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Infant exuberant object play at home: Immense amounts of time-distributed, variable practice

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Abstract

Object play yields enormous benefits for infant development. However, little is known about natural play at home where most object interactions occur. We conducted frame-by-frame video analyses of spontaneous activity in two 2-hour home visits with 13-month-old crawling infants and 13-, 18-, and 23-month-old walking infants (*N*=40; 21 boys; 75% White). Regardless of age, for every infant and time scale, across 10,015 object bouts, object interactions were short (median=9.8s) and varied (transitions among dozens of toys and non-toys) but consumed most of infants' time. We suggest that infant exuberant object play—immense amounts of brief, time-distributed, variable interactions with objects—may be conducive to learning object properties and functions, motor skill acquisition, and growth in cognitive, social and language domains.

Keywords

play; learning; object interaction; exploration; natural curriculum for learning

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Environments abound with objects. And object play is vital for infant learning (Needham, 2016). Object interactions facilitate increasingly complex, flexible, and controlled motor actions (Libertus, Joh, & Needham, 2016). Manual interactions with objects support perceptual development and learning about the physical properties of objects, including the understanding that objects are 3-dimensional (Soska, Adolph, & Johnson, 2010). By exploring objects, children discover their designed actions—that lids twist, latches unlock, and blocks fit into shape sorters—and eventually acquire the biomechanical skills to implement such actions (Rachwani, Tamis-LeMonda, Lockman, Karasik, & Adolph, 2020). Moreover, object interactions enhance infants' physical capacities when they use objects as tools (Kahrs, Jung, & Lockman, 2013) and enhance infants' symbolic capacities when they use objects to stand for other things in pretend play (Tamis-LeMonda & Lockman, 2020). Object interactions also establish the conditions ripe for language learning: Infants' active engagement with objects, makes objects salient in the visual field and is likely to elicit language input ("round ball") that refers to objects and their associated properties (e.g.,

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Deak, Krasno, Triesch, Lewis, & Sepeta, 2014; Smith, Yu, & Pereira, 2011; Yu & Smith, 2012).

Nonetheless, despite widespread consensus about the benefits of object interactions for infant development, little is known about the natural input to learning. The science of object play is confined largely to structured settings: Researchers typically predetermine the materials for exploration (a few novel toys); the duration of sessions (usually a few minutes); and the positioning of infants (e.g., at a table with toys within reach). However, the rigor of experimental control comes at a cost. It presents a static image of behavior in the "average" infant and leaves unanswered questions about the characteristics of infants' spontaneous object interactions at home—the familiar setting where infants spend most of their waking hours.

Natural Input for Learning

The study of infant development rests on understanding the natural input for learning. Language research enjoys a long history of characterizing the nature of the input through detailed descriptions of infant-directed speech and the contexts that surround infant-caregiver language exchanges (Hoff, 2006; MacWhinney, 2000; Roy, Frank, DeCamp, Miller, & Roy, 2015; Soderstrom & Wittebolle, 2013; Tamis-LeMonda, Custode, Kuchirko, Escobar, & Lo, 2019; Tamis-LeMonda, Kuchirko, Luo, & Escobar, 2017). However, research in other developmental domains relies primarily on descriptions of infant behaviors during brief structured tasks.

In the rare instances when researchers observe "learning in the wild," they find that infants generate immense amounts of rich and varied input. For example, during free play, infants average 2400–4000 steps and 17 falls per hour (Adolph et al., 2012; Hoch, O'Grady, & Adolph, 2019); many bouts entail short bursts of activity (1–3 steps); infants take steps in every direction (forward, backward, and sideways); and they cover most of the accessible locations and surfaces in the environment (Cole, Robinson, & Adolph, 2016; Hoch et al., 2019; Lee, Cole, Golenia, & Adolph, 2018). Infants' natural visual world is similarly rich and varied. At first, infants' visual world is dense with faces and then shifts over the first year to an array of hands that act on objects (Fausey, Jayaraman, & Smith, 2016). Amidst the clutter of infants' visual scenes, a small number of objects dominate each activity (e.g., spoons, cups, and bowls during mealtime), providing a foundation for learning the names of objects that are visually salient and functionally important (Clerkin, Hart, Rehg, Yu, & Smith, 2017).

What is the importance of immense amounts of time-distributed, variable practice? Time-distributed practice (as opposed to massed practice) allows infants time to consolidate their knowledge and prevents boredom and fatigue. Variable practice (as opposed to repeated exposure to the same words, movements, and other inputs) leads to greater generalization and flexibility. And an immense amount of exposure (as opposed to "one-trial learning") is vital to learning.

Indeed, a long history of experimental work reveals superior learning for time-distributed relative to massed practice for children and adults. Originating with the research of Ebbinghaus (1885)—who manipulated practice schedules to test learning of nonsense syllables—researchers conclude that distributed practice is advantageous over massed practice in domains spanning surgical skill training (Andersen, Konge, Cayé-Thomasen, & Sørensen, 2015); memory (Carpenter, Cepeda, Rohrer, Kang, & Pashler, 2012; Seabrook, Brown, & Solity, 2005); second-language learning (Bird, 2010); motor learning (Schmidt & Lee, 2011), performance in academic subjects (Carpenter et al., 2012), and so on. Similarly, a long history of experimental work reveals superior learning for variable relative to blocked practice for learning motor skills such as landing baskets and kicking soccer goals, learning math concepts, and so on (Rohrer, Dedrick, & Stershic, 2015; Schmidt & Lee, 2011; Taylor & Rohrer, 2009).

But unlike experimental work, where researchers, educators, and clinicians impose particular practice regimens on learners, infants must actively create their own “curriculum for learning.” Across language development, motor skill acquisition, and every other type of learning, infants’ natural practice regimens constitute self-generated curricula that may optimize learning in domains spanning motor development (Adolph et al., 2012), face processing, memory, object recognition, and vocabulary (Smith, Jayaraman, Clerkin, & Yu, 2018).

What about infants’ spontaneous object play? Despite longstanding claims about children’s active role in constructing their psychological world through sensorimotor interactions with objects (Bradley, 1985; Gibson, 1988; Piaget, 1952), little data exist on object play in the unconstrained setting of the home (but see Clarke-Stewart, 1973). Dozens of studies of structured play with novel toys in the laboratory show that infants flit from one object to another in brief bursts of activity—which researchers commonly interpret as high distractibility, low sustained attention, limited persistence, and an “underdeveloped executive attention network” (Kannass, Oakes, & Shaddy, 2006; Power, Chapieski, & McGrath, 1985; Ruff & Capozzoli, 2003; Ruff & Lawson, 1990; Yarrow et al., 1983). However, emphasis on what infants *cannot do* is often rooted in comparing infant behavior to the longer, more sustained play of older children, and may inadvertently overlook the adaptive nature of spontaneously generated learning curricula during infancy—the developmental period when nearly everything is novel.

Current Study: Quantifying Natural Object Interactions

Understanding infant learning and development requires data based on infants’ actual experiences (Smith et al., 2018). Thus, we aimed to address gaps in prior work with an ecologically valid lens on infants’ spontaneous object interactions in the natural home setting. We video-recorded infants during unconstrained activity in two 2-hour home visits—a time duration that swamps brief laboratory sessions with novel objects. Frame-by-frame coding of each bout of object interaction allowed us to quantify the variety of object interactions and number of object bouts (akin to “types” and “tokens” in language learning) and the temporal features of object interactions—duration of each bout, distribution of bouts over the visit, and accumulated amount of time engaging with objects. We observed

13-month-old crawling infants and 13-, 18-, and 23-month-old walking infants to test whether infants' locomotor status and age affect characteristics of object play. Because most behaviors improve with age, we expected an increase in object interactions with age. However, given the lack of prior data and theorizing about infant natural object interaction, our approach was exploratory rather than confirmatory.

Based on prior home observations and free play in the laboratory, we expected both crawling and walking infants to accumulate large amounts of time interacting with objects (Karasik, Adolph, Tamis-LeMonda, & Zuckerman, 2012; Karasik, Tamis-LeMonda, & Adolph, 2011). Eleven- to 19-month-olds interact with objects about half of each hour, and they frequently carry objects to no recognizable end-destination and for no apparent reason (Heiman, Cole, Lee, & Adolph, 2019; Hoch et al., 2019; Karasik et al., 2012; Karasik et al., 2011). Although crawling infants are hampered in their ability to carry objects, crawlers can shift to sitting posture or pull to a stand to access and interact with objects. However, walkers access more distal locations than crawlers (Karasik et al., 2012; Karasik et al., 2011; Karasik, Tamis-LeMonda, & Adolph, 2014), so we expected 13-month-old walkers to engage with a greater variety of objects than same-age crawlers.

To our knowledge, nothing is known about the duration of object bouts, the distribution of object bouts across extended periods of time, and the specific objects that infants choose for play. Infants' familiarity with the objects and spaces of their homes, and the opportunity to play with whatever they choose rather than standard objects placed in front of them, might result in relatively long object bouts with a small set of objects. Alternatively, infants might accumulate large amounts of time playing with objects through extremely brief object interactions as they do in short, structured play tasks, and mirroring infants' natural inputs for visual experiences, language, and motor behaviors. Likewise, prior research does not inform on the distribution of object play over long periods of time. Infants might cluster object bouts toward the start of each visit (when they are presumably well rested based on the scheduling of visits) and fatigue over time (as they approach naptime), or they might play with objects continuously across each 2-hour visit. Moreover, prior work does not inform on the types of objects infants privilege. Infants might show intense interest in objects of a certain type such as balls, brooms, and tea sets (DeLoache, Simcock, & Macari, 2007), or infants might transition from one type of object to another, accumulating a large variety of object experiences as they do for visual inputs at home (Fausey et al., 2016). The colorful and salient features of toys and their designed fit to infants' bodies might make toys especially appealing. Or infants may not discriminate between toys and household objects. Why should infants be aware that certain objects were manufactured specifically for them?

Method

With participants' permission, videos and demographic data, and Datavyu coding spreadsheets from each session are shared with authorized investigators in the Databrary video library (databrary.org/volume/563 and databrary.org/volume/1118, respectively). Illustrative videos of the infant and the researcher recording the visit and exemplar video clips of key findings are publicly shared at databrary.org/volume/1118/slot/44869. The video coding manual, scripts to select portions of video for reliability coding and identify disagreements, and scripts to export data are publicly shared at databrary.org/volume/1118/slot/44868. The processed data and analysis scripts are publicly shared at databrary.org/volume/1118/slot/44870.

Participants

We observed 40 infants: 20 13-month-olds (11 boys, *M* = 13.1 months; *SD* =.18), 10 18-month-olds (4 boys, *M* = 18.0 months; *SD* =.13), and 10 23-month-olds (6 boys, *M* = 22.9 months; *SD* =.16). Because crawlers use their hands to locomote and for support and walkers have their hands free to interact with the environment we observed twice as many 13-month-olds to enable comparisons between crawlers and walkers (10 infants per locomotor group, 5 boy crawlers and 6 boy walkers). At the time of the first visit, crawlers could move on hands and knees, and "cruise" by moving upright while holding onto furniture for support, but they could not walk independently, based on mother report on the first visit and confirmed in the video-recordings. Two crawlers began walking by the second visit but were still wobbly and often reverted to crawling during the visit, so we continued to classify them as crawlers. Thirteen-month-old crawlers had 2.9 to 6.1 months of crawling experience (*M*= 4.9, *SD* = 1.1), and 13-month-old walkers had 3 days to 3 months of walking experience (*M* = 1.6 months, *SD* = 1.1) based on mothers' report of "the first time they saw their child crawl on hands and knees or walk across the room for 3 meters without stopping or falling" prior to the first home visit (Adolph, Vereijken, & Shrout, 2003). Eighteen-month-olds and 23-month-olds averaged 6.9 (*SD* = 3.9) and 9.7 (*SD* = 1.4) months of walking experience, respectively.

We recruited families in New York City through hospitals, referrals, and brochures. Most infants were from White (75%), middle-class, English speaking families. All infants were only children. All were born at term with no birth complications and had no known disabilities. Mothers ranged from 27 to 46 years of age (*M* = 34.2, *SD* = 4.1); most (93%) had earned college or higher degrees; 65% worked part- or full-time. Data collection was conducted between December 2017 and September 2019. Families received a $75-dollar gift card for each visit.

Procedure

A female experimenter video recorded infants and their mothers during two home visits on weekdays (when presumably family life is more consistent than on weekends); 95% of second visits occurred within a week of the first visit (*M* = 5.7 days, range = 1 to 15 days). Visits were conducted between 8:30 a.m. and 5:30 p.m.; 75% of second visits were scheduled within one hour of the scheduled time of the first visit (*M* = 55 min; range 0 to 6.5 hours difference). Visits were conducted between infants' meals and naps, when only mother and infant were present. The experimenter aimed to record infants' natural activity for two hours per visit, for a total of four video hours per infant. Most infants (85%) were observed for the full 2 hours at both visits; however, 10 visits were shorter because the infant fell asleep (*n* = 2), the mother had to leave for work (*n* = 1), camera malfunctioned (*n* = 3), father came home (*n* = 1), or experimenter error (*n* = 3); range per visit = 1.6 to 2.0 hours, *M* = 3.94 hours over both visits.

The experimenter followed infants with a handheld digital video camera (30 fps) and recorded infant behaviors with minimal interference. She told mothers to ignore her and to go about their everyday activities. Mothers played with their infants or let infants play independently while they did household chores, worked, and engaged in their daily activities. Indeed, mothers did laundry, cooked, worked on laptops, made phone calls, and so on. All mothers engaged in activities that did not involve their infants and all mothers played with their infants several times during the visit. All mothers spent some time in close proximity to their infants, but they also came in and out of the room leaving infants to play independently. Thus, infants were free to interact with whatever objects were accessible. During recording, the researcher remained at the periphery of the room, did not interact with infants or mothers, and focused the camera on the infant. Infants quickly acclimated to the presence of the experimenter, going about their activities with little attention to the camera (see video examples databrary.org/volume/1118/slot/44869).

Data Coding and Processing

Videos were coded with Datavyu (datavyu.org), a computerized coding tool that provides frame-by-frame analysis of user-defined behaviors and time-locks codes to video frames.

Temporal characteristics of object interactions.—Coders scored the onset and offset of each bout of object interaction to determine the accumulated time infants played with objects; duration of each object bout; and the distribution of object interactions across time. Infants' hands are nearly always in contact with something—an object, a surface, or their own body, often during support or locomotion. Thus, following extensive discussions with experts on infant play (play-project.org), we defined a bout of object interaction as the *manual* displacement of an object(s). Our requirement that infants manually displace an object, rather than simply contact an object, was intentionally conservative. Banging hands on a table, swiping hands on a surface, and so on did not count if the infant did not displace the object. We did not credit touches on surfaces (floor, coffee table, bed, etc.) that did not displace the object. We did not credit touch if the infant displaced an object with body parts other than the hands (e.g., kicking a ball, sucking on a pacifier). We did not count touches to infants' own body (including clothing), the mother's body, or a pet's body. Thus, our conservative criteria for object interaction *underestimates* the amount of time infants spent interacting with objects.

Based on prior work, the onset of each bout was marked by contact with an object and the offset marked by at least 3s off objects (Suarez-Rivera, Smith, & Yu, 2019; Tamis-LeMonda, Kuchirko, & Tafuro, 2013). Any criterion, of course, is arbitrary, but 3s allowed for reliable coding and it captured repeated brief touches (e.g., turning the pages of a book, pressing a button, banging a drum) without requiring the coder to identify each millisecond touch. An object bout could include interaction with multiple objects simultaneously or multiple objects in sequence if the transition between objects was shorter than 3s. Our time-based rule for what counted as a break in activity allowed us to capture infants' quick shifts from touching one object to touching another, without creating an unwieldy coding burden. A shorter criterion for inter-bout intervals (e.g., 1 or 2 sec) would yield more short object bouts. Reciprocally, a longer criterion would yield fewer short object bouts. But the pattern of the distribution would remain the same. Our coding system automatically returned the breaks between object interactions—and the durations and distribution of those breaks from objects were also of interest.

If an infant's hands were occluded, and the coder could not determine whether the infant was manipulating an object, the time period was coded as off camera. Thus, bout lengths for time interacting with objects and bout lengths for time off objects were underestimated if infants' hands could not be seen before or after a bout. If infants played with an object, then hands were occluded, and they played with the same object after the occlusion, two bouts were coded to avoid inferring what the infant was doing. We compared average bout durations with and without off-camera segments included and found no differences. We also tested reliability for the onset and offset of each bout of object interaction and time off objects by merging off-camera segments with prior on-camera segments and found no differences in inter-observer reliability or infant object interactions.

Type of Object Bout—Each object bout was classified as involving "*toys*" (objects designed for child play such as balls, cars, stuffed animals, crayons, and books), "*non-toys*" (any household object, including doors, food, and spoons), or "*mixed*" (a combination of toys and household objects). Different objects of the same category were coded as a single bout. For example, if an infant played with crayons, a coloring book, and blocks without breaking for 3s, it was coded as a single bout of "toys." Similarly, if an infant interacted with a spoon, cup, and fruit, it was coded as a single bout of "non-toys." Likewise, mixed bouts could involve multiple toys and non-toys, and could be simultaneous or successive. For example, an infant might simultaneously hold a crayon in one hand and a sippy cup in the other. Alternatively, an infant might transition between toys and non-toys in quick succession, such as playing with a crayon, dropping it, then picking up a sippy cup—all without a 3s break between touches.

Unique objects—To assess the variety of play objects, coders noted each "unique object" that an infant touched during the visit (e.g., blocks, books, cups, pillows, phones, and so on), similar to language researchers' classification of the diversity of word types. Specifically, the first instance of a specific object being displaced by an infant was credited as a "unique" object in the context of the observation. Based on initial coding of 10 infants, we compiled a list of objects with common nomenclature to ensure consistency in the naming of objects across infants. If an infant interacted with several objects of the same type, each unique exemplar was marked. For example, if an infant interacted with four different books during a visit, each book was credited as a unique object. Exceptions were objects that contained multiple pieces, such as a set of blocks, handful of cheerios, or box of tissues, which were coded as a single unique object (i.e., we did not classify each block, each cheerio, and each tissue as different objects). The list of unique objects began again for the second visit, using the same coding system.

Interobserver Reliability—To ensure inter-observer reliability, a primary coder scored every variable and a second coder independently scored 25% of each two-hour visit randomly selected from the beginning (i.e., first 40 minutes), middle (second 40 minutes), and end of the visit (third 40 minutes). We double-coded 25% of each visit (rather than

25% of infants) to ensure reliability *across every infant* without adding burden to reliability coding time. By conducting reliability on each visit, we ensured that codes were robust across the range of home contexts, infant behaviors, mother behaviors, and so on. Random selection of reliability coding blocks (drawn from each 40-minute interval across the two hours for each visit) ensured that reliability testing: (1) sampled across the full two hours; (2) included a variety of activities for each infant; and (3) prevented spurious findings for any given segment of the session.

Best practices require researchers to test inter-observer reliability at the smallest level of detail analyzed and reported (Adolph, 2015). Assessment at finer levels of granularity places undue burden on coders and adds unnecessarily to coding time. Assessment at broader levels of granularity fails to test the data reported. Thus, we analyzed data at the bout level (i.e., to ensure reliability for the distribution of bouts on and off objects and the duration of each bout) by computing exact frame agreement for each visit and overall Kappas (to control for base rates of behaviors) per visit.

To determine whether coders could reliably identify object bouts, we compared every video frame in the double-coded segments for percent agreement (e.g., if two coders identified the same 10s bout, but one coder marked the bout as starting 0.5s earlier and ending 0.5s earlier than the other coder, exact frame agreement would be 90%; if one coder saw a 3s bout that the other coder missed, then the exact frame agreement for those 3s would be 0). Overall frame agreement between coders was 93.9% pooled across visits (*Kappa* = .88, $p < .001$), and median frame agreements for time interacting with objects was 97.5%, time off objects was 95.0%, and time off camera was 80.0%; (range in *Kappas* across sessions = .51 to .99, *Median Kappa* = .89). Inter-observer agreement for accumulated durations of time interacting with objects and time off objects (while on camera) per visit was $r(78) = .93$, $p < .001$ and $r(78) = .94$, $p < .001$, respectively. Inter-observer agreement for type of object (toy, non-toy, mixed) based on 2578 bouts (range = 15 to 58 per visit) drawn from 25% of each visit was 94.9% pooled across visits; (*Median* % agreement = 96.5%, *Median Kappa* = .92, $p < .001$).

To avoid coder drift, coders reviewed disagreements after every few sessions were coded. Although the number of disagreements was small, typos and careless errors were fixed for the final dataset to avoid propagating known errors into the final analyses. For “gray areas” (e.g., one coder thought the baby was touching an object and the other did not), the primary coder’s data were retained in the final dataset.

Results

In total, infants produced 10,015 bouts of object interactions across the dataset, ranging from 41 to 99 bouts per hour for each infant ($M = 63.5$). We examined the distribution and durations of object bouts, infants’ accumulated time playing with objects, and the specific objects of infant interaction. We analyzed age effects across the three groups of walkers (13, 18, and 23-month-olds) using ANOVAs. We analyzed effects of locomotor status (13-month-olds crawlers versus walkers) using *t*-tests. Analysis of sex differences showed no differences between boys and girls, *t*s (38) < 1.68, *p*s > .10, so sex was collapsed in further analyses.

Object Bouts Are Brief

Object bouts were brief (databrary.org/volume/1118/slot/44869/-?asset=295630). Figure 1A presents timelines for each infant grouped by age and locomotor status, ordered by most to least amount of object interaction across the four hours. Orange bars represent times infants interacted with toys; blue bars denote times when infants interacted with non-toys; yellow bars denote times infants interacted with a mix of toys and non-toys; grey bars represent times infants did not interact with objects, and white bars represent time off camera. Infants interacted with objects in short bursts, interspersed with short breaks. Examination of Figure 1A shows many narrow bars of object interaction across the entire timeline, reflecting extremely brief durations of most bouts. Figure 1B highlights the brevity of object bouts for an exemplar 23-month-old. Each row in the figure reveals a finer resolution of infants' shifts between time with and without objects at one-hour, 10-minute, and 1-minute time scales.

Indeed, durations of object bouts across the four hours yielded a heavy-tailed distribution (Figure 2A). To address the skewed distribution, we report bout durations per child with medians rather than means (both measures yielded similar findings). In aggregate, most bouts (85.3%) were short, that is, they lasted less than a minute (*median* bout duration pooled across visits and infants = 9.8s; range = 0.03s to 22.3 min); 13% of bouts were of medium duration between 1 and 5 minutes; and few bouts (1.5%) were long, that is, lasted over 5 minutes (Figure 2B).

Infants interspersed frequent object bouts with short breaks (grey bars in Figure 1 and Figure 2C). Breaks from object interactions mirrored object bouts, resulting in a heavy-tailed distribution. Most breaks (92.6%) were short and lasted less than a minute (*median* break duration = 9.2s; range = 3s to 17 min); only 7.5% of breaks were of medium duration, between 1 and 5 minutes; and only 0.5% of breaks were long and lasted over 5 minutes (Figure 2D). In the rare cases when infants' breaks from objects lasted more than 1 minute, typically mothers constrained them from interacting with objects—infants were being breastfed, carried by the mother, getting their diapers changed, sitting in a highchair while mothers did chores, and so on. Thus, even when infants paused from interacting with objects, they quickly resumed play, and the rare, sustained breaks were largely imposed by mothers.

The pattern of activity bursts, interspersed by brief breaks, occurred at every hour of observation. Again, to account for the heavy-tailed distribution, we report medians rather than means (but both measures yielded similar results). Median bout duration did not differ between hours 1 and 2, $t(39) = .15$, $p = .88$, or between hours 3 and 4, $t(39) = .98$, $p = .33$ (Table 1, Row 1). Median bout durations for each infant varied, from 5.5s to 26.1s ($M =$ 11.1s, $SD = 4.0$); Figure 3. Every age group, and crawlers and walkers alike, showed brief bout durations. Median bout durations did not differ among walkers (*M*s = 10.6s, 11.3s, 11.9s, for 13-, 18-, and 23-month-olds, respectively), $F(2, 29) = .23$, $p = .79$. And median bout durations did not differ between 13-month-old crawlers ($M = 10.7$) and 13-month-old walkers, $t(18) =.03$, $p = .98$.

Infants Accumulate Immense Time with Objects

Infants interacted with objects most of the time. Figure 4 shows that infants averaged 61.2% (*SD* = .10) of each hour with objects. Despite our conservative criterion for object interactions, 80% of infants spent more time interacting with objects than not, $t(39) = 6.45$, $p < .001$. The least active infant (a 13-month-old crawler) spent 40% of each hour interacting with objects (24.0 min) and the most active infant (a 23-month-old) spent 80% (47.4 min). Although visits lasted two hours, infants did not fatigue: Infants spent equivalent amounts of time with objects during hours 1 and 2, $t(39) = .82$, $p = .42$; and between hours 3 and 4, $t(39) = .30$, $p = .76$ (Table 1, Row 2).

Figure 4 shows large differences among infants in their time with objects, especially among the 13-month-old crawlers and 23-month-old walkers. Unexpectedly, 13-month-old walkers accumulated less time with objects compared with the other groups. An ANOVA confirmed that 13-month-old walkers (*M* = 53.4%, *SD* = 5.2) spent less time interacting with objects than did 18- (*M* = 66.2%, *SD* = 6.2) and 23-month-old walkers (*M* = 62.4%, *SD* = 11.4), $F(2, 29) = 6.54$, $p < .01$. Thirteen-month-old walkers also spent less time interacting with objects than did 13-month-old crawlers (*M* = 62.9%, *SD* = 12.1), $t(18) = 2.29$, $p < .04$.

By definition, accumulated time with objects reflects the aggregate of all object bouts. Thus, to determine why 13-month-old walkers accumulated less time with objects, we examined group differences in short, medium, and long bouts with objects. As shown in Figure 2E, we found no differences in the number of short or medium object bouts (*p*s > .56). Although every 13-month-old walker had at least one long bout, on average, they displayed fewer long bouts (*M* = 2.0 bouts) compared to 13-month-old crawlers (*M* = 3.9 bouts) and 18-month-old (*M* = 4.9 bouts) and 23-month-old (*M* = 3.5 bouts) walkers (*p*s < .01). Indeed, when we excluded long bouts over 5 minutes from analyses, differences in time with objects between 13-month-old crawlers and 13-month-old walkers and among the three groups of walkers (13-, 18-, 23-month-olds) disappeared (*p*s > .55).

Variety of Object Interactions: Infants Play with All Types of Objects

Infants played with toys and non-toys equally, and often mixed the two (databrary.org/volume/1118/slot/44869/-?asset=294801, databrary.org/volume/1118/slot/44869/-?asset=294797, databrary.org/volume/1118/slot/44869/-?asset=294799). They spent 32.3% of their object time in toy bouts, 30.8% in non-toy bouts, and 36.9% in mixed bouts. As shown in Figure 5A, individual infants varied in their object time in toy bouts (range = 12 to 69%), non-toy bouts (range = 8 to 61%), and mixed (range = 11 to 63%). Time in toy bouts, non-toy bouts, and mixed bouts did not differ in hours 1 and 2 (*t*s < 1.70, *ps* > .09); hours 3 and 4, (*t*s < .94, *p's* > .35); or between visits 1 and 2 (*t*s < .86, *ps* > .39), Table 1, Row 3, 4, and 5. The distribution of time across toy, non-toy, and mixed bouts was consistent across age groups (Figure 5B). Walkers did not differ in their distribution of time in toy, non-toy, and mixed bouts, *Fs*(2,29) < .47, *ps* >.63. Similarly, 13-month-old crawlers and walkers did not differ, *ts*(18) = < .72, $p > .48$. Because mixed bouts involved toys and non-toys, we further assessed how much time infants spent with toys versus non-toys in those mixed bouts; infants spent 47% of their mixed object time interacting with non-toys (*SD* = 15%).

Infants transitioned among dozens of objects per hour. On average, infants interacted with 62.7 (range = 31 to 108) unique objects on visit 1 and 56.7 (range = 32 to 95) on visit 2. Notably, these statistics underestimate the variety of object interactions because infants often engaged with multiple objects of a set and coders did not distinguish among related objects (e.g., several blocks of a shape sorter; cup, saucer, and spoon in a tea set; crayons in a box). Infants in the three walker groups did not differ in the variety (total number of unique) of objects with which they interacted on each visit, Fs(2,29) < 1.53, ps > .26. Likewise, variety of object interactions did not differ between 13-month-old crawlers and walkers, ts(18) = < .24, p > .81.

Moreover, infants continually found unique objects for play. During the first 15 minutes of each session, when each object was "unique" within the bounds of the visit (see Methods), infants averaged 11 unique objects. One hour into the visit, infants reached an asymptote of 5 unique objects, which remained constant throughout the full two hours.

Despite the countless objects in infants' homes, infants played with a common set of objects. Figure 6 depicts the types of toys (n = 32) and non-toys (n = 36) played with by at least 25% of infants. Figure 6A shows that every infant interacted with books (100% of infants); most interacted with stuffed animals (98%), balls (82%), vehicles (73%), musical instruments (63%), push toys (60%), toy food (58%), toy kitchen items (58%), blocks (55%), electronic toys (55%), shape sorters (55%), arts and crafts (53%); and half interacted with nesting toys (50%), and plastic animals (50%). Figure 6B shows that interactions with non-toys included objects of every size and function. Most infants interacted with cups (98% of infants), food (98%), boxes and baskets (98%), bedding and blankets (80%), drawers and cabinets (80%), clothes (73%), chairs (68%), pillows (68%), doors (65%), technology devices (65%), towels (58%), eating utensils (55%), and phones (53%); half played with child gates (50%) and shoes (50%).

Discussion

Our naturalistic observations of infant play at home—outside the confines of experimental control and pre-selected toys—yielded an unprecedented picture of infants' spontaneous object interactions. In everyday activity where objects abound and infants are free to play as they wish, infants transitioned among dozens of objects per hour in short bursts of activity, flitting between toys and non-toys alike. However, the short interactions added up: Infants spent 60% of their time interacting with objects. Immense amounts of time-distributed, variable practice with objects likely yields an ideal curriculum for learning about object properties and functions that propels growth in motor, cognitive, social, and language domains (Smith et al., 2018).

Quantifying Natural Play in the Home

Structured play observations typically last only a few minutes, limit the objects presented to infants, encourage infants to remain stationary at a table, and present infants with only a few objects at a time. Systematic testing of infant attention and distractibility yields valuable data on individual differences under controlled conditions. But control may come at a cost. It does not allow description of how much time infants spend with objects over extended periods; how infants distribute their time with objects; and which objects infants select for play. Indeed, our home observations revealed characteristics of infant object interactions that would be impossible to glean from conventional structured tasks.

Despite our conservative definition of touch, infants averaged 36 minutes per hour interacting with objects. Notably, infants accumulated time with objects through dozens of short, time-distributed bursts. And they never petered out: Play at the start of each two-hour visit was as dense and frequent as play at the end. Extrapolating from the average of 63.5 object bouts per hour, the typical infant may engage in over 600 object interactions during 10 hours of each waking day. Frequent manual contact with objects may be a fact of human life that is already apparent in the second year.

Nonetheless, infants varied in their time interacting with objects, ranging from 40% to 80% of the visit, which raises questions about the sources of individual differences. Characteristics of infants (e.g., temperament) and social inputs from caregivers (e.g., joint engagement) may shape infants' interactions with objects. Additionally, although infants transitioned among many activities over the course of each visit—snack time, watching television, diaper changes, book reading, and so on—activity contexts may affect which objects infants manipulate and when. Infants may display more object interactions during certain daily routines (e.g., meal/snack times) relative to others (e.g., watching television).

Finally, variety in objects was striking. Infants shifted among objects that differed in function, size, texture, shape, weight, and so on, interacting with 30 unique objects per hour. Moreover, infants spent half their time with non-toys, including unanticipated objects such as baby gates, phones, pillows, wires, trashcans, doors, and shoes. Thus, despite the colorful, "child-designed" features of toys, their fit to little hands, and the prevalence of toys in the homes we visited, infants played with whatever captured their interest in the moment. The indiscriminate nature of infant object play makes sense: There's little reason for infants to understand that some objects are meant for play, but others are not.

Notably, in the context of intra-individual object variety, infants—from different homes with different materials and spaces to roam—interacted with a common set of objects across toys and non-toys: Nearly every infant interacted with books, animals, balls, cups, food, and boxes. Commonalities among infants align with data on the consistency of infants' visual experiences during mealtime (Clerkin et al., 2017). Such regularities may foreground certain objects relative to others, offering a foundation for learning words for objects of infants' interest.

Locomotor Status and Infant Age

Characteristics of infant object interactions were generally similar across walking status and age. Although we hypothesized that walkers (relative to crawlers) and older infants would interact with a wider variety of objects, this was not the case. Infants' proclivity to play with whatever is available may account for developmental continuity. Crawlers exploited objects nearby but did not remain stationary—they moved from place to place to access new objects for play. Similarly, walkers of all ages interacted with a variety of objects throughout their homes.

Thirteen-month-old walkers showed a small but significant dip in time interacting with objects relative to infants in the other groups. Exploratory examination of scatterplots indicated that 13-month-old walkers had the fewest long bouts (i.e., over 5 minutes)—which disproportionately affected their overall time with objects. We thus wondered whether long bouts were qualitatively distinct in their content. Review of the 50 longest bouts across infants suggested that long bouts did not necessarily indicate “sophisticated object play.” Some long bouts were due to objects seemingly glued to infants’ hands (databrary.org/volume/1118/slot/44869/-?asset=294793) as when an infant walked around holding a snack cup or a crayon (Heiman et al., 2019). In other instances, long bouts involved play with multiple toys sequentially. Consequently, we remain cautious about drawing inferences based on the fewer long bouts by 13-month-old walkers relative to other infants. Moreover, long bouts were rare. Indeed, what is most striking, is the consistency of *short bouts* across all infants: Object interactions were predominantly short—median bout length 9.8 seconds—with short bouts of less than 1 minute constituting over 85% of object interactions.

Less Can Be More in Infant Development

Brief object bouts and rapid transitions from object to object naturally spark questions about how researchers should interpret infant behaviors. Like Wechan and Amso (2017), we posit that infants’ seemingly “flighty and distractible behaviors” do not necessarily mean that infants’ less mature state relative to older children is problematic. Immaturity is not the same as inefficiency (Bjorklund, 1997; Bjorklund & Green, 1992). In fact, infants flexibly adapt to their current ontogenetic niche (Bruner, 1972; Turkewitz & Kenny, 1982). In development, sometimes “less is more” (Newport, 1984, 2016). Indeed, limitations in attention, knowledge, and memory more readily facilitate infants’ language learning (morphology, sign language, etc.) compared to the more mature status of these functions in adolescents and adults.

An extension of Newport’s “limitations as benefits” view would likewise conceptualize infants’ immense amount of time-distributed, variable practice with objects as a benefit, not a liability. In fact, if infants of different ages in homes with different spaces and materials incessantly forage in their environments for objects of different sizes, shapes, textures, and functions, such behaviors might be adaptive. At a time in development when infants must acquire information about what objects are and what they can do with them, variety is beneficial for learning. Indeed, in language learning, variety or “types” contributes unique variance to children’s vocabulary growth above the sheer amount of language or “tokens” (Rowe, 2012; Song, Spier, & Tamis-LeMonda, 2014).

What are the potential benefits of exuberant activity? Infants may adapt to their ecological and developmental niche by exploring as many things as possible (Adolph & Robinson, 2015). Frequent and varied interactions with objects allow infants to generate perceptual information that supports increasingly complex, flexible, and controlled manual actions. Infants’ exuberance creates opportunities to practice varied grips and actions (turns, twists, stabilizing) and to practice balance as they squat to pick things up and push, drag, and carry objects across the room. Moreover, frequent and varied object interactions support learning about object properties and their affordances, including the designed actions of objects

(Rachwani et al., 2020). Indeed, each object provides unique opportunities for action—dolls can be hugged; balls can be thrown; blocks can be stacked; pillows can be squeezed; lids can be twisted; and fruit can be squished. Finally, object interactions are ripe for social input and language learning (Tamis-LeMonda et al., 2013; Yu & Smith, 2012). Infants are likely to hear words that refer to the objects of their play.

Practical Implications

Notably, the finding that infants rapidly transition among many, varied objects in their environment—toys and non-toys alike—has practical implications. At our workshops on infant play, parents often voice concern that their infants do not sit still to play with a puzzle and do not stay focused on a single toy. Others worry that their "flighty, distractible" infants show signs of attention deficit and hyperactivity, and what should they do? Some parents reprimand their toddlers for taking books off shelves or toys out of boxes without sitting down to read or play quietly. No parent had heard the message that infants' exuberant activity may be a developmental asset.

Furthermore, understanding the spontaneous object interactions of typically developing infants has implications for interventions with children with developmental disabilities. Limited, infrequent object interactions (because of physical, cognitive, or perceptual impairments) may reduce children's opportunities for learning across perceptual-motor, social, and language domains. Future experimental research would inform interventions by testing whether systematic manipulation of the schedule of infants' experiences with objects relates to learning about object functions and so on. Computational models might leverage data on the timing and distribution of infant object interactions to illuminate processes of infant learning (e.g., Xu, de Barbaro, Abney, & Cox, 2020). And correlational research might test whether differences among infants in object interactions predict cognitive, language, perceptual, or motor skills within and across development.

Cultural and Social Considerations

Notably, infants were drawn from predominantly white, upper-middle class, educated families living in a large metropolitan area. Thus, our characterization of infants' spontaneous play at home—namely that infants accumulate massive time with dozens of objects, through brief bouts, distributed over time—remains to be tested in other samples, including communities where manufactured toys are rare or even nonexistent. We are currently coding hundreds of video-recordings of infants from markedly different backgrounds than those described here, including infants from U.S. immigrant, Spanish-speaking, low-income families and infants reared in rural communities in Central Asia. Although coding is ongoing in both samples, preliminary data reveal striking parallels to the patterns we document here. For example, infants in rural Tajikistan, largely in homes devoid of toys, spend over half their time interacting with a rich variety of objects (household items, objects of nature, empty water bottles, and so on), in brief bouts, with object play distributed over time (Karasik, Schneider, Kuchirko, & Tamis-LeMonda, 2018). As these data become available and are openly shared, confidence in statements about the characteristics and adaptiveness of infants' self-generated curricula for learning will be bolstered.

Additionally, we did not analyze infants' object interactions under different conditions of mother involvement or interaction. Characteristics of infants' object play likely vary with the involvement of a social partner, particularly knowledgeable adults who guide and support infant learning during bouts of joint engagement (e.g., Bakeman & Adamson, 1984; Deak, Krasno, Jasso, & Triesch, 2018; Vygotsky, 1978). Thus, whether infants' spontaneous interactions change in duration and/or quality in varying contexts of social engagement, remains an open question.

Conclusions

Infants' spontaneous object interactions are far more interesting than structured lab tasks can possibly reveal. Documentation of the natural inputs for learning—here, infant's object interactions—is vital to understanding change mechanisms. It provides the key to opening the black box of learning and development. Our findings represent an essential first step in describing the inputs for learning. Indeed, our description of natural activity can transform how researchers characterize infant behavior by flipping the narrative from a critique of what infants have not yet achieved to an acknowledgment of the potential ecological adaptiveness and everyday infant behavior. As such, we suggest that exuberant activity reflects a self-generated practice regimen that allows infants to learn as much as possible about as many things as possible.

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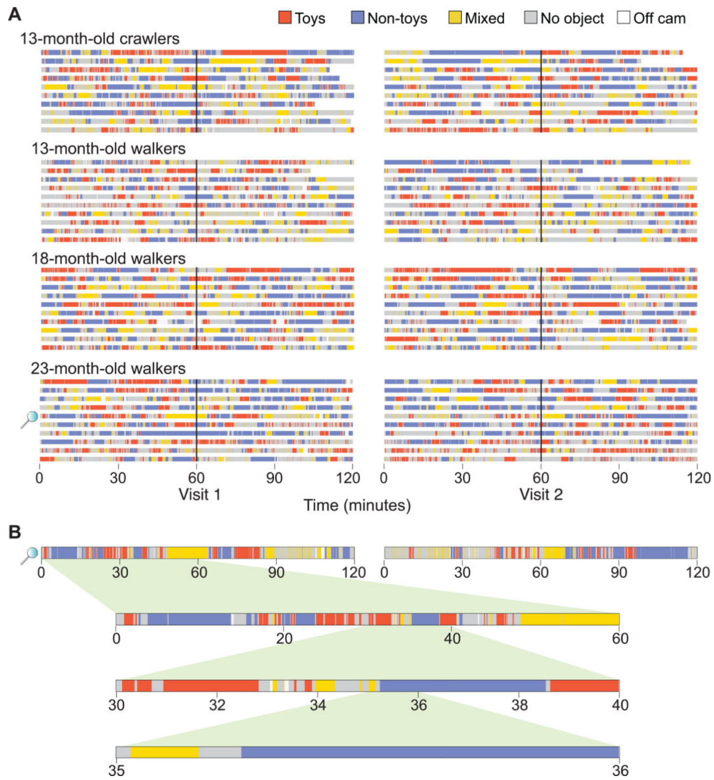

Figure 1.

(A) Timelines for each infant's interactions with objects across the two-hour observations on each visit. Timelines are ordered from most to least time interacting with objects for each age group. Orange bars denote bouts with toys; blue bars denote bouts with non-toys; yellow bars denote bouts that involved both toys and non-toys; grey bars denote time off objects; white bars denote time off camera. (B) Timeline of a representative 23-month-old infant across four hours (top row); each subsequent row shows detailed representations of object interactions by zooming in on 1 hour (second row), 10 minutes (third row), and 1 minute (bottom row).

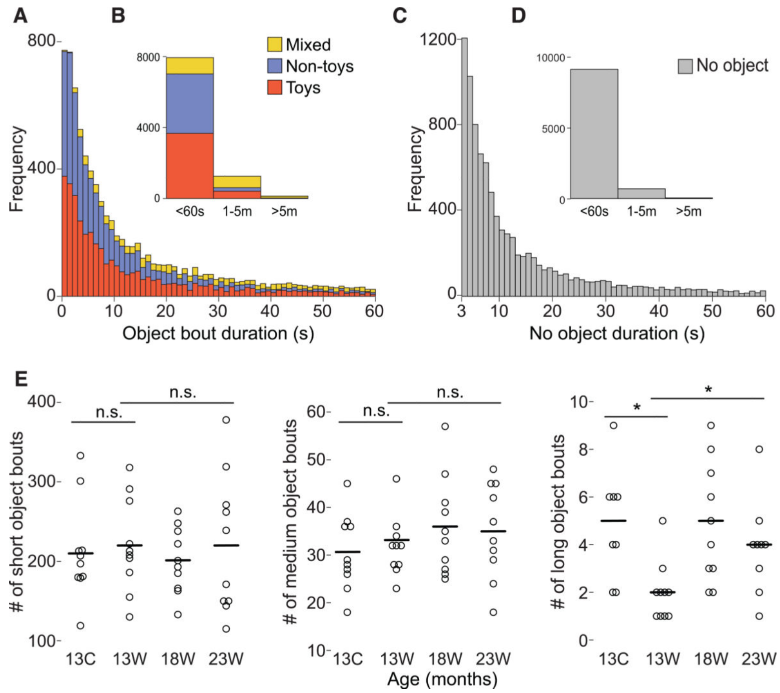

Figure 2.

Frequency histograms of bout durations aggregated across infants. (A) Frequencies of object bouts < 60 s. (B) Frequencies of bouts < 60 s, 1 min to 5 min, and > 5 min. (C) Frequencies of bouts when infants were off objects for < 60 s. (By definition, breaks could not be shorter than the 3-sec criterion). (D) Frequencies of bouts when infants were off objects < 60 s, 1 min to 5 min, and > 5 min. (E) Frequency of short (< 1 min), medium (1–5 min) and long (>5 minutes) object bouts by locomotor status (C = crawlers, W = walkers) and age. Each circle represents one infant's data. Horizontal lines represent group averages.

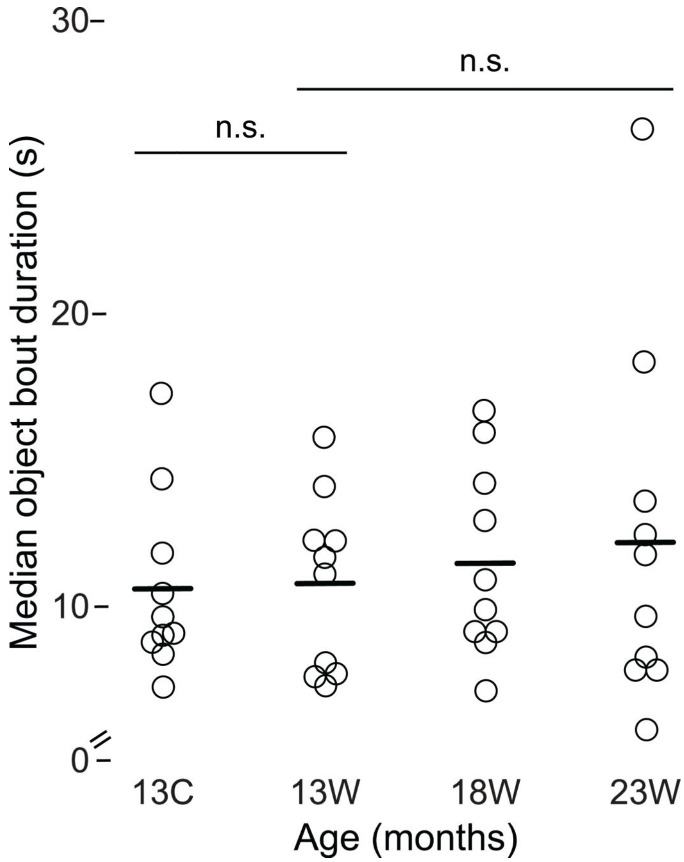

Figure 3.

Median object bout duration by locomotor status (C = crawlers, W = walkers) and age. Each circle represents one infant's median bout length. Horizontal lines represent group averages.

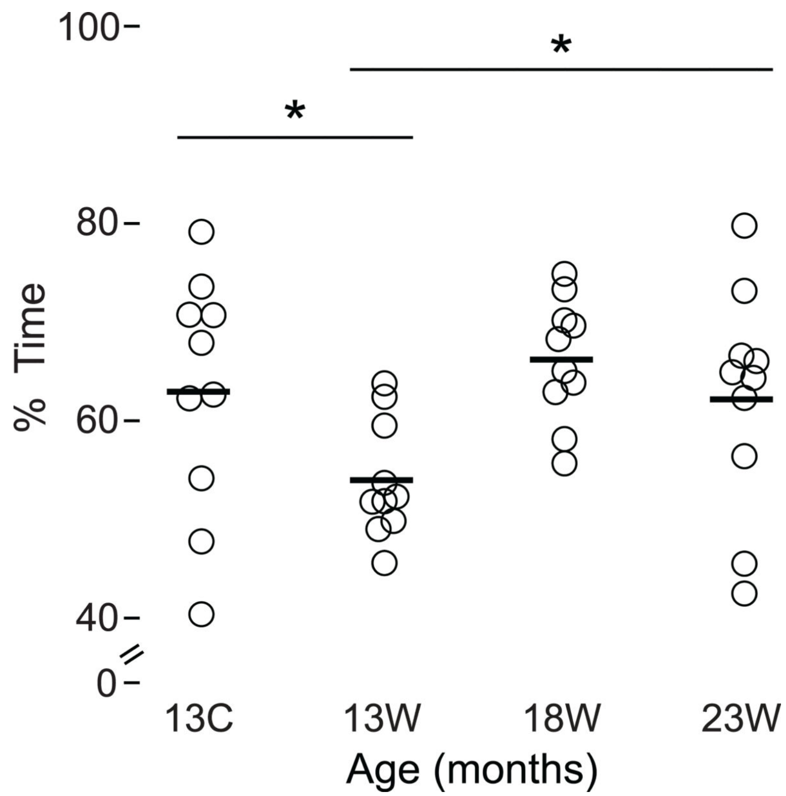

Figure 4.

Percent of time interacting with objects across two home visits by locomotor status (C = crawlers, W = walkers) and age. Each circle represents an individual infant. Horizontal lines represent group means.

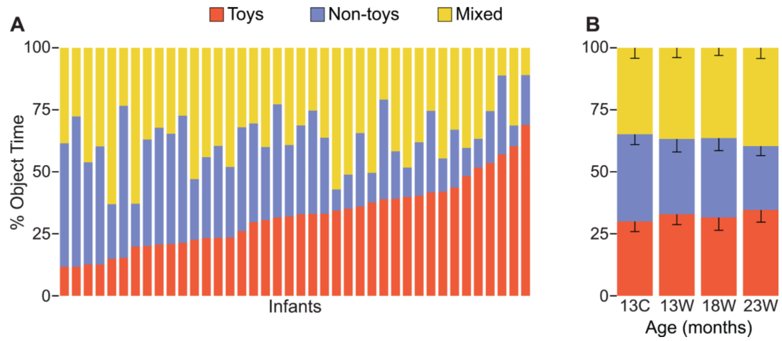

Figure 5.

(A) Individual data for interactions with different categories of objects. Each bar represents one infant, ordered from the infant who spent the least amount of time interacting with toys to the infant who spent the most amount of time interacting with toys. (B) Average time interacting with toys, non-toys, or a mix by locomotor status (C = crawlers, W = walkers) and age.

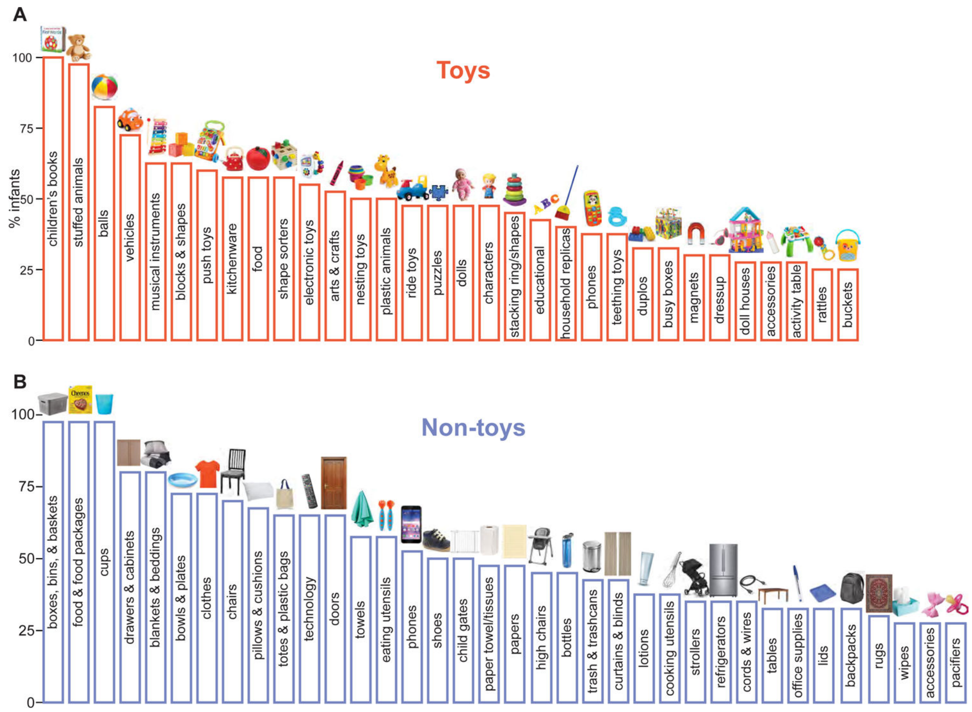

Figure 6.

Variety of objects in infant play. (A) Toys and (B) non-toys that at least 25% of infants interacted with across the two home visits.

Table 1.

Descriptive statistics for object interactions by hour (visit 1 = hours 1 and 2; visit 2 = hours 3 and 4).

	Hour 1	Hour 2		Hour 3	Hour 4
Median object bout duration (sec)	$M = 12.4$ $SD = 6.4$ $Med = 12.4$ $IQR = 5.4$	$M = 12.2$ $SD = 7.2$ $Med = 9.8$ $IQR = 7.2$		$M = 12.2$ $SD = 6.1$ $Med = 10.5$ $IQR = 6.1$	$M = 14.0$ $SD = 11.9$ $Med = 10.7$ $IQR = 6.7$
Time with objects (%)	$M = 59.9$ $SD = 12.4$	$M = 62.2$ $SD = 17.2$		$M = 61.1$ $SD = 13.3$	$M = 61.9$ $SD = 15.9$
Time with toys (%)	$M = 37.1$ $SD = 21.7$ $Med = 36.1$ $IQR = 35$	$M = 29.2$ $SD = 19.7$ $Med = 25.7$ $IQR = 35$		$M = 34.9$ $SD = 23.2$ $Med = 28.9$ $IQR = 28$	$M = 30.5$ $SD = 18$ $Med = 27.1$ $IQR = 30$
Time with non-toys (%)	$M = 28.0$ $SD = 18.6$ $Med = 24.5$ $IQR = 33$	$M = 35.3$ $SD = 21.3$ $Med = 31.5$ $IQR = 37$		$M = 30.2$ $SD = 20.5$ $Med = 28.2$ $IQR = 23$	$M = 32.4$ $SD = 22.5$ $Med = 25.5$ $IQR = 27$
Time with mix (%)	$M = 34.9$ $SD = 16.5$ $Med = 34.5$ $IQR = 26$	$M = 35.5$ $SD = 20.8$ $Med = 34.6$ $IQR = 34$		$M = 37.7$ $SD = 22.4$ $Med = 39.5$ $IQR = 35$	$M = 38.1$ $SD = 18.2$ $Med = 39.9$ $IQR = 23$