem to depend on their productive vocabulary/verb knowledge, potentially casting doubt on learning theories that claim such links between grammatical categories and conceptual categories are generalized over exemplars. We also confirmed that there was no vocabulary difference across conditions within each group of each experiment (all p values for ANOVA with conditions as between-subjects variable are greater than 0.23); this ensures that the differences in test performance were due to condition differences, not due to infants' language development level (as measured by MCDI vocabulary).

We have been discussing the implications of our results based on our interpretations of them, but two caveats in interpreting the results are worth pointing out. First, we cannot conclude from the results that 14-month-olds do not yet have the knowledge of the verb-event link. Their performance in this study could indicate lack of the verb-event link, but could reflect a failure in any of the following: recognizing the "is __ing" dependency as a verb frame, using this frame for verb categorization online, or deploying the verb-event link to learn novel verb meanings within the experimental context. Moreover, failure in any of these may represent a true lack of knowledge (e.g., not knowing the verb-event link, not knowing "is__ing" is a verb context), but may also represent a failure to deploy that knowledge in this task. For example, the current design, by repeating the same token events several times rather than showing several tokens of the same type (e.g., a penguin spinning event type could have different tokens, like a fast spinning, a slow spinning, a spinning in one direction, a spinning in another direction, etc.), may have failed to promote categorization of the events. Future work may examine the role of variability in promoting event categorization in 14-month-olds. Furthermore, it may be of interest of future work to probe the nature of 14-month-olds' mismatch detection behaviors across linguistic and nonlinguistic tasks.

A second caveat is that there may be a leaner interpretation of 18-month-olds' success in our task. Suppose that 18-month-olds know the noun-object link and are able to categorize nouns and verbs using distributional cues, but that they do not yet know the verb-event link. In this case, infants could still succeed in the current study by inferring that novel words that are not nouns do not pick out object concepts. By noticing that "doke" in "it's *dok*ing" is not a noun, infants infer that it refers to some other aspect of the scene, in this case the event. This strategy could make infants *appear* to know the verb-event link, even without this knowledge. Although we cannot rule this possibility out, there is reason to doubt it. In the adjective learning literature, this pattern of inference has not been observed. In experiments examining the link between adjectives and object-properties, knowledge of the noun-object link does not lead infants to link an adjective to a property concept. Rather, infants who know the noun-object link still allow adjectives to also pick out object kinds (Waxman & Booth, 2001). Nonetheless, future work should attempt to test this possibility in the domain of verb learning.

Finally, the current study does not address the richness of the event concepts infants acquired in our task. The current study examines young infants' knowledge of the verb-event link, that is, whether they can identify that the concept picked out by a verb is an event concept. For example, we showed that in a penguin-spinning scenario, young learners were able to identify the word "doke" in "it's doking" as a verb, and thus pick out the event in the scenario (not the object). We have not shown the range of events that learners will take to fall under that concept. For example, are infants are willing to accept changes to the identity or category of the event-participant? The question of how infants extend a word to new instances is an independent question of what class of concepts the word can pick out. And, because verbs vary in their extendibility—some verbs are narrowly extendable, others are broadly extendable—it will take a suite of experiments to begin to develop a

[9]18-month-olds' dishabituation score in the *Same* condition was correlated with their total vocabulary size ($p = 0.05$) and verb size ($p = 0.03$). However, all but one infants in this condition had a negative dishabituation score (i.e. attention at test was smaller than that during the last two habituation trials); so, this correlation would mean that the smaller the vocabulary/verb size, the more "bored" an infant became when seeing the same stimuli at test. We don't think this correlation reflects anything about infants' verb learning ability.

theory of what kinds of event concepts infants initially consider for their first verbs. We pursue this question in ongoing research.

To summarize, our results showed English-learning infants, as early as 18 months, are able to access the relation between the grammatical category *verb* and the conceptual category *event*, and utilize this relation to restrict their hypotheses about the meaning of a novel verb—that is, it names an event concept, not an object category. And, our evidence suggests that this ability may not be in place at 14 months. More work needs to be done to more accurately identify infant's knowledge at 14 months and to map out the developmental trajectory between 14 and 18 months.

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