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The privileging of ‘Support-From-Below’ in early spatial language acquisition

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ABSTRACT

Spatial terms that encode support (e.g., “on”, in English) are among the first to be understood by children across languages (e.g., Bloom, 1973; Johnston & Slobin, 1979). Such terms apply to a wide variety of support configurations, including Support-From-Below (SFB; cup on table) and Mechanical Support, such as stamps on envelopes, coats on hooks, etc. Research has yet to delineate infants’ semantic space for the term “on” when considering its full range of usage. Do infants initially map “on” to a very broad, highly abstract category – one including cups on tables, stamps on envelopes, etc.? Or do infants begin with a much more restricted interpretation - mapping “on” to certain configurations over others? Much infant cognition research suggests that SFB is an event category that infants learn about early - by five months of age (Baillargeon & DeJong, 2017) - raising the possibility that they may also begin by interpreting the word “on” as referring to configurations like cups on tables, rather than stamps on envelopes. Further, studies examining language production suggests that children and adults map the basic locative expression (BE *on*, in English) to SFB over Mechanical Support (Landau et al., 2016). We tested the hypothesis that this ‘privileging’ of SFB in early infant cognition and child and adult language also characterizes infants’ language comprehension. Using the Intermodal-Preferential-Looking-Paradigm in combination with infant eye-tracking, 20-month-olds were presented with two support configurations: SFB and Mechanical, Support-Via-Adhesion (henceforth, SVA). Infants preferentially mapped “is on” to SFB (rather than SVA) suggesting that infants differentiate between two quite different kinds of support configurations when mapping spatial language to these two configurations and more so, that SFB is privileged in early language understanding of the English spatial term “on”.

1. Introduction

Spatial words (e.g., *in* and *on* or their cross-linguistic equivalents) are among the first to be understood by children across languages (e.g., Bloom, 1973; Johnston & Slobin, 1979), suggesting that ‘core spatial concepts’ or universal pre-linguistic ‘primitives’ support children’s earliest acquisitions (e.g., Clark, 1973; Landau & Jackendoff, 1993; Regier, 1996; Talmy, 1983). However, the idea that spatial words map directly to pre-existing, universal, core spatial concepts has been questioned because of the detailed cross-linguistic variability found in spatial term meanings (see Levinson & Wilkins, 2006). For example, English uses “on” to describe three different

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sub-types of support: solid support, which includes support from below, (e.g., cookie on plate), tenuous support (e.g., clothes on line), and encirclement (e.g., necklace on a neck). But Dutch encodes these configurations with distinct terms ("op" for solid support, "aan" for tenuous support, and "om" for encirclement; Gentner & Bowerman, 2009). Research suggests that by the age of two children become sensitive to such language specific word meanings (e.g., Bowerman, 1996; Bowerman & Pederson, 1992; Choi & Bowerman, 1991; Choi, McDonough, Bowerman, & Mandler, 1999), supporting the idea that each child learns, relatively quickly, which of the many possible spatial concepts their language will encode.

But these findings about early language learning still leave open the possibility that certain spatial concepts (instantiated by particular configurations) will be especially available to pre-verbal infants as candidates for spatial meanings. The aim of the current study is to test whether and how a specific spatial configuration - one that has been shown to play a key role in infants' understanding of support, as well as in child and adult language – may afford infants with a privileged[1] representation as they learn the meaning of the basic spatial term encoding support. Specifically, we test the hypothesis that configurations representing Support-From-Below (henceforth, SFB) are privileged candidates to be mapped to the English expression BE *on,* which is the 'Basic Locative Construction' for expressing location in English (see Levinson & Wilkins, 2006 for discussion of Basic Locative Constructions across languages). As will be discussed below, our hypothesis is largely motivated by findings from infant cognition and especially from language production studies with adults and children, which together suggest that BE *on* in English maps preferentially to SFB. In the current study, we test whether this preferential mapping between space and language shows up very early in language development – in comprehension among 20-month-old infants. We ask whether infants initially map BE *on* (i.e., "is on") to SFB, the same pattern as shown by older children and adults; or alternatively, whether infants start by mapping "is on" to a very broad, highly abstract category of spatial support configurations that includes SFB (e.g., cups on tables) as well as quite different kinds of support, in this case, Mechanical Support (e.g., stickers on envelopes).

1.1. Representations of support in infant cognition – a special role for SFB

Research in infant cognition has explored how infants represent support, specifically, SFB. Infants can categorize support relations as early as 10-months; when habituated to six different configurations of SFB (e.g., bug on top of block, dog on top of bowl), infants generalize to a new exemplar of SFB vs. a novel containment relation (Casasola & Park, 2013). At 14-months, infants can map a novel label ("blick") onto a SFB relation (Big Bird placed on a box), suggesting that these concepts are stable enough to be mapped into language (Casasola & Wilbourn, 2004). Further, prior to 10-months, infants are able to reason about objects in a support relation. As explained by Baillargeon and DeJong (2017), at 2.5–4.5 months, infants expect an inert object to fall when released in mid-air but they have no expectation about whether the object should fall or remain stable if placed in contact with a base - including contact involving SFB (object A on top of object B) as well as contact involving Support-Via-Side (object A on the side of object B, via adhesion, for example). This suggests that from a very early age, infants' understanding of support is something akin to '+ contact'. As infants begin to observe variations in the outcomes of events related to objects on bases (e.g., when object A contacts object B, sometimes it remains stable, and sometimes it falls), a process dubbed Explanation Based Learning by Baillargeon and DeJong (2017) is triggered, and infants use their available physical concepts (e.g., gravity and solidity principle) to learn that the *location of contact* for an object on a base matters for support. Specifically, an object that is placed on top of a base (i.e., an object *supported from below*) will remain stable, but an object placed on the side of a base will fall (e.g., Needham & Baillargeon, 1997; see Baillargeon & DeJong, 2017). Baillargeon and DeJong explain this 'location-of-contact rule' as:

"An object is stable when it is released on top of, but not against, a base (e.g., Baillergeon, 1995; Hespos & Baillargeon, 2008; Needham & Baillargeon, 1997). The principles of gravity and solidity provide a ready explanation for this rule: When an object is released on top of a base, the base effectively blocks the object's fall, because the object cannot pass through the base; when an object is released against a base, however, there is nothing to block the object's fall. This first rule thus serves to establish a new event category, "support" (or more specifically, "passive support from below"), which describes a causal interaction between two objects with distinct event roles: A "support" blocks the fall of a "supportee." (p. 1513, Baillargeon & DeJong, 2017).

This account highlights that SFB is an event category which infants learn about early in life, building on knowledge of the physical concepts necessary for this understanding. We hypothesize that this early understanding of SFB in infants' representations of support has consequences for language learning as well. Specifically, we hypothesize that infants will preferentially map the canonical spatial terms encoding support (in English, BE *on*) to SFB over other support configurations, such as Support-Via-Adhesion (SVA). SVA requires mechanisms that are 'sticky' - such as tape, glue, and Velcro. To our knowledge, research in infant cognition has not yet reported when and how infants establish event categories for these types of mechanical support configurations. However, given existing research showing that infants have rich physical concepts (e.g., gravity and solidity; see Spelke & Kinzler, 2007), it is likely that event categories involving adhesion would be acquired after SFB, when infants have had experience with the relevant mechanisms (e.g. for adhesion, stickiness). In the current study, we test whether these possible differences in understanding of SFB vs. SVA by infants result in them preferring to map BE *on* (in English) to SFB over SVA.

[1] By "privileged we mean a representation that is preferred over another representation for a particular purpose. In our case, infants show a preference to map a spatial configuration of SFB to a particular lexical item compared to a spatial configuration of SVA.

1.2. The encoding of support in language

Our hypothesis that infants will map BE *on* to SFB is also largely motivated by a set of findings suggesting that adults and children show a linguistic differentiation within the semantic space of support – a "division of labor" (Johannes, Wilson, & Landau, 2016; Landau, Johannes, Skordos, & Papafragou, 2016; see Landau, 2018 for a review). In these studies, adults and children (4- and 6-years) were shown static images of various support and containment configurations (e.g., for support: cup on plate, picture on mug, stamp on envelope, coat on hook etc.) and were asked "Where is the X" (which is the specific question that elicits the Basic Locative Construction across languages; see Levinson & Wilkins, 2006). For English speaking adults and 6-year-old children, BE *on* was used most frequently to describe configurations of SFB, while other lexical verbs (e.g. *stick, hang)* were used for support configurations that depended on other mechanisms, such as attachment or hanging. Four-year-old children also showed this differential pattern of responding when presented with a forced-choice version of the description task. Landau and colleagues conclude that there is a "division of labor" that characterizes the semantic domain of support: BE *on* maps preferentially to SFB whereas other linguistic devices, such as lexical verbs in English, map to Mechanical Support. Reminiscent of the findings from infant cognition described above, these findings also suggest a 'special' role for SFB–but this time in how it is mapped to language. As early as 4 years of age, the Basic Locative Construction maps to SFB, suggesting that this representation of support, in particular, may be privileged in learning the basic linguistic construction that encodes support.

Recently, Lakusta, Brucato, and Landau (2020) report similar findings for children who are in the very early stages of language production (13 months to 47 months). In their study, 1945 utterances containing *on* were extracted from the Child Language Data Exchange System (CHILDES, MacWhinney, 2000) and were coded for the type of support likely embodied in the configuration being described (SFB, Mechanical Support, and 'other'). Findings revealed that children used *on* primarily to encode configurations of SFB (e.g., "cheese sandwich *on* a plate"), and this was especially true for the youngest children (13–30 months), who used *on* to encode SFB well above chance (67 %). Although children did use *on* to encode Mechanical Support, such as adhesion (e.g., "You have to put a Band-Aid on it"), they did so much less often (zero times for children 13–23 months and 12 % for children 24–30 months and 18 % for children 31–47 months). Thus, even in the earliest stages of language production, children preferentially map *on* to SFB, but not to Mechanical Support, suggesting that SFB is a privileged configuration for the mapping of spatial language in this domain, at least relative to Mechanical Support.

1.3. The current study: a test of language comprehension

The findings reviewed above suggest that SFB may play an integral role in infants' understanding of physical support, and that adults and children encode SFB differently than Mechanical Support (specifically, preferentially mapping the Basic Locative Construction to SFB). Given these findings, we ask whether this linguistic differentiation emerges at the earliest stages of language development, even before frequent production of BE *on.* We therefore use a comprehension test to ask whether infants prefer to map *on* to SFB rather than Mechanical Support.

Our method builds on a study by Meints, Plunkett, Harris, and Dimmock (2002). Using a modified version of the Intermodal Preferential Looking Paradigm (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987), Meints et al. (2002), tested whether infants map *on* differentially to typical rather than atypical support configurations (e.g., a cup that is centrally located on a table (typical) vs. located at a table's edge (atypical)). They report that infants as young as 15-months of age preferentially map *on* to a typical support configuration compared to an atypical one. Note that in these cases, the typical and atypical configurations were both instances of SFB, but infants' ability to distinguish between them when mapping to language suggests that infants' semantic space of *on* is already differentiated at 15 months, with some configurations preferred over others. In the current study, we also test infants' differentiation of semantic space, asking whether infants preferentially map BE *on* to SFB rather than Mechanical Support, specifically SVA.

We test 20-month-old infants, a slightly older group than Meints et al.'s infants, who had shown differentiation within the semantic space of *on*. Moreover, the findings from Lakusta et al. (2020) suggest that children as young 18-months of age encode both SFB and Mechanical Support with *on* in spontaneous production. Thus, by 20-months, infants have acquired a meaning for *on*. The question is whether they differentiate between two quite different kinds of support configurations (SFB, SVA) when mapping the word *on* to these two configurations.

We use a modified version of the Intermodal-Preferential-Looking-Paradigm (Golinkoff et al., 1987) in combination with infant eye-tracking (via a Tobii X2-60). Infants were simultaneously presented with two dynamic events: SFB (cube placed on top of box) and SVA (cube placed on side of box). While viewing these two events, during a Salience trial, infants heard neutral language ("Look here, what do you see? Look here"); during Test they heard spatial language ("Find the toy that is ON the box"). If infants preferentially map *on* to SFB over SVA, then they should look longer at SFB vs. SVA (but not during Salience). Further, measuring infants' looking time using an eye-tracker enables us to precisely measure infants' looking behavior as an indicator of spatial language comprehension – that is, any preferential looking at SFB should occur shortly after the key word – "on" - is uttered. Preferential looking at SFB vs. SVA after "on" is uttered (and not before) would suggest that SFB is privileged in mapping to "on" over SVA.

2. Method

2.1. Participants

Twenty-four 20-month-old infants (17 male; M_{age}19;27, range 19;15–20;14; $N = 20$ White, $N = 2$ Asian/Pacific Islander; $N = 1$

Black; $N = 1$ Hispanic or Latino) were included in the final sample. Participants were recruited from community fairs or lab research postings on various social media groups. All infants were born full-term, were learning English as their first language, and none had been exposed at home to another language. An additional 24 infants participated in the study but were excluded for the following reasons: 12 did not have eye tracking data collected because no calibration was possible with these infants due to the infants moving, eight did not meet the looking time criterion of having at least 35 % of their total looking time captured by the eye-tracker (see Hirsh-Pasek & Golinkoff, 1996), two had trials that had a technical error, and two became fussy prior to the test trials.

2.2. Apparatus

The data were collected using a table-mounted Tobii X2-60 Eye Tracker. The eye tracker has a gaze accuracy of 0.4 degrees and a maximum latency of 35 ms (maximum time needed for the eye tracker to process that eye movement has occurred).The stimuli were viewed on a 103cm×53cm television screen which was placed approximately 65 cm from the eye tracker.

2.3. Stimuli and design

The visual stimuli consisted of a large white box (30 cm^3), a small pink block (4 cm^3), and a person's hand. The background was black (see Fig. 1). Following the design of many IPLP studies (e.g., see Golinkoff, Ma, Song, & Hirsh-Pasek, 2013), infants were presented with audio and visual stimuli in three phases during the experiment: Introduction, Salience, and Test (see Fig. 2). The Introduction and Test phases included two trials each, while the Salience phase included one trial, for a total of five trials presented during the experiment. In between one trial and the next a flashing image of a smiling baby appeared in the center of the screen (3 s) to direct the infants' attention to the center. During the Introduction trials, infants viewed a static image of the pink block located next to a white box (20 s) while hearing, "Look at the toy and the box". On one Introduction trial the static image appeared on the left side of the screen and on the other it appeared on the right side of the screen, counterbalanced across infants. During the Salience and Test trials, infants were simultaneously shown dynamic events of the pink block being placed on, and supported by, the white box. In one event, the person's hand picked up the block and placed the block *on top of* the box (SFB) and in another event the hand picked up and placed the block *on the side of* the box (SVA). The events were shown in-phase such that the first few seconds of the videos were identical. In both events, the hand then retracted from the display and the block was shown on the box (see Fig. 1 for timing). Also, in both events, the block had transparent double-sided tape which ensured that the block would adhere to the box. The events (10 s each) played (looped) twice in the Salience and Test trials (for a total of 20 s for each trial). Whether the SFB or SVA events appeared on the left or right side of the screen was counterbalanced across infants.

Critically, the language that accompanied the stimuli during the Salience and Test trials differed. During Salience infants heard, "Look here! What do you see? Look here!"; during Test, infants heard "Look at the toy that IS ON the box." These sentences were uttered twice for each trial. The auditory stimuli were recorded by a female voice using infant-directed speech (see Fig. 2). If infants preferentially map "is on" to SFB vs. SVA, then they should look longer at SFB than SVA within the critical window during Test, and this looking pattern should differ from the one observed during the Salience trial

2.4. Procedure

Upon arrival at the lab, parents were provided with consent forms, a brief demographic survey, and the 'Prepositions and Locations' section of a standardized language questionnaire, the MacArthur-Bates Communicative Development Inventory (MCDI; Fenson et al., 2007) to assess children's language development of spatial prepositions. The questionnaire included 15 prepositions (e.g. on, to, under) and parents were asked to check off which words they believed their child understood and which words they said spontaneously

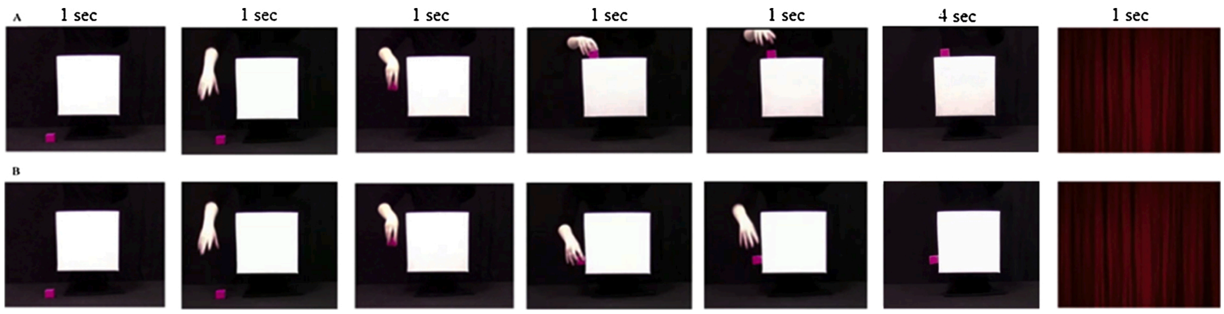

Fig. 1. Pictures of the dynamic events children viewed during the experiment. Panel A depicts the Support-From-Below event in which the block is placed on top of a box. Panel B depicts the Support-Via-Adhesion event in which the block is placed on the side of the box.
Note: In each event, the hand entered the screen (1 s), picked up the block (1 s), and moved (1 s) and placed the block on top of (Panel A - SFB; 1 s) or on the side of (Panel B – SVA; 1 s) the box. The hand then retracted (1 s) to leave the block in place on the box (4 s). The event concluded with red curtains closing over the image (1 s). In both events, the block had a translucent piece of tape which enabled it to adhere to the side of the box. The entire event played twice (i.e., the video looped) for a total duration of 20 s for each trial.

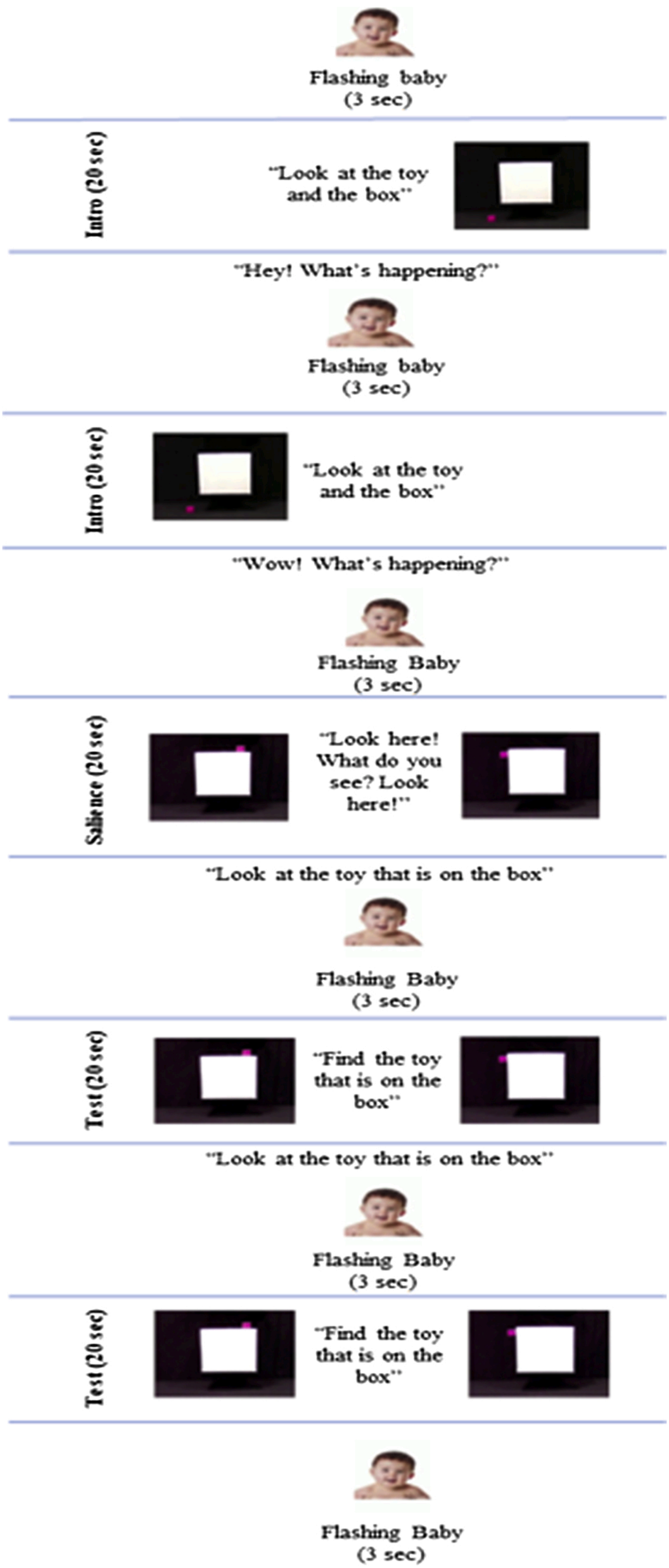

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Fig. 2. Order of presentation and timing of the experimental stimuli.
Note: Stimuli were presented in three phases, Introduction, Salience, and Test. For the timing of the individual dynamic events, see Fig. 1. Each panel in the figure depicts the TV display: left, center, and right. The audio and flashing baby always played from the center. The events played on the left and right sides for the Introduction, and on both sides for Salience and Test.

(i.e. without imitation) to assess children's comprehension and production of these words, respectively. When completed, the experiment proper began. Parents were taken to the testing room and asked to sit in a chair in front of the TV screen with their infant seated on their laps. They were instructed to keep their eyes closed while the stimuli were presented to the infant and to refrain from influencing their infant's looking patterns in any way (i.e., pointing, speaking during the video, etc.). Once the parent's eyes were closed, the eye tracker was calibrated by having the infant look at five points on the screen. Participants repeated calibration until an accurate eye measurement was recorded (i.e., eye-gaze data was recorded for at least 4 out 5 target points). The infant's eye-gaze was recorded for the entire duration of the stimuli presentation (see Fig. 2).

3. Results

The dependent variable was infants' looking duration at the Support-From-Below (SFB) event and the Support-Via-Adhesion (SVA) event. Total looking times for each of the two events were averaged across infants (see Table 1). The total looking times at these two events for Salience and Test (i.e., the average of Test 1 and 2) are shown in Table 1. A paired-samples *t*-test revealed that infants' looking duration at the SFB and SVA events did not significantly differ for Salience, $t(23) = 1.07$, $p = .30$, 2-tailed, or Test, $t(23) = 1.55$, $p = .13$, 2-tailed (note that infants' looking durations at SFB vs. SVA also did not significantly differ when Test 1 and Test 2 were considered separately (Test 1: SFB $M = 4137.50$, $SD = 3328.90$ and SVA $M = 3116.67$, $SD = 3246.76$, $t(23) = .82$, $p = .42$, 2-tailed; Test 2: SFB $M = 3300.00$, $SD = 2999.57$ and SVA $M = 1970.83$, $SD = 2258.41$, t(23) = 1.59, p = .12, 2-tailed).

As shown in Table 1, infants looked longer (although not significantly) at SVA vs. SFB during Salience, but showed the opposite looking pattern during Test, looking longer at SFB vs. SVA. Indeed, a 2 Trial Type (Salience, Test) x 2 Support Type (SFB, SVA) ANOVA revealed a significant interaction, $F(1, 92) = 5.41$, $p = .02$. There were no significant main effects of Trial Type, $F(1, 92) = 2.40$, $p = .13$, or Support Type, $F(1, 92) = .06$, $p = .81$. The different pattern of looking at the SFB vs. SVA events in Salience and Test suggests that the spatial language during Test was influencing infants' encoding of the events. We explore this further below.

Following several studies using the IPLP, a proportion was calculated for each infant (proportion of looking time = PLT): PLT = $\frac{SFB}{SFB + SVA}$. The PLT was computed for both the Salience and Test trials for every 100 ms in the trials, and these proportions were averaged across each time point for each infant. The PLTs for the Salience trial and the average of the two Test trials were then plotted in a time course, as shown in Fig. 3. Following Delle Luche, Durrant, Poltrock, and Floccia (2015), using a time-course analysis in R 4.0.0 and the eye-tracking R package (Dink & Ferguson, 2015), the difference between PLTs for the Salience and Test trials were compared to assess infants' comprehension of the "is on" language during Test. Further, following Delle Luche et al. (2015), a critical window for comprehension was identified; the critical language "is on" was uttered at approximately 4500 ms in the current study (signified by the straight line in Fig. 3). In their review of several IPLP language comprehension studies, Delle Luche et al. (2015) report that the most common critical window used to measure comprehension of language is 367–2000 ms *after* the critical language is uttered. Thus, the current study's critical window for comprehension was identified as 4867−6500 ms (i.e., 4500 + 367–4500 + 2000). If infants preferentially map "is on" to SFB vs. SVA, then they should look longer at SFB than SVA within the critical window during Test, and this looking pattern should differ from the one observed during the Salience trial. This prediction was supported (see Fig. 3). Within the critical window, there was a significant divergence at 5101−5200 ms, $t(37) = 2.08$, $p = .045$. There are also two other significant divergences, one at 9100–9200 ms, $t(27) = 2.93$, $p = .007$, and one at 15100–15200 ms, $t(32) = 2.19$, $p < .036$. These findings suggest that infants preferentially map the critical language "is on" to the SFB configuration vs. the SVA configuration.

In order to further test whether infants' preferentially mapped "is on" to SFB vs. SVA during Test, infants' PLT after "is on" was uttered was directly compared to their PLT before "is on" was uttered. Fig. 4a depicts infants' PLT 2000 ms before "is on" is uttered and 2000 ms after "is on" is uttered. Fig. 4b displays infants' PLT after the time "is on" is uttered (depicted as the red line in 4b) juxtaposed on top of infants' PLT before the time "is on" is uttered (depicted as the blue line in 4b). A time-course analysis in R compared these two PLTs to test if there was a change in looking pattern prior to vs. after "is on" was uttered. The results yielded a significant divergence; infants looked more (i.e., greater PLT) at the SFB configuration *after* "is on" was uttered vs. before it was uttered, $t(36) = 3.14$, $p = .003$.

In order to confirm that the same pattern was not observed for the control—Salience– the same time course analysis was performed, but now analyzing infants' PLT over the course of Salience (see Fig. 5a and b). The neutral language that was uttered for Salience at 2,000 ms (the time when "is on" was uttered during Test) was "What do you see?". This time, the results yielded no significant divergence. $t(36) = .11$, $p = .91$. Thus, the looking pattern the infants demonstrated during the Test trials was driven by the critical language ("is on"), not just differences in salience between the displays, further suggesting that infants preferentially map "is on" to SFB.

Lastly, in order to explore the relation between children's tendency to map "is on" to SFB and their more general spatial language as measured by the MCDI (Prepositions and Location section), two correlations were carried out. For both correlations, the average proportion of looking time (i.e., PLT; see above) was calculated for each child for the critical time window (see Fig. 3), that is, the window after the critical language was uttered (see Delle Luche et al., 2015 and our results above). For the first analysis, infants were categorized as mapping "is on" to SFB or not (PLTs above .50 were coded as a 1 and PLTs below .50 were coded as a 0). This was then correlated with their comprehension and production of "on" as reported by their parents in the MCDI. For the second analysis, infants'

Table 1
Average total looking time (ms) at the Support-From-Below event (SFB) and the Support-Via-Adhesion evdent (SVA) for the Salience Trial and the average of the two Test Trials.

Trial	SFB		SVA	
	M	*SE*	*M*	*SE*
Salience	3362.50	435.18	4316.67	510.28
Test	3718.75	457.20	2543.75	423.25

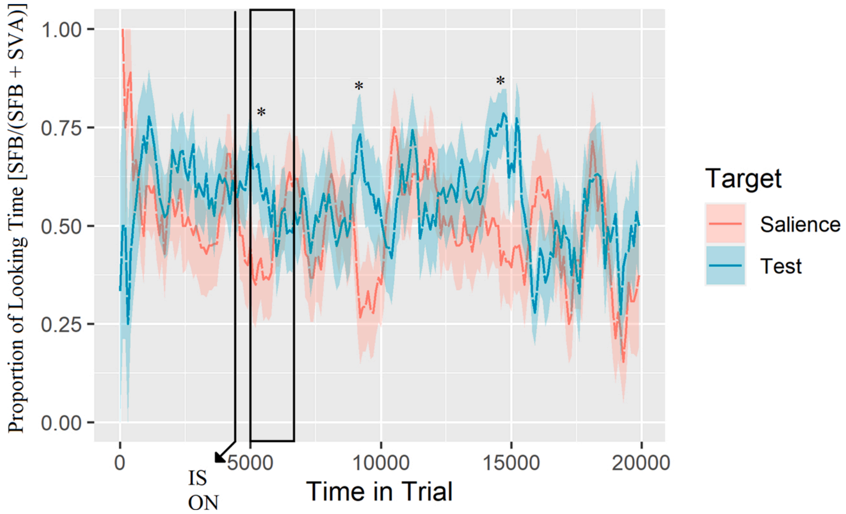

Fig. 3. Time course analysis for Proportion of Looking Time at Test and Salience trials.
Note: The x-axis represents the time from the beginning of each trial (marked by 0 ms) to the end of the trial (marked by 20000 ms). The y-axis of this plot is the PLT, which is the proportion of looks to the SFB configuration relative to total looks to both configurations. As described in the Results, the box identifies the 'critical window' for language comprehension. The shaded region of the graph represents the standardized error per point.

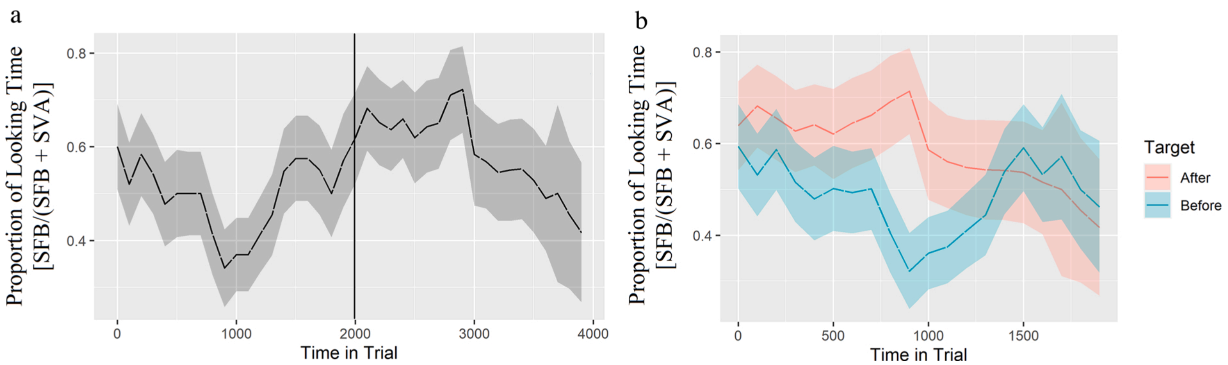

Fig. 4. Time course 2000 ms before and after critical language "is on" is uttered plotted linearly (4a) and overlaid (4b).
Note: Similar to Fig. 3, the y-axis of both these plots is the PLT (Proportion of Looking Time) throughout the windows. In 4a, the critical language is uttered at 2000ms; this plot includes a window of the trial which is 2000ms before the language is uttered and 2000ms after the language is uttered. In 4b, the before, signified by the blue line, and the after, signified by the red line, are plotted over each other. The shaded region of each graph represents the standard error for each time point.

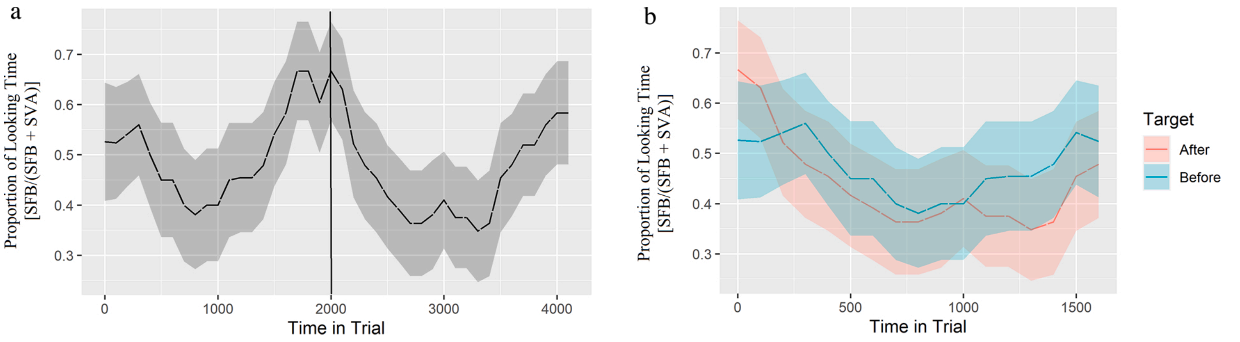

Fig. 5. Timecourse for Salience trial 2000 ms before and after the neutral language is uttered plotted linearly (5a) and overlaid (5b).
Note: Similar to Fig. 4, Fig 5a displays 2000ms before and after the critical language, "What do you see?", is uttered. Fig. 5b displays this same information, but with before and after overlaid on top of each other. The shaded region of each graph represents the standard error per point.

PLTs were correlated with their total comprehension and production scores (over all 15 prepositions included in MCDI Preposition and Location section). No significant correlations were found for analysis one (r=−.05, $p = .81$ and r=−.18, p=.39, for comprehension and production, respectively) or for analysis two (r−.10, $p = .63$, and r=−.11, $p = .60$ for comprehension and production, respectively).[2]

Thus, the preference to map "is on" to SFB was not correlated with parents' report of their infants' comprehension/production of either "on" or the larger set of spatial prepositions in the MCDI. This is perhaps not surprising given that our test of "is on" comprehension examines whether infants have a *preference* to map "is on" to SFB over SVA (one kind of Mechanical Support); it is not a test of whether infants can map "is on" to a correct versus an incorrect referent (that is, "is on" can be used to describe both SFB and SVA.

4. Discussion

When simultaneously presented with two dynamic support events: SFB (cube placed on top of box) and SVA (cube placed on side of box), and hearing, "Find the toy that is on the box", 20-month-old infants looked longer at the SFB event than the SVA event. Further, they showed this pattern during a time in the trial that was predicted *a priori* as the critical window for comprehension. Also, critically, they did not show this looking pattern during the Salience phase when neutral language was uttered ("What do you see"), nor did they show this pattern during the Test phase, prior to when the key language ("is on") was uttered. Thus, infants preferentially mapped the Basic Locative Construction (see Levinson & Wilkins, 2006), "is on" to SFB rather than to SVA - one type of Mechanical Support. This pattern is consistent with those of spontaneous productions of children 13 months to 47 months (Lakusta et al., 2020), the elicited productions of 6-year-olds and adults (Landau et al., 2016), and the forced choice comprehension of 4-year-olds (Johannes et al., 2016), which suggest that BE *on* maps preferentially to SFB whereas other linguistic devices, such as lexical verbs in English, map to Mechanical Support. Our current findings using preferential looking extend these prior findings by showing that the preferential mapping of BE *on* to SFB emerges in infants' comprehension as early as 20 months. Thus, this mapping bias emerges by early in the second year of life in both comprehension and production and the same bias is developmentally continuous through adulthood.

A preference for mapping "is on" to SFB over SVA by 20-months of age has implications for delineating children's semantic space for the English spatial term "on", and for understanding how children learn the language encoding support, not only in English, but for other languages as well. Our findings suggest that infants do *not* initially map "on" to a broad, abstract category covering many different kinds of support– in our experiments, a category that includes SFB as well as SVA. Rather, representations of SFB in pre-verbal reasoning serve as a foundation for the expression of certain spatial relationships, in particular, spatial prepositional phrases that encode 'support' in English. Although we only tested infants learning English, we predict that SFB will serve as a foundation for expressing support across all languages – a prediction that can easily be tested with the current paradigm.

How does SFB serve as the foundation for such spatial term learning? As discussed in the Introduction, around 5 months of age infants use their available physical concepts of gravity and solidity to learn the "location-of-contact" rule; this results in a new event category - passive support from below (Baillargeon & DeJong, 2017). After 5 months infants' reasoning about support becomes even more sophisticated as they learn that the proportion of contact between figure and ground is relevant for support, and then that the proportional distribution of an object is relevant, i.e. that the volume of the entire figure, not just its base, is relevant for support. Thus, over the first year of life, infants learn a great deal about how SFB works in the physical world. The current findings extend this body of research by suggesting that representations of SFB also have reflexes in the linguistic coding of support by 20-months of age – they prefer to map SFB to "is on" over SVA (Support-Via-Adhesion).

One question for future research is whether it is SFB per se that serves as a foundation for the expression "on" in English (and more

[2] Analysis for the MCDI data revealed that 18 (out of the 24) infants were reported to comprehend "on" and 8 infants were reported to produce "on". The average total number of spatial prepositions reported to be comprehended and produced by infants, was 8.21 and 2.96, respectively (range= 14 and 12).

generally to Basic Locative Constructions for encoding support across languages), or whether infants would be just as likely to map "on" to any support configuration that they are able to reason about. Findings from the current study shed some light on this question. Recall that infants did not look reliably longer at SVA vs. SFB during Salience (see Table 1), suggesting that by 20 months, infants understand (to some extent) that an object released against the side of a base can remain stable. In contrast, at 8 months infants are surprised when an object released on the side of a base remains stable (Needham & Baillargeon, 1997). Thus, sometime between 8 and 20 months infants may be learning something about mechanisms of support and how they result in an object's stability. Yet, despite this possible increasing knowledge about mechanism, and infants' understanding that both configurations – SVA and SFB - are possible, during Test, infants still preferred to map "on" to SFB over SVA. This suggests that SFB may indeed serve as the foundation for the expression "on".[3] Infants' ability to reason about and categorize SFB very early in development (see Introduction; Baillargeon & DeJong, 2017; Casasola & Park, 2013) may explain this bias. We hypothesize that SFB is cognitively privileged in infants' representations of physical events and thus biased to map to languages' canonical expressions that encode support. Because infants have concepts of gravity and solidity early in development, they are able to reason about SFB configurations in the physical domain. In contrast, mechanical support often involves specific properties of objects that infants may not *fully* understand until later in development. For example, support via adhesion requires understanding stickiness – a property that may only be understood after infants have first-hand experience with 'stickiness'. Support via hanging may invoke principles such as gravity and solidity (this is an empirical question), but configurations of hanging are different than configurations of SFB. Consider, for example, a ring hanging from a horizontal pole. The ring is circular around the pole rather than lying flat against one surface, and thus the support - the force dynamic interaction between the ring and the pole - may be hard for infants to represent.

It is a question for future research when infants are able to reason about various mechanical support configurations (adhesion, hanging, point attachment, etc.) and whether any of them would be just as likely to map to "on" as was SFB when paired with SVA in the current study. New research could test this possibility by pairing a SFB configuration with another type of non-SFB configuration (such as hanging - a picture hanging from a wall, embedding - a picture drawn on a mug, etc.) and testing whether infants' preference for mapping "on" to SFB persists. We predict that it will because SFB is cognitively privileged and this has consequences for the mapping to spatial language. As children learn about different mechanisms of support and the appropriate use of "on" for these configurations, their preference for SFB could diminish, relative to these other possible support configurations.

In addition to any cognitive privilege of SFB that the child may bring to the mapping of spatial terms, linguistic input surely plays a role in how infants learn the mapping between spatial representations of support and language. Infants might start with a bias that a canonical expression for support corresponds to SFB, but then, only from the input of the specific language they are exposed to, will they learn which specific word(s) map to SFB (e.g., English uses "on", Dutch uses "op", Spanish uses "en", and Japanese uses "ue"; Gentner & Bowerman, 2009).

Moreover, parents may show differences in how they describe SFB and Mechanical Support to their children, thus helping them to differentiate the semantic space of support: "is on" maps to representations of SFB whereas other linguistic devices (in English, specific lexical verbs and prepositions, such as "sticks to") map to 'other' (non-SFB) representations of support. A recent study in our lab sheds light on this possibility. When presented with highly similar SFB and SVA configurations to those used in the current study (block on top of a box and block on the side of a box), parents of children ranging from 6 months to 42 months of age used highly differentiated language; they used more lexical verbs, such as "stick" (e.g., "he took the little pink block and *stuck* it *on* top of the big block") to encode the SVA configuration and more light verbs such as "put" (e.g., "a hand *put* a block on top of the box") to encode SFB. This differentiation was observed primarily among parents of the oldest children who were 2;7–3;6 years of age, suggesting that children's age modulated parents' use of spatial language to their children (Lakusta et al., 2020; Wodzinski, Moya, Lakusta, & Landau, 2020). Thus, parent's language input to children – their use of light verbs to encode SFB and specific lexical verbs to encode SVA - may very well supplement the cognitive differentiation between SFB and other configurations.

In addition to differentiating the semantic space into SFB vs. non-SFB, parents' linguistic input may support children's learning about Mechanical Support as a distinct category of support. Children need to learn about the many different kinds of non-SFB mechanisms of support, that is, the many ways in which one object can effectively support another object, e.g., by adhesion, hanging, point attachment, or encirclement (see Landau et al., 2016). Expressing these different mechanical support relations elicits quite different kinds of descriptions from parents and adults, e.g. the use of different lexical verbs and/or prepositions in a variety of structures. For example, parents' use of different lexical verbs to refer to adhesion vs. hanging, for example ("stick" vs "hang" in English), may guide children to differentiate these two different types of mechanical support (or may even lead to qualitatively different categorization, i.e. adhesion vs. hanging, no commonality at all). Similarly, parents' linguistic input may guide children's further differentiation of types *within* each Mechanical Support type, for example, use of *tape* vs. *glue* to describe events leading to support by these different means. The function of parents' linguistic input in such cases could support the child's differentiation within their semantic/ conceptual space into two separate categories: adhesion vs. hanging; tape vs. glue, etc., reminiscent of learning mechanisms that have been reported the domain of object naming (see Landau & Shipley, 2001). In sum, in these ways, it is likely that children's cognitive representations as well as the linguistic input to which they are exposed join together to fully shape children's semantic representations of support.

In conclusion, the current study suggests that at 20-months infants' semantic space of support is differentiated such that infants prefer to map "is on" (the Basic Locative Construction for encoding support in English) to Support-From-Below over Support-Via-

[3] We thank an anonymous reviewer who provided thoughtful interpretation of the Salience data, thus motivating us to consider this in our discussion.

Adhesion, a case of Mechanical Support. In this way, SFB is privileged in how it maps to the language of support. We hypothesize that this preferential mapping may serve as the very first step for the fuller differentiation of infants' semantic space; the Basic Locative Construction maps to SFB whereas other linguistic devices (e.g., in English, specific lexical verbs) map to the many different kinds of Mechanical Support.

Author statement

Lakusta, Laura: Conceptualization, Methodology, Investigation, Resources, Writing, Supervision, Project Administration, Funding Acquisition.

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