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Visual Variability Affects Early Verb Learning

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Abstract

Research demonstrates that within-category visual variability facilitates noun learning; however, the effect of visual variability on verb learning is unknown. We habituated 24-month-old children to a novel verb paired with an animated star-shaped actor. Across multiple trials children either saw different actions from the same action category (variable actions condition, e.g., travelling while changing into a circle shape, then a square shape, then a triangle shape) or a single action from that category (identical actions condition, e.g., travelling while repeatedly changing into a circle shape). Four test trials followed habituation. One paired the habituated verb with a new action from the habituated category (e.g., "*dacking*" + pentagon shape) and one with a completely novel action (e.g., "*dacking*" + leg movement). The others paired a new verb with a new same-category action (e.g., "*keefing*" + pentagon shape), or a completely novel category action (e.g., "*keefing*" + leg movement). Although all children discriminated novel verb/action pairs, children in the identical actions condition discriminated trials that included the completely novel verb, while children in the variable actions condition discriminated the out-of-category action. These data suggest that—as in noun learning—visual variability affects verb learning and children's ability to form action categories.

Visual Variability Affects Early Verb Learning

Notoriously complex, children's early word learning is affected by environmental variables such as exemplar frequency (Mather & Plunkett, 2009), competition (Horst, Scott & Pollard, 2010) and novelty (Horst, Samuelson, Kucker & McMurray, 2011). Recent research demonstrates that category variability influences toddlers' noun learning (Perry, Samuelson, Malloy, & Schiffer, 2010; Twomey, Ranson & Horst, 2013) while labelling and vocabulary level affect object categorisation (Plunkett, Hu & Cohen, 2008; Gershkoff-Stowe & Smith, 2004). However, how such findings relate to verb learning remains unclear.

Establishing how environmental variables affect early verb learning is important for understanding the beginnings of language acquisition in general, because the referents of nouns and verbs are inherently different. While early-learned nouns refer to solid, rigid objects (Samuelson & Smith, 1999), early-learned verbs describe intangible, changing *relationships* between objects (Haryu, Imai, & Okada, 2011). Consequently, children use a variety of resources to establish the referents of verbs. For example, 18-month-old English-learning children are sensitive to nonlinguistic information such as manner of motion (Maguire et al., 2008), and by 24 months children can infer the referent of a novel transitive verb (e.g., "the duck is *glorping* the bunny*")* from its linguistic frame (Arunachalam & Waxman, 2010; Naigles, 1990). However, verb acquisition differs crosslinguistically (e.g., Sethuraman & Smith, 2013) suggesting that—relative to noun learning—verb learning is a delicate process (Waxman et al., 2013). Indeed, although variability in objects' visual appearance (e.g., variable colours) facilitates noun learning for 30-month-old toddlers (Twomey et al., 2013), comparable visual variability encountered via multiple speakers *impairs* verb learning in 30-36-month-old children (Maguire, Hirsh-Pasek, Golinkoff, & Brandone, 2008). Given such differences, it is not obvious how the factors that affect noun learning will affect verb learning.

Here, we begin to address this issue by isolating the effect of action category variability on verb learning. We habituated 24-month-old children to a novel verb (*dacking*) and animated videos of a star-shaped character moving across a screen while changing shape. We manipulated whether children saw *identical* or *multiple* actions (e.g., same shape change repeatedly versus different shape changes). We examined their looking times to novel verbs and actions at test.

Method

Participants

Thirty-six monolingual, English-speaking 24-month-old children (15 girls, M = 23m, 24d, SD = 46.35; range = 21m, 13d - 26m, 29d) participated, with a mean productive vocabulary of 330.94 words (SD = 192.90, range = 61 – 663 words) and at least one verb (M = 50.03, SD = 38.63, range = 1 – 124). Age and vocabulary did not differ between conditions (all ps >.18). Data from 12 additional children were excluded (fussiness: 11; failure to habituate: 1).

Materials

Four 5-second animated clips showed a yellow star-shaped character on a grey background travelling horizontally back and forth at a constant rate. Halfway from centre the star changed into one of four secondary shapes: circle, triangle, square or pentagon (Fig. 1, panel A). These actions were accompanied by a novel verb ("Look! He's *dacking*! Watch him *dacking*!"), recorded by a female native speaker, using Audacity 1.2.6. In an additional clip (used at test) the shape change was replaced with legs that grew and shrank (see Fig. 1, panel B) and *dacking* was replaced with *keefing*. Clips were looped for up to 30s.

Pre-familiarisation and post-test trials included an unrelated clip of a novel purple toy whistling while being inverted (Horst, Oakes & Madole, 2005). Between trials a red circle ("attention getter") loomed while a staccato whistle played to reorient children to the screen.

Procedure and design

The experiment took place in a quiet, dark room containing a 42-inch Samsung television mounted 80 cm from the floor in a black fabric backdrop. A camera recorded children's gazes through an opening below the screen. Clips were displayed in 4:3 format and auditory stimuli were played over the television speakers. Children sat on their parent's lap approximately 65cm from the screen. To prevent bias, parents wore opaque sunglasses.

In an adjoining room, a closed-circuit video displayed the children's faces. There, the experimenter, blind to the stimulus playing, recorded looking times and advanced trials using Habit 2000 (Cohen, Atkinson, & Chaput, 2000).

Familiarisation phase

Immediately after the child looked at the attention-getter, the pre-familiarisation stimulus played for 30 seconds or until the child looked away for a minimum of one second, then the attention-getter resumed automatically. Familiarisation trials proceeded in the same way. Children saw blocks of three familiarisation trials until they habituated (maximum 18 trials). Habituation was determined by a fixed single-block window with a criterion of 50% decrease in looking.

Children were randomly assigned to one of two conditions (top panel, Figure 2). In the identical actions condition children saw a single verb/action pair repeatedly, for example, the "circle" on every familiarisation trial. In the variable actions condition children saw three verb/action pairs, for example, "circle", "square", "triangle", "square", and so on. Actions were counterbalanced across children. In the variable actions condition children saw each action at least twice and in pseudo-random order such that no action was presented on two consecutive trials.

Test phase

Immediately following the habituation trials children saw a baseline trial consisting of a habituated verb/action pair. Next, children saw four test trials (bottom panel, Figure 2): "same verb/same action" (e.g. "*dacking*" + circle); "same verb/new action" (i.e., "*dacking*" + out-of-category); "new verb/same action" (e.g. *"keefing"* + circle); "new verb/new action" (e.g. "*keefing*" + out-of-category).

Presentation order was counterbalanced across children such that each trial type appeared in each position approximately equally often. Immediately following the final test trial the post-test stimulus played. Following the experiment, parents were asked to complete a UK adaptation of the Macarthur-Bates Communicative Development Inventory (Klee & Harrison, 2001).

Coding and reliability

Data were coded online. 20% of recordings were re-coded offline by a second naïve experimenter, with a high mean inter-coder correlation high, r = .94 (range = .82 – 1.00).

Results

All children habituated, with no differences between conditions in cumulative looking time or number of trials to habituate, all ps > .25 (see Table 1).

Discrimination is indicated by an increase in test looking relative to baseline (Oakes, 2010). Thus, we first used planned, paired t-tests to compare looking on each test trial against baseline (Table 2). Children in the identical actions condition looked longer on new verb test trials (new verb/same action: $t(17) = 3.06$, $p = .007$; new verb/new action: $t(17) = 2.65$, $p = .017$), indicating that they had encoded the verb presented during habituation. However, children in the variable actions condition looked longer on the same verb/new action trial only, $t(17) = 2.58$, $p = .020$, indicating that they responded to the new action category.

Next, we calculated difference scores by subtracting baseline looking from looking during each test trial (Curtin, Campbell & Hufnagle, 2012). We submitted these to a 2 (Condition: identical, variable) x 2 (Verb: same, new) x 2 (Action: same, new) mixed-design ANOVA, which revealed a significant Condition x Verb interaction, $F(1,34) = 7.68$, $p = .0090$, $\eta_p^2 = .18$. Pre-planned follow-up tests confirmed children in the identical actions condition looked longer at new verb test trials than they did at same verb test trials (all *p*s < .05). Looking times increased on the post-test trial relative to the baseline in both conditions (identical actions: Wilcoxon $V = 11$, $p = .0019$; variable actions: $V = 6$, $p < .001$), indicating that decreases in looking time were due to lack of discrimination, not fatigue (Oakes, 2010).

Finally, we found a strong correlation between overall vocabulary and cumulative looking during habituation for the variable actions condition ($r = .57$, $p = .014$, all *p*s two-tailed) but not for the identical actions condition ($r = .01$ *ns*.). Importantly, this pattern held for the relationship between verb vocabulary and cumulative looking during habituation (variable actions: $r = .53$, $p = .025$; identical actions: $r = .113$, *ns*.). Thus, children with more experience of using language, including more experience with verbs, looked longer at variable exemplars than children with less experience.

General Discussion

This study explored whether encountering variable versus identical verb/action pairs affected children's discrimination of novel verb/action pairs. Children in both conditions discriminated changes in stimuli at test. Children in the identical actions condition dishabituated to the novel verb. Recent evidence suggests that children are more likely to categorise objects that share a label (Graham, Booth & Waxman, 2012; Plunkett, Hu & Cohen, 2008; Sloutsky & Fisher, 2012), arguably because children form more similar object representations in the presence of a shared label than without (Westermann & Mareschal, 2014). On this account, children who learned a verb-action mapping during habituation dishabituated to the "incorrect" verb, but not to the same verb stimuli, which shared a label with the habituated category. This raises the exciting possibility that an array of actions – like an array of objects – may be encoded as more similar in the presence of a shared label than when unlabelled.

Alternatively, the new verb may simply have been more salient than the new action stimulus due to "auditory overshadowing". For example, Robinson and Sloutsky (2007; 2010) found that unfamiliar auditory input impaired infants' discrimination of change in the visual component of bimodal test items. This suggests that the increase in processing demands brought about by the novel verb stimulus may have stopped children in the identical actions condition from discriminating the novel action stimulus. An auditory overshadowing account predicts identical behaviour in the variable actions condition, in which children heard exactly the same verbs. However, we found children in that condition showed a different pattern of discrimination.

Children in the variable actions condition dishabituated to the out-of-category action paired with the habituated verb. This finding is consistent with the literature on noun learning, where visual variability helps young children form object categories, label them with nouns, and generalise those nouns to new exemplars (e.g. Perry et al.

2010; Twomey, Ranson & Horst, 2013). Similarly, the developmental categorisation literature suggests that such visual variability triggers object comparison and draws attention to category-relevant features whilst decreasing attention to category-irrelevant features (e.g. Oakes, Plumert, Lansink & Merryman, 1996; Kovack-Lesh & Oakes, 2007; Quinn & Bhatt, 2010). However, an alternative possibility is that children simply responded to the novelty of the out-of-category test exemplar rather than an "incorrect" verb/action *mapping*. If so, we would expect these children to also dishabituate to the new verb/new category stimulus, which was equally novel, but they do not. Future research could disentangle these explanations by presenting multiple action categories using a "switch" design (Stager & Werker, 1997).

We also found a relationship between verb vocabulary and cumulative looking—but only when children had encountered variable action categories. Substantial evidence for a positive correlation between vocabulary and object categorisation (e.g. Samuleson & Smith, 1999) has catalysed exciting research into the cognitive processes underlying categorisation (Colunga & Smith, 2005; Kemp, Perfors & Tenenbaum, 2007; Yee, Jones & Smith, 2012). Our data indicate that vocabulary is also related to *action* categorisation, providing a starting point for new investigations of this relatively under-researched aspect of language acquisition.

The existing verb learning literature largely focuses on how older children bootstrap their way into grammatical verb use via syntax (Fisher, Gertner, Scott & Yuan, 2010; Naigles, 1990), linguistic distribution (Christiansen & Monaghan, 2006; Twomey, Chang & Ambridge, under review; Wonnacott, 2011), or lexical semantics (Ambridge, Pine & Rowland, 2012; Ambridge, Pine, Rowland & Chang, 2012). The current work joins the handful of studies focusing on children at the earliest stages of verb learning (e.g., Arunachalam & Waxman, 2010, 2011; Childers, 2011). We suggest that verb learning and action categorisation can be linked to one of the *low-level* perceptual factors, which demonstrably affect noun learning: visual variability. Specifically, visual variability in action categories influences how young children encode and discriminate verb/action pairs. This work demonstrates that, as in noun learning, categories and verb learning interact, providing an important first step in understanding the complex interplay between verb learning and perceptual variability.

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Table 1. Mean looking times during the habituation phase. Standard deviations are provided in parentheses.

	Identical Actions	Variable Actions
First block	67.74s (20.15s)	70.13s (18.45s)
Final block	21.83s (8.43s)	22.99s (10.28s)
Cumulative Looking	141.42s (61.61s)	173.77s (100.48s)
Trials to Habituate	9.50 (3.88)	9.83 (3.22)

Table 2. Mean looking times during each test trial. Standard deviations are provided in parentheses. Asterisks note significantly increased looking compared to baseline trials, * $p < .05$, ** $p < .01$, *** $p < .001$.

	Identical Actions	Variable Actions
Baseline	10.81s (8.62s)	9.60s (7.69s)
Same verb/Same action	12.45s (8.02s)	11.89s (8.78s)
Same verb/New action	12.49s (8.40s)	17.66s* (11.26s)
New verb/Same action	19.64s** (10.82s)	14.64s (10.96s)
New verb/New action	19.03s* (11.18s)	14.74s (11.68s)
Posttest	24.84s*** (7.19s)	27.93s*** (6.19s)

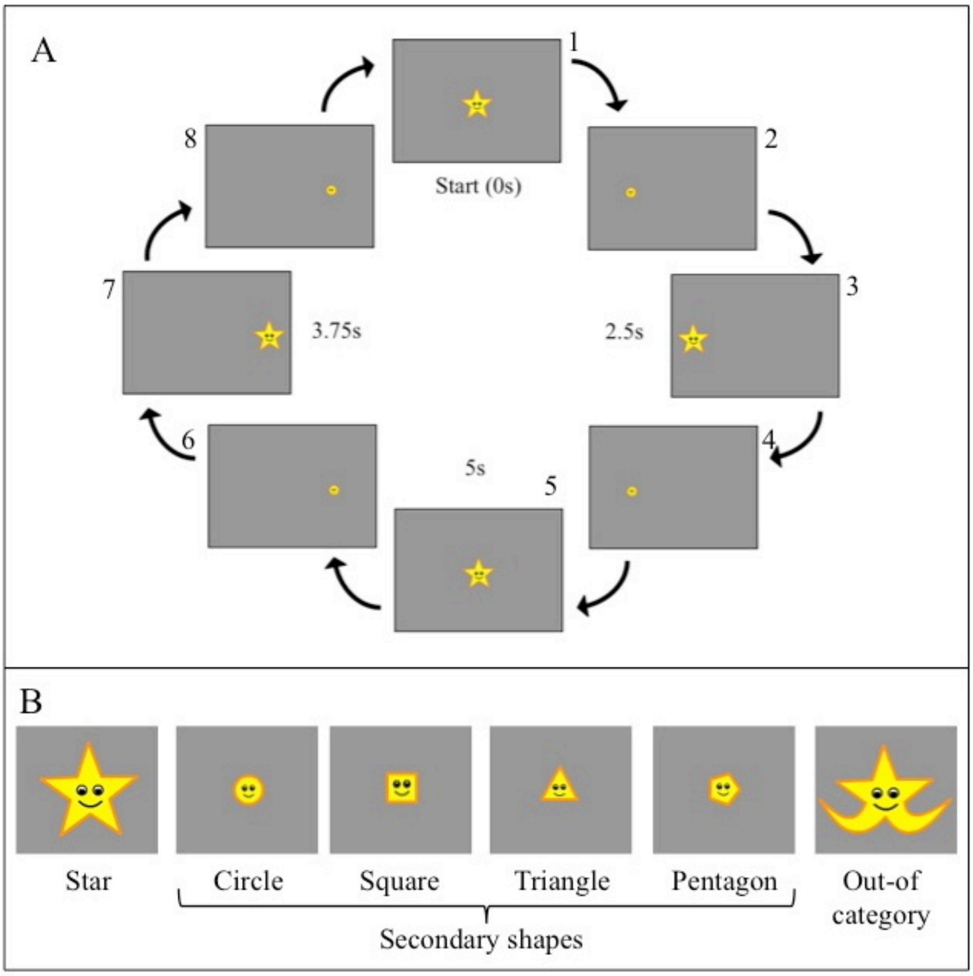

Figure 1. Time course of a single clip (Panel A) and close-up of exemplars (Panel B). Panel A denotes time elapsed in seconds for the looped clips.