Processing Figures and Grounds in Dynamic and Static Events

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1. Introduction

Learning relational terms such as verbs and prepositions are at the core of language development. Verbs and prepositions describe static and dynamic relations between objects and events (e.g., the cup is *on* the table or the woman is *catching* the cat). The study of relational terms brings two distinct fields together: linguistic theory and infants' event processing. This paper explores infants' processing of two foundational constructs in events, *figure* and *ground* that are coded by relational terms.

To learn relational terms, particularly verbs, infants must first notice the actions and events that various languages express, and second learn which event components are encoded in their native language. Finally, children package these components in a way consistent with their native tongue (Gentner, 1982; Gentner & Boroditsky, 2001; Gentner & Bowerman, in press; Golinkoff et al., 2002; Golinkoff & Hirsh-Pasek, 2008). A motion event involves different semantic components codified across languages (Talmy, 1985). Those foundational components studied thus far in the literature are *path* (i.e., the trajectory of an action with respect to a ground; *over* or *below); manner* (i.e., how the action is performed; *jumping* or *rolling*); *source* (beginning point of an event), and *goal* (ending point of an event) and spatial relations (Choi & Bowerman, 1991; Talmy, 1985) like *containment* (putting things *in* a container) and *support* (putting things *on* a surface).

The growing body of evidence from studies on foundational components suggests that infants' processing of these event components follows a universal to language-specific pattern. Consider an imperfect analogy from phonological development. Prelinguistic infants in different environments are able to distinguish between phonemes in the world's languages, regardless of the

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language to which they are exposed (e.g., Eimas, Miller, & Jusczyk, 1987; Kuhl et al., 1997; Werker & Tees, 1984). Learning native language lessens the capability to make phonological distinctions that appear in non-native languages. Infants might learn relational language in a similar way (see also Hespos & Spelke, 2007). They might detect a common set of foundational components of events regardless of the language they are learning, which are later influenced by distinctions encoded in the native language (for a detailed discussion see Göksun, Hirsh-Pasek, & Golinkoff, under review). Thus, exposure to and learning the native language might allow infants to choose a subset of these foundational components.

Yet, to date, relatively few foundational constructs have been examined. In this paper, we add to the burgeoning literature by examining *figure* and *ground*, which are central to learn relational terms.

1.1. Processing Event Components

The event components studied thus far share three common features. First, infants *perceptually* access them in their environment (Mandler, 2004). Second, languages universally code these components (Jackendoff, 1983; Talmy, 1985). For example, the *path* of an event is expressed in many languages with verbs (e.g., *descend, exit)* and prepositions such as *into* and *across*. Third and importantly, languages vary in the ways in which they encode these constructs (e.g., climb *up* in English whereas tırmanarak *çıktı* "*go up* climbingly" in Turkish).

Previous research demonstrates that prelinguistic infants reared with different languages *detect* components of motion events -path, manner, source, and goal- as well as the spatial relations of containment and support (Choi & Bowerman, 1991; Hespos & Baillargeon, 2001a, 2001b; Lakusta, Wagner, O'Hearn, & Landau, 2007; Pulverman, Golinkoff, Hirsh-Pasek, & Buresh, 2008). Furthermore, infants are sensitive to the distinctions that are not lexicalized in their native language. For example, English-reared 5-month-olds differentiate between tight- and loose-fit events (degree of fit relation coded by Korean verbs) in both containment and support categories (Hespos & Spelke, 2004).

Prelinguistic infants also *categorize* event components (e.g., Casasola, Cohen, & Chiarello, 2003; Pruden et al., 2004). For example, infants form a category of *under* when they see this path across various manners (e.g., spinning, twisting, toe-touching; Pruden et al., 2004). Similar to noticing subtle distinctions not necessarily encoded in their native language, English-reared infants also categorize relying on the common degree-of-fit relation between two events (i.e., tight- or loose-fit; McDonough, Choi, & Mandler, 2003), considering "a key in a keyhole" to be the same relation as "a cork in a bottle".

Taken together, infants seem to possess a general set of nonlinguistic constructs within and across their native language that form bases for learning relational terms. This might be analogous to the universal phonological categories infants have before learning their native language. Research is still in the beginning to reveal infants' processing of nonlinguistic dynamic events. This paper broadens the scope of event components and tests infants' discrimination of *figures* and *grounds* in events.

1.2. Figure and Ground

Figure and ground are two core components of motion events. Each motion event requires a moving or possibly movable entity (i.e., figure) to do the action on a stationary setting (i.e., ground). These foundational constructs share the same three features with other semantic components examined in the literature. First, they are perceptually accessible to infants. Second, languages universally express events using figures and grounds. For example, in the sentence "John is walking across the street," John is the figure and street is the ground. Finally and similar to other foundational components, *figure* and *ground* are packaged differently in languages like English and Japanese (Muehleisen & Imai, 1997).

In English, for example, the satellites *over*, *into*, and *across* specify both a path that the *figure* follows and the spatial properties of the *ground* object (Talmy, 2000). For example, 'across' implies a relatively stable surface that can be traversed while 'along' implies a more or less horizontal principal axis (Jackendoff, 1992). In contrast, some languages such as Japanese classify motion path verbs into two categories: directional-path and ground-path verbs. *Directional-path* (DP) verbs define the direction of motion relative to a starting point or goal (e.g., *hairu* 'enter', *iku* 'go', *kaeru* 'return', *kuru* 'come'). DP verbs do not restrict the *ground* on which motion occurs (Muehleisen & Imai, 1997; Tsujimura, 2006).

The other type of Japanese path verbs is *Ground-path* (GP) verbs such as *wataru* 'go across', *koeru* 'go over', *nukeru* 'pass through,' in which the constraints of the ground is incorporated along with the direction of motion (Beavers, 2008; Muehleisen & Imai, 1997; Tsujimura, 2006). For example, *wataru* 'go across' implies that the ground (i.e., river/street) forms a barrier between two sides and is a flat extended surface. Thus, *wataru* 'go across' cannot be used for a ground that is *not* flat (e.g., mountain) or when the ground does not contain a barrier between two sides (e.g., a grassy field). By changing the nature or shape of the ground, the Japanese verb itself changes. These GP verbs are contextually very specific about the ground compared to DP verbs (Muehleisen & Imai, 1997).

1.3. The Present Studies

The purpose of the present studies is to explore infants' processing of figures and grounds in nonlinguistic (1) dynamic events and (2) in the static representations of the same events.

In Experiment 1, we test English-reared infants' discrimination of figures and grounds in a *crossing* event. This event was chosen due to differential encoding between English and Japanese. In particular, the Japanese ground-path verb *wataru* 'go across' can be used with grounds such as railroad, road, bridge, street, but not with tennis court or grassy field. In English, one can use 'go across' with all six grounds. Thus, the Japanese verb *wataru* 'go across' is more specific and restricted in meaning compared to English verb 'cross.'

Infants will initially be exposed to a figure crossing a ground four times (e.g., a man crossing a road) during familiarization. At test, they will be presented with the same event in the split-screen either with a change in *figure* (e.g., a man crossing a road vs. a woman crossing a road) or a change in *ground* (e.g., a man crossing a road vs. a man crossing a railroad). We also manipulated the ground comparisons. Infants were presented some grounds that were coded as two verbs in Japanese *wataru* 'go across' and *tooru* 'go through' (e.g., road vs. tennis court) in Japanese. We hypothesize that (1) infants will look longer to the *novel* figure or *novel* ground in the test trial, if they notice the change from familiarization to test, and (2) English-reared infants might also differentiate grounds better when the comparison is between two categories in Japanese (*wataru* 'go across' vs. *tooru* 'go through').

In Experiment 2, we examine infants' discrimination of figures and grounds in the same events when presented as static representations rather than dynamic. In a recent study, Bornstein, Arterberry, and Mash (2007) showed that 6-month-old infants attend both to figures and their natural context (e.g., the natural context for a bear is the forest) in static pictures. However, we do not yet know how infants process figures and grounds in static representations of dynamic events (e.g., picture of a crossing event when the person is in the middle of the scene). This is important to address for the following reasons. First, movement is not the simple collection of static forms (Cutting & Profitt, 1981). Spatial configuration of events might be different with dynamic events and static scenes of the same events. The continuous relations are better captured through dynamic relations (Jackendoff, 2008, personal communication). Thus, the comparison of dynamic and static scenes for the same events will provide us to evaluate this distinction. Infants' perception of objects is better when they are in motion (e.g., Slater, Morison, & Town, 1985; Smith, Johnson & Spelke, 2003). Additionally, in the absence of motion, Japanese should not make distinctions among grounds, because ground-path verbs represent the combination of the *path* of the *figure* with the *ground*. Using the same design as dynamic events, with the exception of static pictures of actions, we hypothesize that (1) infants will still look longer to the *novel* figure or *novel* ground in the test trial if they notice the change from familiarization to test, (2) infants' detection of static figure would be later than they do with moving figures, (3) infants might notice ground changes earlier than they do in dynamic events, and (4) due to the absence of path information, there will be no difference in infants' notice of different ground comparisons.

2. Experiment 1: Do infants discriminate figures and grounds in dynamic events?

2.1. Participants

Forty-nine 7- to 9-month-old (*M*= 8.01, *SD*= .76) and thirty-nine 10- to 12-month-old (*M*=11.10, *SD*= .82) English-reared infants participated in this experiment. Infants were randomly assigned to either figure or ground discrimination study. All infants were monolingual and full-term at birth. Additional 17 infants across two studies and two age groups were excluded from data analyses due to being bilingual (*n* = 4), low attention (*n* = 11), experimental error (*n* = 1), and side bias (*n* =1). The attention and the side bias of each infant were calculated before analyses. The criterion for the low attention was looking at the movie less than 50%. For the side bias, the criterion was looking at one side of the screen in split-screen trials 80% of their looking time.

2.2. Stimuli

Stimuli consisted of televised displays of four people (a woman, a man, a six-year-old girl and a six-year-old boy) crossing one of the six grounds (railroad, road, narrow street, bridge, tennis court, and grassy field). Stimuli were videotaped outdoors and created using Final-Cut Pro-3D. No linguistic audio accompanied these dynamic events.

In the figure discrimination study, infants were presented one of the three comparisons of figures: adult-adult, adult-child, and child-child. The figures were also shown on different grounds in each condition.

In the ground discrimination study, two conditions emerged depending on the fine-grained encoding in Japanese: within-wataru category (*wataru* ‘go across’, *e.g.*, railroad and road) and out-of-wataru category (*e.g.*, railroad and tennis court or road and grassy field) comparisons. Four of these grounds (railroad, road, narrow street, and bridge) are encoded by the same verb *wataru* ‘go across’ in Japanese. These grounds signal clear boundaries between the starting point and the goal point. Grassy field and tennis court are not typically described by the verb *wataru* ‘go across’ and are coded by *tooru* ‘go through’ in Japanese.

2.3. Procedure

Infants were tested using Preferential Looking Paradigm (Hirsh-Pasek & Golinkoff, 1996). The child was seated on the lap of her parent centered in front of a large screen television. We asked the parent to keep their eyes closed during the study not to influence the child’s direction of eye gaze. If violated, we excluded the child from further analyses.

For both figure and ground discrimination studies, the movie started with an *introduction* phase displaying a puppet first on the one side of the split-screen and then on the other side to make sure that infants looked both sides of the screen. After the introduction phase, infants were initially exposed to the *salience* phase, in which they saw the test trial to examine *a priori* preference to either clips. Following the salience phase, infants were presented *familiarization* phase. This included four 12-second clips of exactly the same stimulus that involved a figure crossing a ground (e.g., woman crossing a railroad).

During the *test* phase in the figure discrimination study, infants were presented the comparison between *same figure/same ground* (a woman crossing a railroad) vs. *novel figure/same ground* (a man crossing a railroad). This assessed whether infants noticed that figure was changed in one of the events presented in the split-screen.

For the ground discrimination, in the *test* phase the comparison was between *same figure/same ground* (a woman crossing a railroad) vs. *same figure/novel ground* (a woman crossing a road) to assess infants' detection of ground change. The procedure was the same for both within- and out-of-wataru-category ground conditions. The only difference was the compared grounds. In within-wataru-category conditions the comparison was between two of the four grounds encoded by the Japanese verb *wataru* (railroad, road, street, and bridge). In out-of-wataru-category conditions, one ground was from the wataru category and the other was either tennis court or grassy field that were not typical grounds for the verb *wataru*. Infants were randomly assigned to one of these conditions.

The side of the novel figure or novel ground was counterbalanced in both salience and test trials. Infants' looking times were recorded for later coding.

2.4. Results

We calculated infants' percentage of looking time towards each event in the split-screen for *salience* and *test* trials. We report results separately for the figure and ground studies.

Figure discrimination. Results from *salience* trials indicated that infants did not have any *a priori* preference for the event clips at any age (7- to 9-month-olds: t (25) = 1.58, p = .127, 10- to 12-month-olds: t (17) = .319, p = .754). A one-way ANOVA yielded a main effect of age for looking times to the *novel* figure in the test trial, F (1, 41) = 4.48, p= .040. As seen in Figure 1 (left graph), only 10- to 12-month-old infants looked longer to the *novel* figure compared to the *same* figure in test trials, t (17) = 3.42, p = .003.

Ground discrimination. Similar to the figure discrimination, infants did not have any *a priori* preference to either event at any age (7- to 9-month-olds: t (22) = .852, p = .403, 10- to 12-month-olds: t (21) = .302, p = .766). No main effects of age or ground condition were obtained in terms of looking at the novel ground at test, F (1, 43) = .24, p= .877 and F (1, 43) = .37, p= .848. Thus, infants at these age groups had similar percentages of looking times to *novel* and *same* grounds in test trial (see Figure 1, right graph).

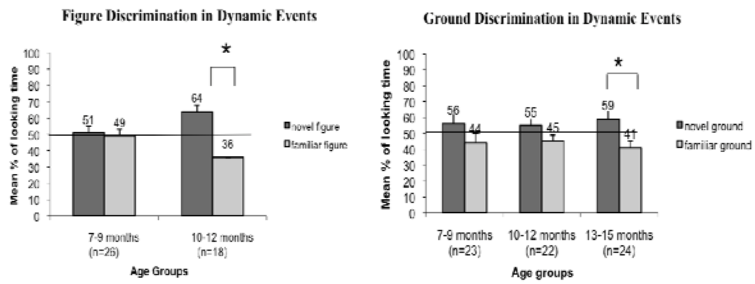

Figure 1. Mean percentage of looking times to novel vs. familiar figure (left graph) or ground (right graph) across age groups in dynamic events.

To examine the possibility of the developmental change in ground discrimination, we recruited an older group of infants: 13- to 15-months (*M*= 14.23, *SD*= .93). At this age, infants looked longer to *novel* ground in test trial, *t* (23) = 2.87, *p* = .050. Importantly, there was also a main effect of ground condition, *F* (3, 23) = 2.49, *p*= .049. As shown in Figure 2, infants looked longer to novel ground only in out-of-wataru category comparison (e.g., railroad vs. tennis court), *t* (12) = 4.07, *p* = .002.

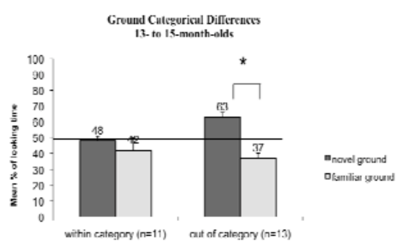

Figure 2. Mean percentage of looking times to novel vs. familiar ground in within-wataru category (e.g., railroad vs. road) and out-of-wataru category (e.g., railroad vs. tennis court).

2.5. Discussion

Results from the first experiment indicated that English-reared infants started noticing the change of figure and ground in nonlinguistic dynamic events by 11 and 14 months of age, respectively. Interestingly, ground differentiation was salient for English-reared infants for the comparisons when two grounds were encoded with different verbs in Japanese (e.g., road vs. tennis court comparison). This distinction of non-native encoding of grounds by English-reared infants suggests that infants might share more universal conceptions of foundational constructs like figure and ground.

3. Experiment 2: Do infants discriminate figures and grounds in static representations of dynamic events?

3.1. Participants

Twenty-seven 7- to 9-month-old (*M*= 8.14, *SD*= .77) and twenty-five 10- to 12-month-old (*M*=11.08, *SD*= .89) English-reared infants participated in this experiment. Infants were randomly assigned to either figure or ground discrimination study. All infants were monolingual and full-term at birth. Additional 22 infants across two studies and two age groups were excluded from data analyses due to being bilingual (*n* =3), low attention (*n* = 13), experimental error (*n* = 4), and side bias (*n* =2). The criterion for the low attention was looking at the movie less than 50%. For the side bias, the criterion was looking at one side of the screen in split-screen trials 80% of their looking time.

3.2. Stimuli

Stimuli consisted of the same televised displays of four people (a woman, a man, a six-year-old girl and a six-year-old boy) crossing one of the six grounds (railroad, road, narrow street, bridge, tennis court, and grassy field). This time, instead of dynamic events, we used the snapshots of them while people were the middle of the screen. All stimuli at all phases were static representations of dynamic events. The movies were made using Final-Cut Pro-3D.

As in the dynamic figure discrimination study, there were three comparisons of figures: adult-adult, adult-child, and child-child. The figures were also presented on different grounds in each condition.

In the ground discrimination study, static representations of these events are not necessarily coded by different verbs. Yet, to compare it with dynamic events there were again two conditions depending on how Japanese encoded these ground verbs in dynamic contexts. One condition involved the comparison of two grounds from the category of *wataru* (e.g., road vs. railroad) and the other condition will be the comparison of a ground from the category of *wataru* with *tooru* (e.g., road vs. tennis court).

3.3. Procedure

The procedure for static figure and ground discrimination studies was exactly the same as dynamic figure and ground studies.

3.4. Results

We calculated infants' percentage of looking time towards each event in the split-screen for *salience* and *test* trials. We report results separately for the figure and ground studies.

Figure discrimination. Infants did not have any *a priori* preferences at *salience* for the event clips at any age (7- to 9-month-olds: t (13) = 1.26, p = .123, 10- to 12-month-olds: t (11) = .145, p = .174). A one-way ANOVA showed a main effect of age for looking at the *novel* figure in the test trial, F (1,

25) = 5.53, *p*= .027. Only 10- to 12-month-old infants looked longer to the *novel* figure compared to the *same* figure at test, *t* (11) = 2.05, *p* = .055 (see Figure 3, left graph).

Ground discrimination. Similar to the figure study, infants did not have any preference for either event at any age (7- to 9-month-olds: *t* (12) = .115, *p* = .272, 10- to 12-month-olds: *t* (12) = 1.116, *p* = .286). No main effects of age or ground condition were obtained in terms of looking at the novel ground at test, *F* (1, 25) = 2.03, *p*= .167 and *F* (1, 25) = .554, *p*= .464. However, as shown in Figure 3 (right graph) and different from dynamic events, infants at both age groups significantly looked longer to the *novel* ground in the test trial (7- to 9-month-olds: *t* (12) = 2.386, *p* = .034; 10- to 12-month-olds: *t* (12) = 4.239, *p* = .002).

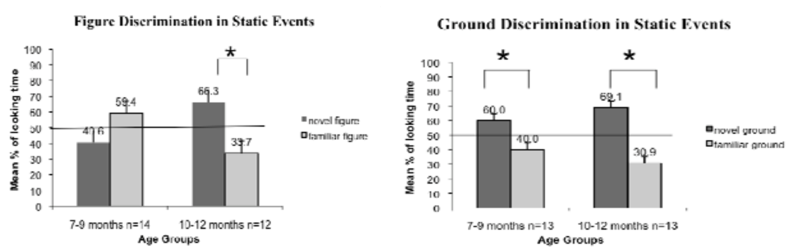

Figure 3. Mean percentage of looking time to novel vs. familiar figure (left graph) or ground (right graph) across age groups in static events.

3.5. Discussion

Results from the second experiment showed that infants differentiated static figures by 11 months of age, which was the same time that they detected moving figures in dynamic events. In contrast, ground discrimination was 6 months earlier when both components were static (i.e., by 8 and 14 months of age for static and dynamic events, respectively). In static events, however, infants did not represent a distinction of grounds. That is, both age groups treated within- and out-of-wataru category comparisons of grounds similarly.

4. General Discussion

Relational terms label multiple aspects of events only some of which have been examined. The current studies present the first evidence that infants process figures and grounds in nonlinguistic dynamic events and their static representations. This is an important first step in learning relational terms, particularly for motion verbs (Gentner & Bowerman, in press; Golinkoff et al., 2002; Golinkoff & Hirsh-Pasek, 2008).

Our findings from dynamic stimuli are in line with previous studies on foundational components in events. Similar to event components such as containment-support, path-manner, and source-goal (e.g., Casasola & Cohen, 2002; Lakusta et al., 2007; Pulverman et al., 2008), figure and ground are perceptually available to infants. First, infants notice these components in events indicating that they seem to come prepared to divide the events into a set of categories that are relevant to later language (e.g., Lakusta et al., 2007; McDonough, et al., 2003; Pruden, 2006; Pulverman et al., 2008). Figure and ground detection in dynamic events present another case suggesting that this might be *universal* in two senses: independent of the language environment infants are in, they notice nonlinguistic components of events, and infants distinguish non-native distinctions in events that are not typically lexicalized in their native tongue (Hespos & Spelke, 2004).

Second, similar to the universal phonological categories prelinguistic infants possess (e.g., Eimas, Miller, & Jusczyk, 1987; Kuhl et al., 1997; Werker & Tees, 1984), there might be a broad set of foundational components in events, which will later be dampened by attending to a subset of them coded in one's native language (see also Hespos & Spelke, 2007). The findings on the *ground discrimination* in dynamic events support evidence for this argument, in which English-reared infants are sensitive to 'the nature of the ground' that is less specific for English verb 'cross.' More research is required to examine (1) the detection of these constructs cross-culturally, and (2) the developmental changes with learning native language. Our lab is currently conducting studies on Japanese-reared infants' discrimination of grounds as well as older English- and Japanese-reared infants' (19- to 21-months of age) detection of ground changes to test these questions in detail.

Finally, we found a differential developmental trajectory in distinguishing figures and grounds in dynamic events. Infants process figures earlier than grounds. One might also argue that animacy is an important factor in noticing figure changes. Future studies should involve inanimate figures such as vehicles or animate figures such as animals to see the role of animacy on figure discrimination.

This paper has also important findings with regard to the distinction between dynamic vs. static events (Cutting & Profitt, 1981; Jackendoff, 1992). Developmental and attention patterns between the results of two studies demonstrate that infants do not consider these events as the same. Grounds are better noticed in the absence of motion, suggesting that figure's movement decreases the attention to other aspects of the event, particularly for younger infants. On the other hand, the subtle cross-linguistic encoding of grounds is not apparent when the event is presented in static scene. Events are dynamic in nature and are not only the combination of static components.

5. Conclusions

Research in the last decade makes progress on uncovering the nonlinguistic constructs in events that are related to learning relational terms. Our findings on figure and ground discrimination expands that growing literature, suggesting that prelinguistic infants have a broad and possibly universal basic constructs that are expressed by verbs and prepositions across languages.

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