19 Infant Object Manipulation and Play

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Natural and manufactured objects saturate human culture. Infants need not do much or go far to find objects of different shapes, textures, sizes, and functions throughout their environments. And, as they manipulate and play with objects, they learn quite a lot along the way. From the time they can swipe and grab, infants spend most of their awake hours exploring objects – moving seamlessly from object to object in short bursts of activity distributed over time. These bouts of object interaction allow infants to practice and refine manual skills, learn about object features and functions, and test the fit between body and environment. Object interactions also allow infants to extend the limits of reality. Infants can pretend that objects exist when they do not, use objects to stand for other objects, and generate unique ways to use objects beyond their intended design. Indeed, to fully engage human artifact culture, infants must become proficient at using objects in twin planes of action – the real and the imagined.

Here, we describe how infants develop in their real and imagined use of objects. We draw from literature on object manipulation and infant play, which remains largely separate theoretically and empirically. Researchers of object manipulation primarily investigate infants' development of manual skills, emphasizing perception–action feedback loops and object affordances, with less attention to how infants embark on the imagined "as if" world of symbolic or pretend play. By contrast, researchers of object play primarily focus on the development of pretense and view object manipulation as undifferentiated actions that are later supplanted by more "cognitively sophisticated behaviors" indicative of representational thought (Belsky & Most, 1981; Piaget, 1952).

Our goal is to dismantle this artificial divide by showing that object manipulation and play are more intertwined than traditionally thought. Object manipulation and play follow similar developmental paths, reciprocally influence one another throughout development, involve related neural pathways, and are embedded in sociocultural practice. We consider theoretical perspectives on the development of object manipulation and play, and examine how

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different approaches have cast unique lenses onto infants' object interactions. Finally, we consider implications of our synthesis for practice and policy.

19.1 Theoretical Foundations

19.1.1 Piaget's Theory

Research on infant object manipulation and play share a theoretical basis in the writings of Piaget, who studied object manipulation to characterize infants' nascent knowledge about the physical world, and symbolic play to characterize infants' abilities to mentally represent their worlds (Piaget, 1952, 1954). The two lines of research, however, have since diverged toward perception–action and cognitive-representational approaches.

For Piaget, object manipulation was of interest less as a topic in its own right than as a means to discover what infants understand about the physical environment. The particular actions that infants use to manipulate and explore objects or how those actions develop were beyond the scope of Piaget's focus. Instead, he looked to the heterogeneity and quality of infants' actions on objects to reveal whether infants understood that objects exist independently of the self, and more generally, whether infants had developed a capacity for representational thinking.

According to Piaget, up until sensorimotor stage 4 (roughly beginning at 8 months), infants typically deploy similar routines to manipulate objects, regardless of objects' features or properties. They may bang, shake, rotate, or mouth an object in hand. Occasionally, infants discover an interesting consequence of their actions and then try to repeat the action – what Piaget termed circular reactions – but this consequence was largely unanticipated, reflecting a gap in infants' representational thinking. Even during stage 4, infants do not immediately foresee what manual routine is appropriate for an object. Rather, infants engage their repertoire of manual actions as if to discover which behaviors evoke interesting effects. Thus, Piaget characterized object manipulation during most of the first year as involving largely undifferentiated and nondiscriminating manual activity.

In the second year – stages 5 and 6 of the sensorimotor period – Piaget noted a qualitative shift in infants' interactions with objects. Infants could now reason fully about objects and appreciate that objects exist independently of the self. Most centrally, Piaget contended that by the end of the sensorimotor period, infants' understanding of objects reflected their general capacity to represent the world symbolically. According to Piaget, pretend play was a key manifestation of infants' underlying symbolic understanding, along with language, object permanence, and deferred imitation.

Researchers from a play tradition have since put Piaget's ideas to the test. If changes to play reflect developments in infants' mental representational

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skills, then play should follow a progression similar to language and relate to the language skills of children at an individual level. This is indeed the case. Developments in infant play closely correspond to developments in language, and associations between children's play and language skills are modest to strong (Orr & Geva, 2015; Quinn, Donnelly, & Kidd, 2018). Across the first 2 years, play progresses from exploration, to concrete actions on objects, to extended bouts of symbolic play that contain elaborate storylines (Bornstein & Tamis-LeMonda, 1995, 2006; Lillard, 2015; McCune, 1995; Tamis-LeMonda & Bornstein, 1991). Across the same developmental period, language progresses from babbles, to single-word utterances about the "here and now," to simple sentences and decontextualized talk about the "there and then" (Gillespie & Zittoun, 2010; Hoff, 2013; McCune, 1995; McCune-Nicolich, 1981). Later, in early childhood, symbolic play develops into complex role play, in line with children's gains in narrative skills (Uccelli, Hempill, Pan, & Snow, 2006).

The cognitive perspective on infant play has led researchers to leverage the play context to test infant cognitive development across a range of areas. Play has become a principal way to assess other things, as has also been the case with object manipulation. Because infants quickly become immersed in play, researchers often observe infant and child play or act out pretend stories to test causal reasoning, perspective taking, theory of mind, generic knowledge about object categories, and understanding of others' goals and intentions (e.g., Leslie, 1987; Lillard, 2015; Sutherland & Friedman, 2013). Furthermore, cognitive approaches to play have sparked the study of infants and children with specific developmental disorders. For example, the connection between pretend play and social-cognitive understanding helps explain why infants at risk for autism spectrum disorder show delays in pretend play (Campbell et al., 2018).

19.1.2 Gibson and Perception–Action Theory

Eleanor Gibson offered an alternative view to Piaget's theory of infant object manipulation and play, focusing primarily on how infants use action to explore and gain information from the environment (E. J. Gibson & Pick, 2000). In the Gibsonian account, perception and action are integrally intertwined. Humans and animals perceive opportunities for action or "affordances" in the environment that are scaled to their own physical characteristics and capabilities (E.J. Gibson, 1982; J. J. Gibson, 1979). Like other features of the environment, the Gibsons considered objects to be rich in information about affordances. And, infants already possess a suite of action systems, including looking, mouthing, and manipulating, which allow them to explore, register, and use this information (E. J. Gibson & Pick, 2000; J. J. Gibson, 1979). The developmental task for young perceivers then is not to supplement or construct information about objects from impoverished stimulation as Piaget suggested, but to recruit and integrate existing action systems to differentiate the relevant affordance information.

In this regard, consider the human object manipulation system. Human hands are exquisitely designed to pick up information about an object's affordances. Humans possess an opposable thumb, which facilitates exploratory actions such as grasping, holding, and pressing. These actions may occur either against the surface of the palm, where a power grip might be involved, or against a surface in the environment, when the object is held with a precision grip extending from the hand (Napier, 1962). Additionally, relative to other primate species, humans possess a more flexible wrist, which can undergo a relatively broad range and arc of motion (Marzke, 1997). When applied to handheld objects, these types of movements permit considerable rotation, thereby facilitating information pickup, oftentimes jointly with other action systems, such as looking. And relative to other primate species, human fingers have evolved to become proportionately shorter, permitting greater control and more effective instrumental action with objects (Wolfe, Crisco, Orr, & Marzke, 2006). Collectively, these morphological and associated functional adaptations of the hand enable a wide range of exploratory and performative actions with objects, and are consistent with J. J. Gibson's characterization of the manual system as one that sustains "active touch" (J. J. Gibson, 1966). Thus, from a developmental perspective, the Gibsons perception–action approach directed researchers to consider how infants begin to harness these unique adaptations of the hand, in concert with other perception–action systems, to explore and register information about object affordances.

For the most part, however, the Gibsons' contributions have not been integrated into the study of play, likely because play researchers viewed the functions and morphology of the hand, for example, as secondary to the primary driver of infant object play – mental representational capacities. We challenge this theoretical dichotomy later in the chapter by showing that object manipulation and play are two sides of the same coin.

19.2 Neural Underpinnings

Researchers have long recognized that advances in object manipulation and play are linked to the development of the nervous system. Arnold Gesell, in his pioneering work on normative development, tied the achievement of various milestones in manual and adaptive behavior, some of which also involved play with objects, to the maturation of the central nervous system (Gesell & Thompson, 1934). Although Gesell had neither identified the specific brain areas underlying motor achievements, nor considered the role of experience in central nervous system maturation, he is nevertheless recognized as drawing connections between changes in brain and behavioral development.

Since Gesell's writings, advances in theory and methods – particularly with respect to the role and timing of experience in brain development – have led to a deeper understanding of how changes in manual behavior are tied to

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developments in specific areas and networks within and across brain regions. At the same time, relating developmental changes in object manipulation and play to brain development poses challenges for infancy researchers. Currently, the most popular methods (electroencephalography, EEG; functional magnetic resonance imaging, fMRI) require infants to remain relatively stationary to guard against motion artifacts in the data. Object manipulation and play, however, are inherently about movement, and certain behaviors in particular, such as object banging, can be quite vigorous. Newer techniques, such as functional near-infrared spectroscopy (fNIRS), may be more forgiving of infant movement than EEG and fMRI, but whether fNIRS can adequately capture functional changes in brain activity as infants manipulate and play with objects remains an open question.

A further challenge to understanding the neural bases of object manipulation and play development centers on theory. Although considerable gains have been made in understanding sensitive periods and experience expectant effects in the perceptual and language domains (see reviews by Maurer, Chapter 6 this volume; and Reh & Werker, Chapter 21 this volume), much less is known about whether such corresponding phenomena occur for domains involving eye–hand coordination and associated experiences during human infancy. Nevertheless, this is a fundamental question for the pediatric rehabilitation sciences, where issues about timing, dosage and delivery of experience are critical for outcome (Heathcock & Lockman, 2019). We return to this issue when we consider policy implications.

With these caveats in mind, knowledge about brain and central nervous system development can enhance an understanding of developments in infant object manipulation and object play. Here, we consider two sets of relevant neural pathways: the pyramidal/extrapyramidal tracts and the ventral and dorsal streams.

The pyramidal tract runs from the motor cortices (primary, pre-, and supplementary) to the brainstem and spinal cord. Among other roles, it is responsible for the highly skilled and flexible motor movements of the hands and individual fingers, and receives and integrates inputs from different sensory modalities for this purpose (Martin, 2005). In contrast, the extrapyramidal tract comprises a diffuse collection of connections from different parts of the brain to the spinal cord. The extrapyramidal tract is largely associated with involuntary forms of movement, and does not play much if any role in regulating the fine movements of the hand and fingers.

Comparative work offers clues about the development of the neural substrates of manual function in humans. Studies with rhesus monkeys indicate that the extrapyramidal tract develops before the pyramidal tract (Kuypers, 1962; Lawrence & Hopkins, 1972). Likewise, in humans, the pyramidal tract is relatively immature at birth and undergoes a protracted period of development, with myelination of this tract proceeding gradually in the first 2 years (Martin, 2005). Some have suggested that the relatively protracted development of the pyramidal tract is reflected in the gradual development of

functionality of the human hand: from clenched fist, to open hand, to gradual control of the fingers individually and relative to one another (Martin 2005; Welniarz, Delsart, & Roze, 2017). This idea is consistent with perception–action approaches reviewed in previous sections, which suggest that motor development may developmentally pace specificity of action during object manipulation (Bushnell & Boudreau, 1993; Lockman & Ashmead, 1983).

Another organizing framework for understanding the neural bases of some forms of object manipulation and play can be found in work on visual processing by the ventral and dorsal streams (Milner & Goodale, 1995, 2008; Ungerleider & Mishkin, 1982). In broad strokes, the ventral and dorsal streams can be distinguished both structurally and functionally. Both ventral and dorsal streams arise in the primary visual cortex. The ventral stream, however, then continues along the ventral surface into the temporal cortex. In contrast, the dorsal stream continues along the dorsal surface into the parietal cortex. The two streams have also been associated with different functions. Whereas the ventral stream is considered the vision for perception or the "what" stream (e.g., visual recognition of shapes and objects), the dorsal stream is considered the vision for action or the "how" stream (e.g., moment-to-moment visual guidance of reaching with respect to an object's location, shape, orientation). Although it is tempting to suggest that object manipulation and some forms of object play primarily engage the dorsal pathway given the involvement of action, it is more likely that ventral and dorsal streams serve object behaviors jointly and in complementary ways (Street, James, Jones, & Smith, 2011). The latter idea thus suggests that advances in object manipulation and some forms of object play may be associated with growth in functional connectivity between the ventral and dorsal pathways.

19.3 The Development of Object Manipulation

As noted, for many years, object manipulation was not studied as a skill in its own right, but as a means to investigate some other cognitive capacity. Furthermore, studies that rely on object manipulation as a proxy to investigate some other ability, including play, typically include objects that vary simultaneously across many physical dimensions, precluding clear conclusions about whether infants are relating their manual behaviors to the physical properties of the objects that they are holding. Other work on object manipulation, however, in part inspired by Gibsonian theory, has directly considered object manipulation as a skill in which manipulation is broken down into its component actions. Additionally, researchers often systematically control the physical properties of objects to examine how and to what extent infants appropriately relate hand to object. In some of this work, researchers distinguish between adjustments of the hand that occur prior to and subsequent to contact of the

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object, with adjustments prior to contact considered as evidence for planning or prospective visuomotor control (von Hofsten, 2007).

When researchers systematically vary the material and/or spatial characteristics of objects that they present to infants a consistent picture emerges. During the second half year, as infants gain more and more control of their finger, hand, and arm movements, they increasingly tailor their manual actions to the properties of the object that they are handling (for reviews see Bushnell & Boudreau, 1993, 1998; Lockman & Ashmead, 1983; Lockman & McHale, 1989). Contrary to accounts that suggest that object manipulation and play are undifferentiated during most of the first year (Belsky & Most; 1981; Piaget, 1952, 1954), infants manipulate objects in a targeted manner, closely gearing their actions to an object's physical characteristics.

To illustrate, when 6-month-old infants are presented with objects that vary in *texture* (smooth or rough), they display more scratching of rough than smooth objects (Bushnell & Boudreau, 1993, 1998; Lockman & McHale, 1989; Ruff, 1984). When presented with objects that vary in *pliability*, 6-month-old infants show more squeezing of soft than rigid objects (Palmer, 1989; Ruff 1984). By the same token, when 6-month-olds are presented objects that vary in *color*, they show more rotation of objects when the sides are differently rather than uniformly colored (Lockman & McHale, 1989). And when infants in the first half of the second half year are presented objects that vary in terms of their *sound potential*, they are more likely to bang a rigid than a soft object, and shake a noise-producing object than one that remains silent when shaken (Bushnell & Boudreau, 1993, 1998; Lockman & McHale, 1989; Palmer, 1989). Even newborn infants (Molina & Jouen, 1998) and infants in the first couple of months (Rochat, 1989) may tailor their manual behaviors to an object's pliability by pressing these objects differentially, although the interpretation of this variation in manual activity as purposeful exploration versus a cyclical grasp–release pattern evoked by a yielding surface is a matter of some debate (Striano & Bushnell, 2005).

What underlies infants' increased specificity of object manipulation in the second half year? Some researchers have suggested that changes in targeted manipulation stem less from advances in cognitive growth (Piaget, 1952, 1954) than motor control (Bushnell & Boudreau, 1993; 1998; Lockman & Ashmead, 1983). In the latter view, the motor system acts as a rate-limiting factor vis-à-vis object exploration. As new manual capabilities (e.g., the ability to fractionate movement of the fingers, to control of the wrist, to produce a pincer grip) come online during the first year, new opportunities arise to apply previously unavailable types of action to objects. In one version of this account, progress in motor development enables infants to engage in new haptic exploratory procedures to register information about objects (Bushnell & Boudreau, 1993, 1998; Lederman & Klatzky, 1987). On this account, developmental changes in the manual skills that underlie haptic exploration would largely predict when sensitivity to different kinds of material properties (e.g., substance,

weight, texture) emerges during the first year. This approach is consistent with a Gibsonian theory, which as noted, highlights a reciprocal relation between perception and action in real and developmental time.

19.3.1 Object Manipulation: Prospective Adjustments

Individuals typically adjust the hand to match an object's properties even before they physically contact the object (Jeannerod, 1988; von Hofsten, 2007). Prospective adjustments like these help ensure that once an object is contacted, subsequent manipulation will be efficient and effective. Prospective adjustments of the hand are typically evoked by visual information about an object and thus involve a form of visuomotor coordination. Even infants show prospective adjustments for object features while reaching, and for some object features before others. Although infants extend their arms in the radial direction of an object soon after birth (von Hofsten, 1983), infants generally only begin to show prospective adjustments of the hand to other spatial features of objects (e.g., orientation, size, shape) during the second half year. Specifically, when reaching, infants increasingly make appropriate anticipatory adjustments of the hand based on an object's *orientation* before the middle part of the second half year (Lockman, Ashmead, & Bushnell, 1984; von Hofsten & Fazel-Zandy, 1984; Witherington, 2005). Likewise, they systematically vary reaching strategies (uni- vs. bi-manual reaches) and hand-opening width based on the visually perceived *size* of an object by the middle or latter part of the second half year (Berthier & Carrico, 2010; Corbetta, Thelen, & Johnson, 2000; Fagard & Jacquet, 1996; von Hofsten & Rönnqvist, 1988). And they begin to prospectively vary their grips according to an object's shape during the second half year, and to other aspects of an object's spatial structure (e.g., symmetry) by the end or even after the first year (Barrett & Needham, 2008; Smith, Street, Jones, & James, 2014). Finally, when multiple spatial features (e.g., size and orientation) of an object change across trials, 10-month-old infants experience difficulty in prospectively adjusting their grips, even though they prospectively adjust their grips when only one such feature changes (Schum, Jovanovic, & Schwarzer, 2011). Here, then, the role of cognitive load or complexity in constraining early forms of skilled action becomes apparent, an issue we return to when considering the early development of play.

19.3.2 Objects and Surfaces: Putting It Together

When infants manipulate objects, they not only palpate them in their hands, but also combine them with surfaces. Such combinatorial acts generate information about object composition and the effects produced by particular object–surface interactions. As in research on object manipulation and play, it was long assumed that infants combine objects and surfaces indiscriminately during much of the first year (Belsky & Most, 1981; Piaget, 1952, 1954). Infants, for instance, were thought to relate objects to surfaces indiscriminately,

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independent of the material composition of each and without regard to the object's conventional use (e.g., banging a spoon against a tabletop surface).

When researchers, however, began to systematically control the material composition of the objects and surfaces presented to infants, a new picture began to emerge about the specificity of infants' object–surface combinations (Bourgeois, Khawar, Neal, & Lockman, 2005; Palmer, 1989; Rips & Hespos, 2015). In many instances, infants in the first half of the second half year are already selective in how they combine objects and surfaces, taking into account the material properties of each. For instance, infants display more striking of hard than soft objects on rigid surfaces, and more striking of hard objects on rigid than flexible foam surfaces (Bourgeois et al., 2005; Palmer, 1989). Likewise, they show similar patterns when playing with objects on hardwood versus carpeted floors (Morgante & Keen, 2008). Moreover, even when transitions in the material composition of surfaces are abrupt (e.g., a tabletop surface that is half rigid, half flexible), infants adjust their manual behaviors with an object appropriately, based on the particular substrate that infants contact with the object (Fontenelle, Kahrs, Neal, Newton, & Lockman, 2007). Together, these findings highlight the specificity of infants' manual actions: Infants combine objects with surfaces selectively, taking into account the material properties of each.

19.3.3 Object Manipulation as a Gateway to Tool Use

The fact that infants relate objects to surfaces in systematic ways has led some researchers to suggest that object manipulation in the first year paves the way for the emergence of tool use in the second year (Lockman 2000; Lockman & Kahrs, 2017). On this account, objects change the affordances or functional capabilities of the hand. As infants during the first year explore and relate objects to surfaces, they learn how objects cause different effects on surfaces – a key requirement of tool use. As they do so, infants also gain practice in performing certain actions that they subsequently incorporate into tool use. For instance, object banging in the first year, transitions into controlled hammering in the second and third years (Kahrs, Jung, & Lockman, 2013, 2014). Likewise, infants may adapt object scooting into scribbling, as they begin moving graphic tools across surfaces in the second year. More generally, such developmental patterns suggest a synergy between affordance and motor learning. As infants combine objects and surfaces in real time, they gain expertise in the action patterns that they later will adapt for tool use (Lockman & Kahrs, 2017).

19.4 The Development of Object Play

Although the study of infant object manipulation is systematically grounded in how infants interact with objects of different shapes, textures, sizes, and so forth – whether a spoon or block or sponge – research on infant

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object play traditionally focused on infants' interactions with *toys.* Thus, a key aim of play research is to document how infants progress from actions based on the functions of specific toys – such as pushing buttons on a busy box – to using toys to reenact experiences in pretend stories. Typically, researchers describe the ways that object play changes in form and content across development as infants acquire new skills. And, just as is the case for object manipulation, motor, cognitive, social, and language abilities govern what infants can and will do at any moment in time with the objects available to them. A young infant might bang a spoon in play; a 1-year-old might pretend to eat imagined food; and a 2-year-old might place a bowl on her head as though it were a hat. Although developmental changes in infant play have been described at different levels of granularity, three broad types can be distinguished: exploration, nonsymbolic play, and symbolic play, with symbolic play being the most advanced in terms of representational demands.

19.4.1 Exploration

Infants' entry into play begins with exploration. Yet, unlike the rich characterization of object manipulation described by perception–action researchers, play researchers have largely ignored the nuanced behaviors that comprise infants' exploratory actions, such as how infants modify their actions as they explore different objects. The general lack of attention to exploratory play reflects the favoring of symbolic play as most cognitively advanced. In fact, because exploration is an early emerging, basic form of object interaction, some researchers consider it to fall outside the scope of play entirely (Lillard, 2015).

19.4.2 Nonsymbolic Play

Toward the end of the first year, infants shift from primarily exploring objects visually, orally, and manually to engaging in nonsymbolic or functional play (Ruff, 1984). Infants begin to discover the designed features of objects, as when they press buttons on phones or turn dials on busy boxes. At first, infants primarily direct nonsymbolic play actions to single objects, but soon relate objects to one another, for example placing objects onto or into other objects. Despite the exquisite specificity seen in infant object manipulation, as described previously, researchers of play sometimes consider infants' initial object combinations to be random: An infant might put a plate on top of a cup, or a cup inside a toy truck. With experience and motor skill, infants gradually combine objects in the ways that objects were intentionally designed. Thus, infants transition from what has (inappropriately) been referred to as "inappropriate object combinations" toward combinations based on perceptual similarities and functional relations – fitting lids on teapots and blocks into shape sorters (Belsky & Most, 1981; Bornstein & Tamis-LeMonda, 2006; Damast, Tamis-LeMonda, & Bornstein, 1996). As infants combine and fit objects, they

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acquire critical knowledge about spatial relations, including concepts around object support (a block can rest on a larger block) and containment (a cup can nest in a larger cup) (Casasola, 2017).

Again, a solely cognitive focus on play development, to the exclusion of considering motor skill, has led to shortfalls in how researchers assess nonsymbolic play behaviors. Typically, the infant's presumed intention rather than success at implementation reigns most central. So, for example, an infant who attempts to fit blocks into a shape sorter would be coded as playing nonsymbolically, whether or not the infant succeeded at inserting the shapes. Even something as seemingly straightforward as creating 3-D designs with blocks such as Duplo requires much more than spatial-cognitive know-how about where to place the bricks in replicating simple designs. Infants must twist their hands and hold a Duplo brick just so, align the studs of one brick with the holes of another, and press down with sufficient force to ensure interlocking (Kaplan et al., 2018). The perceptual and biomechanic requirements involved in implementing the designed actions of many toys explains why it takes months and even years for children to transition from simply interlocking bricks to creating complex designs (Kaplan et al., 2018).

19.4.3 Symbolic Play

Around the start of the second year, object play grows in abstractness as infants move from sensorimotor exploration and functional, nonsymbolic actions to displaying their first acts of symbolic or pretend play. Infants shift from seemingly asking, "What can this object do?" to "projecting an imagined situation onto an actual one" (Lillard, 1993, p. 349; Lillard, 2015). As toddlers imbue objects with imagined characteristics and functions, play grows in complexity and symbolic demand. For example, infants who pretend to feed teddy transform their prior experiences at mealtime into an "as if" scenario (Fein, 1981; Garvey, 1990), reenacting the past in a nonliteral present context. In reality, there is no food, and teddy is an inanimate object. An infant who cups her hand to her ear, pretending to talk on a phone, has transformed her hand into an imagined object and created a scenario in which someone is speaking on the other end. In both instances, infants have entered the imagined plane of object use. Pretend play, therefore, is quite special. It reflects the child's understanding that actions with objects can be based on made-up situations that are separate from reality (Vygotsky, 1967).

Like all forms of play, symbolic play grows in complexity across development. The simple, fleeting bouts of early pretend play at the start of the second year evolve into lengthier, elaborated play scenes from the second through third years, as infants increasingly string actions together to create play scripts, extend their play from self-directed actions to other-directed actions – such as when a toddler feeds then burps a doll, lays a doll on a pillow, and pats a doll to sleep – and begin to use objects to stand in for other objects.

Again, however, studies on symbolic play emphasize intention, rather than outcome or process, in line with the dominant cognitive foundation. Thus, unsuccessful attempts remain undistinguished from successful outcomes, overlooking how motor skills might contribute to implementation. For example, pretending to have a tea party requires fitting a lid squarely on top of a teapot, tipping the pot over at a specific angle without knocking the cup over, and stirring with a spoon without banging the cup's sides. Infants might be credited with "symbolic play" whether or not the teacup falls over during the pour or the stir.

19.5 Bridging the Divide: The Distancing of Object Interactions

There remains a curious disconnect between studies of infant object manipulation, guided by a perception–action framework, and studies of infant play, guided by a cognitive-developmental framework. The artificial divide lacks ecological validity and falls short of capturing changes in what infants do with objects on a regular basis. Infants explore objects, discover how to use objects in the ways they were designed, and then flexibly extend objects to novel uses in planful ways, whether playing with toys or tools. Thus, "object manipulation" and "toy play" offer complementary perspectives to identifying the mechanisms that underlie how infants engage with their physical environments. As infants move from real to imagined planes in their interactions with objects, they display increased *distancing* – from the concrete properties of objects, from the self, and in time and space.

19.5.1 Distancing from the Self

Infants initially direct actions to the self, and then extend actions to other people and inanimate objects such as stuffed animals. Distancing from the self extends to everyday object manipulation, tool use, and pretend play. Changes in motor and cognitive skills enable these developments. Specifically, the perception–action demands involved in directing an action toward oneself differ from those required when acting toward others. For example, tying your own shoelaces is a lot easier than tying the laces of someone else. Likewise, it is easier for infants to feed themselves than to feed someone else. That's because although infants learn to correctly orient a spoon to feed themselves, it takes several months for them to successfully modify their grip to orient the spoon to feed others. Similar advantages for self-directed relative to other-directed actions are evident when infants use other common tools (McCarty, Clifton, & Collard, 2001). Cognitive development, however, also contributes, as evidenced in the ability to anticipate which grips will be most comfortable given the goals of a task and as expressed vividly in the extension of pretend acts beyond the self.

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Indeed, play's progression from self-to-other directed pretense exemplifies theories of cognitive decentering or distancing (Piaget, 1945; Werner & Kaplan, 1963). Infants direct their first pretend acts toward the self, often simulating their own activities, such as eating, drinking, and sleeping (Fenson & Ramsey, 1980). But several months later, infants pretend toward others, whether a caregiver, pet, or doll, with play becoming increasingly abstract and distanced from the child's own sensorimotor actions (McCune-Nicolich, 1981). For example, infants pretend to eat from a spoon or drink from a cup before they pretend to feed dad or teddy (Tamis-LeMonda & Bornstein, 1993, 1996). Still later, toddlers engage in vicarious forms of play, in which the "other" is not simply a passive recipient of actions, but instead is actively involved, such as when a toddler pretends a puppet is combing its own hair or talking on a phone (Fenson & Ramsay, 1980).

19.5.2 Distancing from the Functions of Objects

Manufactured objects are designed to serve specific purposes. Infants must learn the functions of objects and how to successfully implement them if they are to navigate a world brimming with cultural artifacts. After a prolonged period of exploration, as infants gain the perceptual and manual skills and know-how required to exploit the unique functions of objects, they increasingly use objects as manufacturers intended (Rachwani, Tamis-LeMonda, Lockman, Karasik, & Adolph, 2020). Infants use spoons to scoop up food, toothbrushes to clean teeth, and blocks to create towers. In some instances, however, the actions required to use the object as intended by manufacturers or by the everyday larger artifact culture that infants inhabit may not be transparent or immediately detectable. Consider containers with twist-off or pull-off lids. Infants may need to engage in exploration over an extended period of developmental time spanning the first few years until they routinely and effectively implement the required actions of stabilizing the base while twisting to the left (Rachwani et al., 2020).

Likewise, infants must also learn that objects can be used in novel ways to solve new problems. In essence, infants' actions with objects must flexibly move beyond the conventional uses of objects to identify alternative possibilities. This takes time. At first, infants rigidly adhere to the common functions of objects, in tool use and pretend play. In tool use, once infants discover how to use specific implements, they have difficulties considering alternative uses of the object, a phenomenon related to the concept of functional fixedness (Duncker, 1945). For example, when an experimenter encourages infants near a year of age to light up a box by inserting the long handle of a spoon into a hole, infants insist on grasping the spoon's handle as they would to eat, which prevents them from inserting the handle into the hole to illuminate the box. By 18 months of age, however, infants will flip the spoon around and insert the slim handle into the hole to accomplish the novel goal (Barrett, Davis, & Needham, 2007).

Pretend play likewise shifts from the use of objects as designed to using objects flexibly and imaginatively. For example, around the start of the second year, infants might pretend to drink tea from empty teacups, stir hot food in empty bowls, and put tired animals to sleep on miniature blankets. But, midway through the second year and into the third year, infants gain the representational insight that objects can stand for other things (DeLoache, 2004). Representational insight allows toddlers to creatively substitute objects for other objects – sticks and pencils can function as spoons to stir in empty cups, blocks can substitute as cars to be driven around the floor, and boxes can serve as cradles for dolls. That is, although pretending is initially tied to knowledge about what is typically done with specific objects, with age and cognitive advance, children distance themselves from concrete object functions to imagined ones (McCune-Nicolich, 1981). Later in development, around 3.5 years of age, children substitute objects that are highly dissimilar in shape and form for the objects that they are meant to replace, such as by using a shoe as a hammer or a softball as a pencil to write (Hopkins, Smith, Weisberg, & Lillard, 2016). Children's novel application of objects to purposes beyond the objects' intended design lies at the core of creativity and divergent thinking (Bruner, 1978).

19.5.3 Distancing in Time and Space

With development, infants grow in planning and prospective control, thereby distancing their actions in time and space. As reviewed previously, infants' growing abilities at visual and manual integration allow them to prospectively control their actions, as seen when infants alter the speed of arm approach and the shape of their hands before a grasp when reaching for objects of specific sizes and shapes, or when infants effectively change the orientation of their hands and objects as they relate objects to other objects. By the middle of the second year, infants begin to anticipate which grip will prove most effective for accomplishing a subsequent goal with a handheld object, even if that means initially grasping the object in a physically awkward manner (McCarty et al., 2001). And by 24 months, when presented with an object fitting task, children will pre-align the object even before it contacts the aperture, suggesting that they anticipate how the object must be oriented in order to solve the task (Jung, Kahrs, & Lockman, 2015, 2018). In short, during the first 2 years, infants become increasingly better at planning manual actions with objects that extend beyond the here and now, and beyond immediately available information.

In play, planning develops as well. During nonsymbolic play, infants visually search for the next block once they have fitted a prior block, seemingly planning the next step in ways that extend their bouts of play. In symbolic play, sequenced actions that follow a logical order indicate that toddlers are laying out a pretend story not yet evident in the context-dependent, single acts of pretense seen at the start of the second year. That is, 1-year-olds will act on whatever objects are available, often serendipitously stumbling upon objects

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for play, perhaps pretending to pour from a toy teapot, or drink from an empty toy cup, or stir in a toy bowl in front of them. Notably, however, each pretend action occurs largely in isolation of the next. There is no evidence that the infant has a plan in mind about how the story will go.

Several months later, between 18 months and 2 years of age, infants logically combine actions in sequence, indicating their planning verbally and through search behaviors. For example, a child might pretend to eat from a bowl, and then remark "mommy spoon" while searching for another spoon to feed mommy, or even without speaking a word, the infant will persist in trying to find another spoon to permit the story's continuity. The child's verbal and search behaviors suggest that the child has mentally constructed a pretend story *before* acting, rather than simply acting on whatever object happens to be nearby (McCune-Nicolich, 1981).

Notably, prospective control and planning likely work together to support increasingly longer bouts of play across early development. Improvements in prospective control allow infants to more effectively manipulate and interact with objects, making it unlikely that the infant will tip a teapot while placing a lid on top. Successful implementation, then, might support sustained pretend play. A cup that falls over during stirring might interrupt the play flow in ways that limit the episode to a single action rather a string of smoothly executed actions – stirring, pouring, drinking, pouring again, and so forth. Whether and how developments in motor skill work in concert with developments in symbolic understanding to facilitate the length and complexity of play remains an open question.

19.6 Social Influences on Object Manipulation and Play

Developments in brain and body, together with infants' experiences interacting with hundreds of objects over the course of a day, contribute to changes in infant object manipulation and play over the first years of life. But, infants' experiences with objects largely depend on social input and opportunities. That is, caregivers guide what infants do with objects, when, where, and with whom. And, adults serve as models who interact with hundreds of objects over the course of a day, offering infants opportunities to watch what can be done with specific objects. Thus, developments in object manipulation and play cannot be divorced from social life or the home environment in which children develop. In fact, Vygotsky observed that in the context of joint activity with a caregiver, young children begin to master skills that they would be unable to perform independently. And, decades of research on object manipulation and play confirm that experienced members of the culture bridge or scaffold young children's skills. Over time, children internalize what they've learned through their interactions with caregivers until they are able to perform a particular action on their own.

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19.6.1 Scaffolding of Infant Object Manipulation

The theoretical accounts of Piaget and the Gibsons largely neglected the contribution of caregivers to the development of infants' sensorimotor or perception–action skills. Indeed, caregivers' contributions to the development of object manipulation have been sorely underestimated (Lockman & McHale, 1989). In Western cultures at least, caregivers often demonstrate to infants how to handle and explore objects and they manipulate objects with their infants in targeted ways. In essence, caregivers act like a coach. To illustrate, when properties such as color, texture, and sound potential are systematically varied across objects, allowing clear conclusions about the appropriateness of action, mothers not only demonstrate actions that are tailored to those object properties, but jointly perform the relevant actions with their 6- to 10-month-old infants (Lockman & McHale, 1989). Other investigators have likewise observed that caregivers often exaggerate their actions – such as through greater amplitude and more frequent repetitions of actions – when showing an object to their infants as compared to familiar adults (Brand, Baldwin, & Ashburn, 2002). Such infant-directed action, often referred to as "motionese," enhances attention and exploration of objects by 8- to 10-month-old infants (Koterba & Iverson, 2009). Thus, infants have opportunities to hone their object manipulation skills by watching and jointly interacting with others.

19.6.2 Scaffolding of Infant Play

Although parents and other caregivers have often been neglected in the study of object manipulation, parents' role in infant play has been the focus of study for several decades. Parents introduce objects for play and model play for children (Bornstein & Tamis-LeMonda, 1995); contingently respond to infants' object play by naming, describing, and talking about actions and object functions (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008; Tamis-LeMonda, Kuchirko, & Tafuro, 2013); and verbally elaborate on and encourage exploration, nonsymbolic and symbolic actions in their infants (Bretherton, 1984; Damast et al., 1996; Quinn et al., 2018). Furthermore, the mere presence of an adult during play allows infants to embellish storylines in new ways, such as by extending actions with objects from self to other when pretending to feed mommy after feeding teddy.

Parents' keen attunement to the play skills of their infants makes them especially effective play partners. When mothers and infants play with toys, mothers' play actions closely correspond to those of their infants. Mothers' nonsymbolic play acts relate to toddlers' nonsymbolic acts, and mothers' symbolic play acts relate to infants' symbolic play acts, with associations seen at the transition to symbolic play (13 months) and midway through the second year when symbolic play is frequent (20 months) (Tamis-LeMonda & Bornstein, 1991). Furthermore, analysis of the real-time unfolding of dyadic play shows

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that mothers respond within 3 seconds of infant behaviors, recommending play at levels that match or are slightly more advanced than infants' play actions. But, mothers rarely suggest lower levels of play to their infants, such as prompting exploration to a child who is pretending (Damast et al., 1996). The temporal attunement of mother–infant play in real time cuts across age. Over the course of infants' second year of life, mothers shift to more advanced forms of symbolic play in line with their infants' growing skills (Haight & Miller, 1993; Tamis-LeMonda and Bornstein, 1991).

As infant–mother dyads participate in symbolic play in particular, they engage in frequent joint engagement and verbal and nonverbal forms of communication (Quinn & Kidd, 2018). Compared to nonsymbolic play, infants and mothers display high rates of iconic/representational gestures, like cupping the hand to represent a cup, and similarly low levels of deictic gestures such as pointing during symbolic play (Quinn & Kidd, 2018).

Additionally, mothers deploy a variety of behaviors to scaffold infants' understanding that they are merely "pretending." For example, when researchers instructed mothers to interact with their 18-month-old infants in real and pretend activities such as grooming and eating, mothers displayed distinct behaviors during pretend activities versus actual activities, even though the content of the activities was identical: they looked at infants more, used more words, sound effects, prolonged actions such as holding a hand to the mouth for an exaggerated period while eating, and engaged in more frequent and longer "social referencing smiles," likely to communicate that the infant should not take the activity seriously (Lillard, 2007, 2011; Lillard et al., 2007).

Infants, in turn, benefit from the responsive attunement and social inputs that mothers provide during play. Infants look at objects longer during bouts when their mothers touch and talk about objects than during bouts when mothers do not get involved (Yu & Smith, 2016). Mothers also scaffold infants to higher levels of play, with infants engaging in more frequent and sophisticated forms of symbolic play, including more object substitutions and longer bouts of symbolic play in the presence of their mothers than when playing alone (e.g., Belsky and Most 1981; Bretherton, O'Connell, Shore, & Bates, 1984; Campbell et al., 2018; Fein, 1981; Fiese, 1990; Haight & Miller, 1992; Lillard, 2007; O'Connell & Bretherton, 1984; Slade, 1987).

19.7 Cultural Variation

Most of what is known about infant object manipulation and play is based on families from WEIRD cultures (Western, educated, industrialized, rich, democracies). However, the process by which skills are socially transmitted from more to less experienced individuals may vary from culture to culture and even within a culture. Cultural norms or beliefs about infant development shape how often, for example, parents jointly manipulate objects or participate

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in play with their infants, thereby establishing different social contexts for learning. In some cultures, caregivers engage in overt pedagogy, whereas in others, caregivers expect infants and young children to learn through observation (Rogoff et al., 1993). In some cultures, manufactured toys are rare, and in others, it can be challenging to get around without stumbling across an object for play. Yet, the narrow, convenience sampling of developmental research leaves relatively unexamined the characteristics of infant object manipulation and play across cultural communities that differ in beliefs and practices.

19.7.1 Cultural Differences in Caregiver Play Participation

Parents vary considerably in their perceptions of play, the value they place on play, and how often they play with their infants (Fogle & Mendez, 2006; LaForett & Mendez, 2017), with much variation explained by cultural norms and expectations. In US Caucasian families, many parents consider themselves to be play partners to infants, until siblings and peers take over when children are around 3 to 4 years of age (Lillard, 2015). Parents' belief in the educational benefits of play and their ability to impact children's learning helps account for their frequent encouragement and modeling of play.

However, parents in many communities – as observed in certain regions in Mexico, Guatemala, Indonesia, and in hunter-gatherer and agricultural villages – view play as solely for a child's amusement, rather than a vehicle for learning, and do not think that it is appropriate for adults to engage in play with their children (Edwards & Whiting, 1993; Farver & Howes, 1993; Farver & Wimbarti, 1995; Power, 2000; Rogoff, Mistry, Göncü, Mistry, & Mosier, 1991; Rogoff et al., 1993). As a result, sibling caregiving is common, even at very young ages (Hrdy, 2009; Weisner, 1987).

19.7.2 Cultural Differences in Object Interactions

Cultural communities also differ in *how* parents play with their infants in the context of object play. For example, when researchers compared mother–toddler play in US middle-income families to a non-Western indigenous community of Ni-Van caregivers from Vanuatu, they found that Ni-Van caregivers displayed less visual attention to their infants' faces than did US mothers, but greater physical touch. During play, Ni-Van caregivers coordinated their touching of objects with touching of their toddlers and did so without looking to one another's faces (Little, Carver, & Legare, 2016).

19.7.3 Cultural Differences in Materials for Play

Finally, cultures differ in the physical materials available for infant play. Infants from different cultural communities encounter and interact with different types of objects, which then affects their learning and expectations about object

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functions. For example, 8-month-old Chinese but not Swedish infants visually anticipate the goal of feeding actions with chopsticks (Green, Li, Lockman, & Gredebak, 2016), suggesting that object-goal knowledge is already becoming culturally specific early in the second half year. Presumably, such differences would also be evident during object manipulation, although cultural studies on this issue remain scarce.

Materials for everyday play differ across cultural communities as well. Most infants in the United States have access to many toys, and parents commonly play with their infants using replica objects, such as miniature cups, trucks, furniture, and so forth (Lillard, 2011). Toys cover the floors or walls of even common spaces like living rooms, dens, kitchens, and dining rooms. Toys are likewise pervasive in other countries, such as Taiwan (Gaskins, Haight, & Lancy, 2007).

However, infants often play with objects other than toys. As infants navigate their environments, they encounter dozens of objects along the way, pausing to play for a few seconds, and sometimes several minutes with whatever is available – small and large household objects, food, clothes, and so forth (Orit et al., 2018). In communities where toys are largely absent, rocks, sticks, flowers, pots, and empty water bottles serve as play objects (Karasik, Schneider, Kurchirko, & Tamis-LeMonda, 2018). Cultural differences in the availability of objects for play affect the types of play infants display and even the complexity of play (Gaskins et al., 2007; Lillard, 2015). However, cultural descriptions of infant play in the natural home environments are rare, and questions on how play partners and materials intersect with object manipulation and play development remain largely unanswered.

As a cautionary note, cultural differences are often conflated with differences in family socioeconomic status (SES), which might also influence the materials available to infants, caregivers' time for play and views around play, and thus the frequency and quality of infant object manipulation and play. When high- and low-SES infants in the United States are compared on their object manipulation and exploration skills, infants in the second half year from high- relative to low-SES households in the United States show more complex forms of object manipulation, including more transferring and rotating of objects and more selective forms of object-surface exploration (Clearfield, Bailey, Jenne, Stanger & Tacke, 2014; Tacke, Bailey, & Clearfield, 2015). These studies help to illuminate the processes that underlie the effects of poverty on early perception and cognition and suggest avenues for intervention, as discussed next.

19.8 Practice and Policy Directions

Interactions with objects provide opportunities for infants to learn about themselves and the world – how objects work, what can be done with objects, how to create pretend stories, and even the words that map onto objects

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and actions. Still, parents, educators, and policy makers may be unaware of the benefits of object manipulation and play for learning. Furthermore, adults often wonder about how much they should involve themselves in play, and which types of toys they should purchase to maximize their infants' interest and learning. In particular, messages about the importance of play sometimes fail to reach families who are most in need of support. In this final section, we suggest directions for programming and policy that should be incorporated into public campaigns, parenting workshops, parenting programs, early interventions, and federally funded curricula for infants and toddlers, such as Early Head Start.

19.8.1 Working with Parents

Parent–infant play promotes learning. Yet, infants also learn a lot through independent exploration and play, including how to control their body and actions and the types of actions that objects afford. So, how much should parents involve themselves in infant object manipulation and play, and when should they get involved? Balance is key. Parents cannot always stop what they are doing to interact with their infants around objects, and so messages to parents should include when infants might need assistance and guidance and when they should be left to explore independently. In many situations, parents should do no more than allow infants to navigate their environments safely. Yet, parents can also scaffold infant object engagement and play, including guiding infants around how to use objects and co-constructing pretend and elaborated stories through prompts, demonstrations, turn-taking, and hands-on participation.

Indeed, interventions around object manipulation and play have long been shown to foster motor, language, and cognitive development in infants. Historically, federal programs such as Head Start and home-based interventions recognized interactive object exploration and play as a primary source of support for infant learning in both typically developing and high-risk infants (e.g., Field, 1983; Scarr-Salapatek and Williams, 1973). And, a 2-week intervention aimed at helping parents from lower SES households explore objects in targeted ways with their infants led to sustained improvements in infant object manipulation weeks after the intervention ended (Clearfield, 2019). Additionally, interventions aimed at promoting playful interactions between parents and toddlers during block play resulted in greater vocabulary growth in children in a treatment compared to control group of toddlers (Christakis, Zimmerman, & Garrison, 2007).

However, it is insufficient to merely educate parents on the importance of infant object manipulation and play. Rather, parents must be aware of the ingredients to productive interactions, including the value of hands-on learning and the types of objects that facilitate discovery and learning. Unfortunately, the current toy market contains many popular toys with unnecessary bells and whistles. These enticing toys can be deceiving: Infants' initial attraction does little to scaffold learning and may in fact interfere with the imaginative plane of play. Moreover, adult guidance decreases in the context of electronic toy play.

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Adults display fewer bouts of pretense and elaboration (Bergen, Hutchinson, Nolan, & Weber, 2009), lower responsiveness to children's bids (Wooldridge & Shapka, 2012), fewer references to spatial concepts (Zosh et al., 2015), and less parent–child discussion during play with electronic toys than with non-electronic counterparts (Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, & Collins, 2013). Because the digital media and electronic landscape will continue to expand over the future years, parents should be educated on ways to use such toys responsibly (Dore, Zosh, Hirsh-Pasek, & Golinkoff, 2017). Furthermore, parents should be aware of how much infants learn through interactions with everyday objects. Indeed, the imaginative potential of object play can expand when toddlers are allowed to create new affordances out of regular materials. Cross-cultural studies serve as a reminder that infants find ways to play with whatever is available – boxes, empty containers, and keys.

19.8.2 Working with Educators

Play is disappearing from preschool and kindergarten classrooms. Play in infant/toddler daycare and programs might soon diminish as well. A comparison of two nationally representative data sets, one from 1998 and another from 2010, found that Kindergarten classrooms increasingly resembled older elementary classrooms: Standardized assessments grew as activities around arts, music, and play declined (Bassok, Latham, & Rorem, 2016). Often, teachers choose "learning" over play due to performance pressures, an orientation that is erroneously grounded in the idea that play and learning are incompatible (Tamis-LeMonda & Schatz, 2019).

Although educational play curricula are rarely studied in infancy and toddlerhood, research with young children shows that "guided play" offers a promising approach for teaching children foundational school-relevant skills (Weisberg, Hirsh-Pasek, Golinkoff, Kittredge, & Klahr, 2016). Guided play curricula encourage children to express their autonomy and curiosity by initiating play, as teachers or parents follow, lead, offer structured feedback, and introduce materials in a game-like fashion (e.g., Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Morris, Croker, Zimmerman, Gill, & Romig, 2013). Play-based curricula include *Tools of the Mind* (Bodrova & Leong, 2015), Montessori (Lillard, 2013), and guided play (Weisberg et al., 2016), which commonly recognize that children learn *through* play, not outside play.

19.8.3 Working with Practitioners

Finally, research on interventions to promote early object manipulation and play in children with typical development holds promise for improving outcomes in infants and young children who face motor challenges. Research on pre-reaching infants with typical development suggests that the use of "sticky

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mittens" (mittens covered with Velcro) for 10 minutes a day over a 2-week period at 3 months of age facilitates immediate grasping and exploration of objects (Needham, Barrett, & Peeterman, 2002) and leads to more advanced forms of object exploration and play 1 year later at 15 months (Libertus, Joh, & Needham, 2016). The sticky-mitten manipulation mirrors a growing trend in the pediatric rehabilitation sciences involving the use of wearables – clothing or devices that can be worn for an extended period of time – to deliver experience and/or increase the likelihood that young children will obtain needed experience to promote development (Lobo et al., 2019). At the same time, the use of wearables can enable researchers to address fundamental questions about how the dosing, timing, and delivery of experience affects the development of action-based skills, including object manipulation and play (Heathcock & Lockman, 2019).

19.9 Conclusions

Infant object manipulation and infant play have remained siloed domains of inquiry, despite being two sides of the same coin. Object manipulation and play reflect common developments in perception–action, cognitive, and neural domains that allow infants to display increased *distancing* – from the self, from the conventional use of objects, and in time and space. Moreover, object manipulation and play unfold in sociocultural contexts that determine which objects are available to infants, how caregivers interact with infants around objects, and what object-specific actions infants acquire. Theoretical and empirical integration of the object manipulation and play literatures can generate new knowledge about how infants act on objects in real and imagined planes, while informing translational efforts to benefit children and families.

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