Early knowledge of the verb-event link

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Verb learning in 14- and 18-month-old English-learning infants

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RESEARCH HIGHLIGHTS

• Knowledge of the verb-event link is shown to be in place in 18-month-olds, but not 14-month-olds.

• This is the earliest demonstration of this knowledge to date.

• This knowledge precedes substantial growth of a productive verb lexicon.
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 doking”, a penguin-cartwheeling scene paired with “it’s pratching”. At test, we found dishabituation (i.e. recovery of attention) in both age groups when the scene-sentence pairings got switched (e.g. penguin-spinning – “it’s pratching”). This finding is consistent with two explanations: a. infants were able to link verbs to event concepts (as opposed to other concepts, e.g. objects), and b. 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. The learnability problem here is that the extralinguistic context of use provides unboundedly many possible meanings for any particular word form (e.g. Quine, 1960), signaling the need for constraints that shape a learner's inferences about a word's meaning. 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”), some combination of these features (“furry + head”; “furry + running”), or even something irrelevant to the present scene (“it’s sunny today”). 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 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 referred to by count nouns, and events tend to be referred to by verbs, for example, such correspondences can serve as a good heuristic for learners to constrain their search space of possible word meanings. For example, 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 picks out an event concept, avoiding the need to consider meanings from other conceptual categories like object or property. The present study investigates the emergence of the verb-event link at early stages of English-learning infants’

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)
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 it has been shown that labeling with a novel noun facilitates object categorization compared to no labeling for infants around the same age, i.e. 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), suggesting that the noun-object link emerges soon after the first birthday. This early emergence of the noun-object link may support subsequent growth of noun vocabulary: from the first birthday to about the 17th to 18th month, the lexicon grows steadily, with a preponderance of words referring to object categories. 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 (Bates et al., 1994; Caselli et al., 1995; Fenson et al., 1994; Gentner, 1982). (For a review of lexical development and the noun-verb asymmetry, see Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005). Given the robust noun advantage in productive vocabulary development, it is reasonable to expect that in comprehension, knowledge of the verb-event link may emerge later than knowledge of the noun-object link. The literature to date bears this expectation out: while the noun-object link is formed soon after the first birthday, the verb-event correspondence has not been shown to emerge until late in the second year (Bernal, Lidz, Millotte, & Christophe, 2007; Oshima-Takane, Ariyama, Kobayashi, Katerelos, & Poulin-Dubois, 2011; Waxman et al., 2009).

Waxman et al. (2009), using the Preferential-Looking Paradigm, demonstrated that 24-month-old English-learning infants were able to map novel verbs to event categories: infants
presented with dynamic scenes (e.g. a man waving a balloon) and descriptive sentences involving a novel verb (e.g. “the man is larping 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 infants: using a pointing task, they showed that infants familiarized with scenes (e.g. a flower rotating) and accompanying sentences involving a novel verb (e.g. “it’s pouning”) 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 infants: they habituated 20-month-old Japanese-learning infants 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 – “it’s moke-ing”; Scene B – “it’s seta-ing”), and they found that infants dishabituated when there was a mismatch between the action and the verb (e.g. bouncing labeled by seta-ing). This result suggests that infants may have established the verb-event link as early as 20 months of age, an earlier point than previously reported.

The above findings all point to 20-24 months of age as the time when the verb-event link first emerges in comprehension. This is also around the time when infants’ productive vocabulary starts to include an appreciable number of verbs (Fenson et al., 1994; Gleitman et al., 2005; inter alia). If infants utilize the correspondence between event categories and verbs in learning new verbs, then we should see evidence that children know this correspondence prior to the appearance of a substantial number of verbs in their productive vocabulary. In the domain of noun learning, for example, evidence of the noun-object link is seen by 14 months (Waxman & Booth, 2001), but a substantial increase in productive noun vocabulary is reported at 17-18 months (cf. Gleitman et al., 2005). Thus, if the verb-event link provides an effective initial guide
for verb learning, we should expect to see it several months prior to the appearance of a productive verb vocabulary. Meanwhile, forming the correspondence between the linguistic category verb and the conceptual category event presumably requires certain conceptual and linguistic underpinnings that support categorizations of verb and event. We should expect the verb-event link to be established after these underpinnings are largely in place.

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 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 language, 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 you __ it or the __ is are good cues to nouns and verbs, respectively (Mintz, 2003). Second, evidence from behavioral studies has shown that infants 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, infants 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 infants’ early categorization of verbs comes from both neurological measures and behavioral studies. Bernal et al. (2010) observed an early left-lateralized (ELAN) brain response2 in 24-month-old French infants when 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 infants. 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

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

Taken together, previous findings have pointed out a window in development during which the verb-event correspondence is most likely to emerge. First, for the verb-event link to work as an effective learning guide to narrow down learners’ search space of possible verb meanings, we expect it to be established at a point earlier than the substantial increase of verb vocabulary, which is around 20 months of age (Fenson et al., 1994; Gleitman et al., 2005; inter alia). Second, we expect the link to be formed after the relevant linguistic (Bernal et al., 2010; Mintz, 2006; Peterson-Hicks, 2006) and conceptual underpinnings (Buressh et al., 2006; Casasola & Cohen, 2000; Gergely & Csibra, 2003; Gergely et al., 1995; Hespos & Baillargeon, 2001; Leslie & Keeble, 1987; Luo & Baillargeon, 2005; Sommerville et al., 2005; Wagner & Carey, 2005) are in place, which is by the end of first year at the earliest. Therefore, the present study zooms in on the window between 12 and 20 months; specifically, we look at 14- and 18-month-old English-learning infants.

In addition to the primary goal of mapping the early developmental trajectory of infants’ use of the verb-event link, 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 *doking*”, and “it’s *praching*”), and tested them on a new event-verb combination (e.g. spinning labeled with *doking* at habituation was labeled with *praching* at test). In this task, successful acquisition of the novel verbs’ meanings would require a) ability to use the morphosyntactic information to categorize the novel words as verbs, and b) 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 addressed one such alternative.

**EXPERIMENT 1**

**METHOD**
Participants

Forty-two English-speaking infants (21 boys, 21 girls) with a mean age of 14;2 (range: 13;19-14;16) and thirty-four 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 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 Studies Consortium Database at University of Maryland College Park.

Stimuli

The visual stimuli were computer-animated objects engaged in different self-propelled actions. For example, a penguin engaged in a spinning action (Figure 1a) and a cartwheeling action (Figure 1b). Each event lasted 15 seconds and was repeated up to two times per trial, giving a maximum trial length of approximately 30 seconds. These visual stimuli were paired with sentences containing intransitive novel verbs labeling the events, with the pronoun it referring to the animal; and the sentences were all in present progressive tense/aspect. For example, “it’s doking!” and “it’s pratching!”

During the 15-second event, the linguistic stimuli were played six times, in slightly different frames: “Look, it’s doking”, “Wow, it’s doking”, “Yay, it’s doking”, “Do you see it doking”.

*** FIGURE 1 ABOUT HERE ***

If an infant looked away from the screen for more than 1 second, a video of a butterfly perched on a leaf (i.e. attention-getter) was played until the infant’s attention was recaptured. This is a standard adopted by most other studies using this paradigm (e.g. Casasola & Cohen, 2000). Another pair of visual and linguistic stimuli was used at the beginning (pre-test) and end
of the experiment (post-test), in which a flower bouncing event was paired with the sentence “it’s snebbling!” The duration of this event was the same as other events (i.e. 15 seconds), and was also played up to two times in its trial (i.e. 30 second maximum). Pre-test and post-test were used to control for fatigue; see Design section for more discussion.

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-inch plasma television, with built-in speakers, located 66 inches 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, this 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 pre-set habituation criterion, a new event-sentence
combination was introduced; we measured the amount of attention recovery upon getting the novel combination.

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 (Werker, Fennell, Corcoran, & Stager, 2002) “it’s snebbing” was shown. Then, during the habituation phase, infants were presented trials of event-sentence pairs 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 et al., 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. Each condition had two orders (Order A and Order B), differing in the order of the two test trials. Following these two test trials, one post-test trial that was the same as the pre-test trial but very distinctive from the habituation and test trials was presented. The purpose of having the pre-test and post-test trials was to control for fatigue: if infants were still involved in the experiment
towards the end (habituation but not fatigue), we would expect their attention to recover upon seeing the post-test, which was perceptually very distinct from the habituation and test trials. I will discuss how we analyzed habituation controlled for fatigue in the *Measurements* section. See Table 1 for a summary of the design.

*** TABLE 1 ABOUT HERE ***

*Procedure and coding*

The procedure began with obtaining the parent(s)’ informed consent and collecting the MacArhur Communicative Development Inventory (MCDI) – a standardized measurement of productive vocabulary development. When the infant was ready, he/she was led to the test room where the TV monitor and the digital camera were located. 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 an attention-getter (the butterfly). Once the infant looked at the attention-getter, the experimenter pressed the space bar on the computer to begin the first trial, so 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-second attention was required for it to be counted as a look. A trial continued until the infant
looked away for more than 2 continuous seconds or until the end of the trial (approximately 30 seconds). The attention-getter came back on the screen to recapture the infant’s attention at the end of each trial and stayed on the screen until the start of next trial. The experimenter was not able to hear the audio, thus 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 to 0.999, with a mean of 0.997.

PREDICTION

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\(^3\) with that of the two test trials; and we took significant increase of looking time from habituation to test as indicator of dishabituation.

*Predictions*

Infants in the Same condition were predicted to show no dishabituation at test. For those in the Switch condition, if they learned the associative links between the events and the novel verbs, we expect dishabituation to a familiar event labeled by a different verb (i.e. a novel combination between the event and the verb), reflected by a significant increase in looking time from last habituation trials to test trials. But, if they did not learn the link between the novel word and the event, they were expected to remain habituated. Therefore, such an asymmetry in dependent variable between conditions would suggest infants’ ability to learn the verb-event link.

**RESULTS**

*(i) Habituation controlled for fatigue*

Habituation data for the two age groups of participants were analyzed separately. For the 14-month-old group, to determine whether infants were successfully habituated, we conducted planned comparison between the first and last habituation block using one-tailed t-test, and found the mean looking time of the last block (M = 12.02s, SD = 5.00s) was significantly less than that of the first block (M = 21.45s, SD = 7.55s), t(41) = 11.43, p < 0.001. Thus, there was a significant drop in attention throughout the habituation phase. To make sure this habituation was

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\(^3\) 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).
not due to fatigue, we compared post-test to the last habituation block, as planned (one-tailed),
and found that the mean looking time of the post-test (M = 16.77s, SD = 10.35s) was
significantly greater than that of the last block (M = 12.02s, SD = 5.00s), t(41) = 2.89, p = 0.003.
This showed that infants’ attention recovered from habituation upon seeing the perceptually
distinct post-test trial, suggesting they were not fatigued. The same analyses were conducted for
the 18-month-old group, and confirmed that this group was also successfully habituated without
becoming fatigued: first, the mean looking time of the last habituation block (M = 15.51s, SD =
3.66s) was significantly less than that of the first block (M = 26.4s, SD = 15.35s), t(33) = 19.99,
p < 0.001; second, post-test attention (M = 22.15s, SD = 19.47s) was significantly greater than
that of the last habituation block (M = 15.51s, SD = 3.66s), 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 = 16.77s, SD = 10.35s)
compared to pre-test (M = 21.97s, SD = 9.80s), t(41) = 2.63, p < 0.01, one-tailed; and 18-month-
olds lost about 15% attention in post-test (M = 22.15s, SD = 0.84s) compared to pre-test (M =
26.31s, SD = 9.47s), t(33) = 2.15, p = 0.02, one-tailed. In previous studies, Fennell and Werker
(2003) found that their 14-month-old participants’ post-test attention recovered to pre-test level,
whereas Oshima-Takane et al. (2011) found that their 20-month-old participants lost about 25%
attention in post-test compared to pre-test. Given the inconsistent findings on pre-test and post-
test relation, and also because the presence of pre-test might have made post-test less novel and
thus less interesting, we decided to remove the pre-test phase in Experiment 2.

The above results were illustrated in Figure 2a and 2b. Clearly, infants in both age groups
began the task with a relatively high level of attention (i.e. pre-test); during the habituation phase,
there was a clear decreasing trend from the beginning (Hf1, Hf2 and Hf3 stand for first 3 habituation trials, respectively) to the end (Hl1, Hl2 and Hl3 stand for last 3 habituation trials, respectively, with Hl3 being the very last one); and attention recovered to some extent in post-test, but not back to the same level as in pre-test.

*** FIGURE 2 ABOUT HERE ***

(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, $F(1, 72) = 18.00, p < 0.001$; and a significant interaction between condition and trial block, $F(1, 72) = 7.61, p < 0.01$. Specifically, for Same condition, attention during test ($M = 11.49s, SD = 7.72s$) was not significantly different from that in the last two habituation trials ($M = 10.00s, SD = 5.27s$), $t(37) = -1.13, p = 0.26$, two-tailed; for Switch condition, however, attention during test ($M = 17.74s, SD = 7.83s$) was significantly greater than that in the last two habituation trials ($M = 10.73s, SD = 14.91s$), $t(37) = -4.64, p < 0.001$, one-tailed. There was no main effect of age group, $F(1, 72) = 2.53, p = 0.12$; and no other interactions. These results suggested the following points: 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.
Early knowledge of the verb-event link

Next, data were 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 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 ($M = 10.82s, SD = 7.29s$) was not significantly different from the last two habituation trials ($M = 9.17s, SD = 5.06s$): $t(20) = -0.86, p = 0.40$, two-tailed; but for the Switch condition, attention during test ($M = 17.78s, SD = 7.29s$) was significantly greater than that of the last two habituation trials ($M = 8.97s, SD = 4.49s$), $t(20) = -4.88, p < 0.001$. For 18-month-old infants, there was a marginally main effect of condition, $F(1, 32) = 3.77, p = 0.06$; and a marginally main 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 ($M = 12.31s, SD = 8.47s$) was not significantly different from that during the last two habituation trials ($M = 11.03s, SD = 5.49s$), $t(16) = -0.7112, p = 0.49$, two-tailed; but for the Switch condition, attention during test ($M = 17.69s, SD = 8.69s$) was significantly greater than that during the last two habituation trials ($M = 12.89s, SD = 4.64s$), $t(16) = -1.92, p = 0.04$, one-tailed. See Figure 3a and 3b for illustrations of the results.

*** FIGURE 3 ABOUT HERE ***

DISCUSSION

The results of Experiment 1 showed that both 14-month-olds and 18-month-olds dishabituated in the Switch condition but not in the Same condition. This asymmetry between conditions was
consistent with the hypothesis that they 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 a 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.

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;5 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 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 Lab Database at University of Maryland College Park.

Stimuli

The visual stimuli were same as those used in Experiment 1 - a penguin engaged in a spinning action (Figure 1a) and a cartwheeling action (Figure 1b). The linguistic stimuli paired with these visual stimuli were simple intransitive sentences, varying with conditions. For example, there were sentences containing an intransitive novel verb labeling the action (e.g. “it’s doking”), 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 doking label the spinning event and the noun a pratch labeling the penguin, while the other group heard the verb pratching label the spinning event and a 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
This experiment also used the Habituation-Switch Paradigm (Casasola & Cohen, 2000; Werker et al., 1998), adopting a similar design logic. 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 Noun-Switch condition, where the audio with a novel noun was paired with a different event but the same object; and the Verb-Switch 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 Verb-Switch 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 Table 2 for an example illustrating the design in Experiment 2.

*** TABLE 2 ABOUT HERE ***

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; 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, whereas those in Experiment 2 were the same trial presented twice; this was because the two ways of switching in Experiment 2
were different in nature – one maintained the meaning of the novel word (Noun-Switch), the other changed the meaning (Verb-Switch).

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 to 0.999, with a mean of 0.997.

PREDICTION

Measurement

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

Predictions

The main purpose of Experiment 2 was to examine the possibility of infants using a general-purpose mismatch-detecting strategy to dishabituate to any type of switch, regardless of meaning. If this were the case, then we would expect to see dishabituation in both Noun-Switch and Verb-Switch conditions – that is, significant increase of looking time from last two habituation trials to test, and no dishabituation in Same condition. If, however, they were not using such a strategy, but were truly analyzing the linguistic stimuli into meaningful units and knew the verb-event and noun-object mappings, then, we would expect to see dishabituation only in the Verb-Switch
condition where meaning was changed, but no dishabituation in the Noun-Switch or the Same condition.

RESULTS

(i) Habituation controlled for fatigue

As in Experiment 1, to determine whether infants were successfully habituated, we conducted planned comparison between the first and last habituation block using one-tailed t-test. If there was habituation, then we compared post-test to the last habituation block to make sure this habituation was not due to fatigue, also using one-tailed t-test. Habituation data for the two age groups of participants were analyzed separately. For 14-month-olds, the mean looking time of the last block (M = 12.23s, SD = 4.82s) was significantly less that that of the first block (M = 20.46s, SD = 7.19s), t(42) = 12.41, p < 0.001, indicating a significant drop in attention throughout habituation phase; and the mean looking time of post-test (M = 18.80s, SD = 9.66s) was significantly greater than that of the last block (M = 12.23s, SD = 4.82s), t(42) = -4.51, p < 0.001, assuring us that infants’ habituation was not due to fatigue. For 18-month-olds, the mean looking time of the last habituation block (M = 13.70s, SD = 3.43s) was significantly less than that of the first block (M = 22.30s, SD = 6.19s), t(40) = 13.20, p < 0.001; and post-test attention (M = 18.49s, SD = 8.59s) was significantly greater than that of the last habituation block (M = 13.70s, SD = 3.43s), t(40) = , p < 0.001; indicating habituation without fatigue.

The above results were illustrated in Figure 4a and 4b. Clearly, infants in both age groups began the task with a relatively high level of attention, which decreased over habituation trials; and attention recovered to some extent in post-test.

*** FIGURE 4 ABOUT HERE ***
(ii) Dishabituation analysis

Having determined that infants were successfully habituated, infants’ performance at test was analyzed. Data were first entered a three-way mixed ANOVA with age group (14- vs. 18-month-olds) and condition (Same vs. Noun-Switch vs. Verb-Switch) as between-participant factors, and with trial block (last two habituation trials vs. two test trials) as a within-participant factor. This analysis revealed a main effect of condition, $F(1, 78) = 3.94, p = 0.02$; a main effect of trial block, $F(1, 78) = 8.46, p < 0.01$; 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. Noun-Switch vs. Verb-Switch) 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 ($M = 8.63s, SD = 4.33s$) was significantly less than that of the last two habituation trials ($M = 13.07s, SD = 6.43s$), $t(14) = 3.00, p < 0.01$, two-tailed; for Noun-Switch condition, attention during test ($M = 14.77s, SD = 5.57s$) was significantly greater than that habituation ($M = 8.01s, SD = 2.23s$), $t(13) = -4.35, p < 0.001$; and for Verb-Switch condition, test ($M = 15.5s, SD = 8.13s$) has a longer looking time than habituation ($M = 9.37s, SD = 4.98s$), $t(13) = -3.11, p < 0.01$. These suggested that 14-month-old infants dishabituated to test stimuli in both the Noun-Switch and Verb-Switch conditions, but not in the Same condition. See Figure 5a 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 ($M = 7.72s, SD = 3.41s$) was significantly less than that during the last two habituation trials ($M = 11.02s, SD = 4.81s$), $t(12) = 3.56, p < 0.01$, two-tailed; for the Noun-Switch condition, attention during test ($M = 12.33s, SD = 5.32s$) was not significantly different than that of habituation ($M = 11.98s, SD = 4.41s$), $t(13) = -0.33, p = 0.37$; and for Verb-Switch condition, test ($M = 16.78s, SD = 5.74s$) had a significantly longer looking time than habituation ($M = 12.01s, SD = 2.28s$), $t(13) = -3.78, p = 0.001$. These suggested that 18-month-olds dishabituated to test stimuli only in Verb-Switch condition, but not in Noun-Switch or Same condition. See Figure 5b for illustration.

*** FIGURE 5 ABOUT HERE ***

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. Verb-Switch). These findings suggested 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 category verbs), and mapping novel words onto their corresponding event categories (i.e. verb-event, noun-object), their four-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. Noun-Switch and Verb-Switch 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. Verb-Switch 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 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, it required infants to have knowledge, and to be able to deploy their knowledge, in at least two aspects: 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 novel verbs; 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.

Word learning is an impressive ability because the context of use provides indefinitely many possible meanings for any given word form, and therefore calls for guided learning, with constraints on learners’ search space. 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
Early knowledge of the verb-event link

verb meanings. We see evidence that infants may have the linguistic and conceptual underpinnings that support establishment of this link 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). However, previous findings do not show the verb-event link being deployed for novel verb learning until quite late in the second year: 20 months for Japanese-learning infants (Oshima-Takane et al., 2011), 23 months for French-learning infants (Bernal et al., 2007), and 24 months for English-learning infants (Waxman et al., 2009). This time period is also the same time that we see an appreciable number of verbs start to be included in infants’ productive vocabulary (Fenson et al., 1994; Gleitman et al., 2005; inter alia). Given that infants’ use of this link to learn novel verbs was tightly correlated in time with growth in verb vocabulary, it is unclear whether the growth of a verb vocabulary supports the induction of the verb-event link or whether the discovery of the verb-event link supports rapid growth in verb vocabulary. The current study pushes down the age at which infants are able to use the verb-event link for novel verb learning to 18 months of age. In turn, this observation implies that deployment of a potential heuristic for verb learning is in place a few months before substantial increase of verb usage, which in turn may suggest that the verb-event link allows for the growth of the verb vocabulary, and not the other way round.

In addition to mapping the developmental trajectory of the verb-event link, a secondary contribution of the present study is to augment the literature on learning from morphosyntactic cues. Previous studies have shown young English-learning infants are sensitive to morphological cues to verbs (Santelmann & Jusczyk, 1998), and also documented infants’ ability to use the cues for novel verb categorization (Mintz, 2006; Peterson-Hicks, 2006). The present study adds to this
literature by showing that young infants are also able to utilize this morphosyntactic-based categorization in learning novel verb meanings.

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, because their performance in this study could indicate lack of the verb-event link, but could also be a reflection of 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, 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.

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 doking” 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. There is reason to doubt this possibility, however. 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 (Waxman & Booth, 2001). Nonetheless, future work should attempt to test this possibility in the domain of verb learning.

In sum, the present study is consistent with the hypothesis that 18-month-old English-learning infants are able to learn novel verbs by a) online recruiting morphosyntactic cues for verb categorization, and b) using the verb-event link to restrict the set of candidate word meanings. The finding that establishment of the verb-event link precedes the growth of a productive verb vocabulary also suggests this correspondence is not the result of abstracting a common semantic core out of a large set of already acquired verbs, but rather provides the scaffolding for the growth of the verb vocabulary.
ACKNOWLEDGEMENTS

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Figure 3a: 14-month-olds’s mean looking time across trial blocks in different conditions

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Figure 5a: 14-month-olds’s mean looking time across trial blocks in different conditions

Figure 5b: 18-month-olds’s mean looking time across trial blocks in different conditions
TABLE 1

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Table 1a: Stimuli used in Experiment 1

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Table 1b: Stimuli in different condition-order assignments in Experiment 1
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Table 2a: Stimuli used in Experiment 2

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Table 2b: Stimuli in different condition-order assignments in Experiment 2
FIGURE 1

(a) Figure 1a: Spinning action; a1-a4 are snapshots of the action

(b) Figure 1b: Cartwheeling action; b1-b4 are snapshots of the action
FIGURE 2

Figure 2a: 14-month-olds’ habituation timeline

Figure 2b: 18-month-olds’ habituation timeline
FIGURE 3

Figure 3a: 14-month-olds’s mean looking time across trial blocks in different conditions

Figure 3b: 18-month-olds’s mean looking time across trial blocks in different conditions
FIGURE 4

Figure 4a: 14-month-olds’ habituation timeline

Figure 4b: 18-month-olds’ habituation timeline
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FIGURE 5

Figure 5a: 14-month-olds’s mean looking time across trial blocks in different conditions

Figure 5b: 18-month-olds’s mean looking time across trial blocks in different conditions