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Young Children's Interactions with Objects: Play as Practice and Practice as Play

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Abstract

Objects permeate human culture and saturate the imagination. This duality offers both opportunity and challenge. Here we ask how young human children learn to exploit the immense potential afforded by objects that can exist simultaneously in both physical and imaginary realms. To this end, we advance a new framework that integrates the presently siloed literatures on manual skill and play development. We argue that developments in children's real and imagined use of objects are embodied, reciprocal and intertwined. Advances in one plane of action influence and scaffold advances in the other. Consistent with this unified framework, we show how real and imagined interactions with objects are characterized by developmental parallels in how children a) gradually move beyond objects' designed functions, b) extend beyond the self, and c) transcend the present to encompass future points in time and space. As well, we highlight how children's real and imagined interactions with objects are intertwined and reciprocally influence each other throughout development: Play engenders practice and skill in using objects, but just the same, practice using objects engenders advances in play. We close by highlighting the theoretical, empirical and translational implications of this embodied and integrated account of manual skill and play development.

Keywords

play; pretense; pretend play; manual skill; motor development; object manipulation; tool use

Introduction

Objects suffuse human culture. We use objects to perform the tasks of daily living, solve problems, interact with others, and in general, engage the physical and social world. Likewise, objects saturate our imagination. We can imagine that objects are present when they are not; that an object can stand for some other thing; and that objects can be used in novel ways to serve our goals (e.g., spoons as levers to pry open pickle jars). For the human actor, and particularly from a developmental standpoint, this duality offers both opportunity and challenge. How does a young human learn to exploit the immense potential afforded by objects that can exist simultaneously in physical and imaginary realms?

In this review, we offer a new framework to examine the object duality challenge by integrating literatures on infant object manipulation and play. We show that although the two

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literatures have much to contribute to each other, they remain largely siloed. Research on object manipulation is primarily grounded in perception-action theory, yielding rich insight into how infants and toddlers tailor their manual behaviors to the physical properties of objects: the predominant emphasis is on the plane of reality. In contrast, research on play primarily draws on cognitive developmental theory, spotlighting how advances in symbolic thought enable children to engage in elaborate forms of pretend play: the predominant emphasis is on the imaginary plane. In this review, we surmount this artificial divide by showing that developments in children's use of objects at real and imagined planes are closely intertwined: Advances in one plane of action influence and scaffold advances in the other.

Our review begins with a brief introduction of the literatures on young children's object manipulation and play (birth to 3 years) and consideration of the theoretical and methodological reasons for the longstanding disconnect between the two. The balance of the review aims to bridge the divide by spotlighting intersections rather than differences. To this end, we illustrate parallels in the "distancing" of young children's object interactions from self to other, conventional to novel usage, and present to future points in time and space. Relatedly, we show that developments in the real and imagined use of objects are intertwined: Advances in motor skill allow children to produce increasingly fluid and complex instrumental actions with objects that facilitate the creation of pretend stories in play. Reciprocally, limitations in skilled motor action may disrupt the flow of play (e.g., tipping over a cup while stirring), and thus hamper the elaboration of imaginary stories. In bridging the divide, we likewise highlight cross-cutting themes on the social contexts of object manipulation and play. Although research on pretend play spotlights the role of knowledgeable partners in scaffolding children's actions with objects, the main theoretical approaches on object manipulation have sorely neglected social context.

Finally, we advance the proposition that play in infancy offers practice for engagement with the artifacts of everyday life, just as practice with everyday artifacts motivates and facilitates infant play. We end with directions for future research on developmental changes in children's use of objects across real and imagined planes of action.

Manipulation and Play

Historically, studies of infant object interactions could be classified under two siloed literatures—one on the perception-action foundations of skilled object use and the other on the cognitive bases of imagined object use, particularly in pretend play. Although both literatures focus on developmental changes to infants' interactions with the object world, they diverge theoretically, methodologically, and conceptually.

Perception-Action Perspectives on Object Manipulation

During the first year, infants gain increasing control of their manual actions, and harness those actions to explore the world around them. Movement of the shoulder and elbow joints are engaged for percussive action, lateral movement and wielding; rotation of the wrist permits an object in hand to be explored in its entirety; individual and combined finger movements enable fine-grained action on a particular area or feature of an object.

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Collectively, these movements allow exploration and instrumental action to be targeted and focused. From a perception-action perspective, these movement possibilities constitute the ingredients of active touch (Gibson, 1962; Lederman & Klatzky, 1987; Turvey, 1996): individuals deploy these manual actions to apprehend and exploit basic object properties such as shape, extent, substance, texture, weight and slant.

A key question in the object manipulation literature centers on the extent to which infants tailor their actions to objects' physical properties. Empirical evidence accumulated over the past three decades, guided in large part by perception-action theory (E. J. Gibson, 1982; J. J. Gibson, 1979), suggests that infant object manipulation during much of the first year is selective. In the second half year, as new manual behaviors come online, infants deploy these behaviors in targeted ways, based on an object's spatial features and material properties. Several reviews have highlighted how infants attune their manual actions to objects' physical characteristics well before the end of the first year (Bushnell & Boudreau, 1993, 1998; Lockman & McHale, 1989; Needham, 2016; Stahl & Feigenson, 2018; Tamis-LeMonda & Lockman, 2020; von Hofsten, 1993). For instance, by the middle of the second half-year, infants are more likely to bang hard than soft objects, press and finger pliable than rigid objects, rotate non-uniform than uniform objects, and so on (e.g., Bourgeois et al., 2005; Lockman & McHale, 1989; Palmer, 1989; Ruff, 1984). Soon after the first year, infants use subtle information about object shape and are more likely to grasp asymmetric than symmetric objects away from their center of mass, thereby enabling secure grips for subsequent action (Barrett & Needham, 2008). Just as impressive, when infants observe an event involving an object that violates a constraint of physical reality, they subsequently explore and manipulate the object to identify the source of the violation (e.g., repeatedly dropping an object after witnessing a violation of object support; Stahl & Feigenson, 2015).

Infants explore *extended surfaces* in discriminating ways as well (Rips & Hespos, 2015). When infants encounter extended surfaces, either when seated at a table or as they prepare to locomote, they quickly use haptic exploration to maximize information gain by selecting manual behaviors that are geared to the material composition of the surface before or underneath them (Fontenelle et al., 2007; Gibson et al., 1987; Kretch & Adolph, 2017). For example, when infants explore fully transparent, partly transparent, or opaque barriers, their manual behaviors align with the visual properties of the barrier (Diamond, 1990; Lockman, 1984; Lockman & Adams, 2001; Matthews et al., 1996). Likewise, when sitting before a tabletop surface or in prone position prior to locomoting, infants uniquely adapt their manual actions to the material properties of the surface before them (e.g., slapping a liquid surface, but pressing a pliable one). As was the case with objects, infants' behaviors optimize information gain, allowing them to discover what surfaces afford for action (Adolph, 1997; Adolph & Hoch, 2019; Gibson et al., 1987).

Finally, by the last quarter of the first year, infants engage in actions to discover and exploit information that is entailed by the *relation* between an object and a nearby surface, a class of behaviors that many view to be more psychologically complex than acting on an object or surface alone (cf. Belsky & Most, 1981). They combine objects and surfaces selectively, based on the relation between the material properties of each: they are more likely to bang hard objects on rigid than pliable surfaces, press objects more into pliable than rigid

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surfaces, and scoot hard more than soft objects along rigid surfaces (Bourgeois et al., 2005; Morgante & Keen, 2008; Palmer 1989). Moreover, infants even do so when they encounter abrupt transitions in adjacent surfaces (e.g., a rigid tabletop surface abutting a pliable one; Fontenelle et al., 2007).

Collectively, these examples indicate that well before the end of the first year, manual exploration already functions as a haptic spotlight. Infants direct manual behaviors to a particular region, whether an object or surface. They explore that region purposefully and selectively, using either their bare hands or a handheld object, thus optimizing information gain. Critically, infants gear their actions to the material properties of the object and/or surface being explored, and the relation entailed between them. As we suggest later in our review, infants' purposeful, selective, and targeted behaviors are evident in play as well, and pave the way for more complex adaptive behaviors involving the real and imagined use of objects.

Cognitive & Social Perspectives on Object Play

Like research on object manipulation, researchers of infant "play" document the impressive changes in infants' object interactions (mostly toys) across the first and second years. But unlike research from a perception-action perspective, studies of play largely attribute developmental changes to advances in symbolic thought, cognitive reasoning, and social-cognitive skills involved in understanding the intentions of self and others. For example, when a toddler feeds an adult a plastic banana, and the adult munches away, the toddler has both represented the banana as real food and understands that the adult's intention is not actually to eat the plastic toy, but rather to pretend to do so. As such, pretend acts are "instances of ellipsis: something is left out of a scene and must be filled in" (Lillard, 2011).

In light of the privilege ascribed to symbolic play, much research from a cognitive tradition describes developments that bring an infant from exploratory, so called "relatively primitive manipulations" of objects, to using toys to re-enact imagined pretend stories. Moreover, because children often engage in pretend play with other people, researchers consider how adults scaffold higher levels of thinking and acting in children.

Developments in Play—The theoretical basis for the study of play originated in the writings of Piaget, who observed infants' object interactions as a window into their emerging knowledge about the physical world (Piaget, 1945; 1952). Piaget noted that infants undergo a qualitative shift in their interactions with objects in the second year, when they understand that objects exist independently of the self. According to Piaget, pretend play indexes children's "symbolic understanding" or mental representational abilities—the underlying mechanism that likewise accounts for advances in language, deferred imitation and physical knowledge.

Building on Piaget's cognitive developmental theory, researchers have carefully described progressions in infants' play with objects. Although different researchers code play at different levels of granularity, they largely distinguish among three broad categories: Exploration, non-symbolic or functional play, and symbolic play. More specifically, infants' initial manipulations of objects (exploration) progress toward nonsymbolic/functional

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manual actions that are geared to the designed purpose of toys—pushing buttons on a busy-box, inserting pegs into a pegboard, and throwing balls (e.g., Belsky et al., 1980; McCune-Nicolich, 1981; Tamis-LeMonda & Bornstein, 1996). With age, infants begin to use objects at the imagined plane in pretend play. To illustrate this progression, a young infant might bang a toy car; a 1-year-old might push the car along the floor while producing "vrrrmm" sounds; and a 2-year-old might place a doll atop the car for a drive to school, and then act out what happens once the doll arrives.

Acts of symbolic play are considered to be developmentally meaningful from a cognitive standpoint because infants shift from seemingly asking "What can this object do?" to imposing imagined situations onto real ones (Lillard, 1993). Indeed, during pretend play, children enter an "as if" realm, in which activities of the past (e.g., eating breakfast) are brought into a non-literal present context (e.g., feeding Teddy pretend cereal) (Fein, 1981; Garvey, 1990; Lillard, 2013).

As toddlers grow in language, attention, and social understanding, their symbolic play progresses further. Early bouts of pretend play are simple and brief, but evolve into lengthier, elaborate stories in the second and third years, with just about any object being a candidate substitute for any other object in the service of pretense. For example, a 1-year-old might pretend to eat from a toy spoon and then stop to play with something else; an 18-month-old might pretend to eat, feed dolly, and then lay dolly down on a blanket to nap; a 24-month-old might use a stick to feed dolly if spoons are unavailable, and cover dolly with a tissue when blankets can't be found. As such, the embellishments in children's pretend play spotlight their understanding that objects can be used in made-up situations that are separate from reality (Vygotsky, 1967). (Figure 1).

Evidence for a cognitive interpretation of pretend play—Piaget's cognitive account of pretend play has empirical support. In particular, associations between play and language suggest a common underlying ability may instigate changes in both. Specifically, as early exploration of objects expands to incorporate functional and symbolic play with objects across development, language progresses from babbles, to single word utterances, to simple sentences and decontextualized talk (Gillespie & Zittoun, 2010; Hoff, 2013; McCune, 1995; McCune-Nicolich, 1981;). Moreover, differences among infants in amount and type of symbolic play consistently relate to their language skills, particularly before age 3 years (e.g., Fletcher et al., 2020; Orr & Geva, 2015; Quinn et al., 2018).

Nonetheless, the jury is out on whether play-to-language associations reflect a shared underlying capacity, as Piaget suggested; whether advances in play spill over to language skill; and/or whether gains in language enable children to engage in more elaborate bouts of pretend play (Lillard, 2013). Likely, reciprocal cascading influences explain play-to-language relations. That is, toddlers gain practice with language and communication while engaging in pretend play; and growing language skills allow children to create and share pretend stories in new ways with others (including adults), who respond with language input that further promotes learning. Indeed, children's engagement in play fosters their learning of new concepts (Sutherland & Friedman, 2013), and reciprocally, a growing understanding of the world, particularly around causal understanding, engenders advanced

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forms of pretend play (Gopnik & Walker, 2013). A toddler may understand that placing "dirty" teddy inside a toy tub will result in a clean teddy, and counterfactually if water is "emptied out" from the imagined tub, mud-covered teddy will remain dirty. Indeed, children's causal and counterfactual reasoning coincides developmentally with the growing prevalence and elaborateness in pretend play (~3 to 5 years) (e.g., Gopnik & Walker, 2013).

Social Context of Play—Piaget's writings spurred debate with Russian psychologist, Lev Vygotsky, who shifted focus to social and cultural influences in learning. Vygotsky called into question Piaget's seemingly narrow focus on how children generate information —primarily through engagements with the physical (not social) environment. According to Vygotsky, children co-construct knowledge at the interpersonal level that they eventually internalize until they can perform those actions on their own. A key tenet of Vygotsky's theory is that through interactions with adults, young children master higher levels of thinking and acting than they would achieve independently.

Applying Vygotsky's theory to children's object play spotlights the need to understand whether and how knowledgeable partners shape what infants do with objects, how long play bouts last, and so on. Parents demonstrate how to play with specific objects; contingently respond to infants' object play by talking about objects, actions, and object functions; and use verbal and physical prompts to engage children in exploration, non-symbolic and symbolic play (Bornstein et al., 2008; Bornstein & Tamis-LeMonda, 1995, 2006; Bretherton, 1984; Quinn et al., 2018; Tamis-LeMonda et al., 2013). Additionally, adults display exaggerated facial, vocal, and manual behaviors that signal they are merely pretending and the infant should not take the activity seriously (Lillard et al., 2007; Lillard, 2011).

The benefits of playing with a partner, relative to playing alone, manifest in several ways. Infants exhibit more frequent and sophisticated forms of functional and symbolic play, including more object substitutions, longer bouts of symbolic play, and less stereotypical play in the presence of their mothers than when playing independently (e.g., Belsky and Most 1981; Bigelow et al., 2004; Campbell et al., 2018; Bretherton et al., 1984; Haight and Miller, 1992; O'Connell & Bretherton, 1984; Slade, 1987). Moreover, during symbolic play, dyads engage in frequent joint engagement and verbal and non-verbal forms of communication (e.g., iconic or representational gestures, such as cupping the hand to an ear as a telephone) (Quinn & Kidd, 2018). Furthermore, the mere presence of a social partner allows children to embellish play scenarios in new ways.

The Great Divide

As seen, prior treatments of infants' manipulation and play have led to deeply informative but non-intersecting literatures. What explains these divides? The theoretical foundations of symbolic representation, social cognition, and socio-cultural influences distinguish research on infant play from perception-action research on object manipulation (with some exceptions). In turn, distinct theoretical orientations have resulted in diverging methodological approaches to studying how infants engage with the object world.

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Theoretical Divides

The disconnect between literatures on manipulation and play is rooted in tendencies to (1) pit the properties of physical and imagined objects against one another; (2) characterize the material world as rich or impoverished, and (3) emphasize children as solitary scientists versus social partners.

Pitting the Real Against the Imagined—Theoretical accounts draw a sharp divide between children's real and imagined use of objects. Piaget (1952) claimed that physical objects are limited to the here and now, but objects imagined during pretense, for instance, can transcend the laws of reality. Werner and Kaplan (1963, in their developmental-organismic approach, highlighted the distancing that occurs between a symbol and its real-world referent as development proceeds. Likewise, according to dual representation theories, a symbol can be employed effectively only if the child mentally separates the symbol from the object that it embodies (DeLoache, 2004). And in Vygotsky's sociocultural theory of development, children become progressively able to distance the cultural function or meaning of an object from its immediate perceptual or physical representation, a process that is partly mediated by children's speech and the language of their culture (Müller et al., 2013; Vygotsky 1967).

The pitting of real versus imagined use of objects privileges certain behaviors over others. Cognitive-developmental theories privilege pretend acts or the imagined plane of object interactions. As a result, mouthing, fingering, turning, flipping, banging—behaviors of interest to perception-action researchers, historically have been viewed as unsophisticated by cognitive developmental researchers. That is, infants were assumed to apply similar actions or schemes to all objects (cf. Piaget, 1952) in bouts of simple manipulation, juxtapositions, or relational behaviors that were not functional (Belsky & Most, 1981; Fenson et al., 1976; Uzgiris, 1976), with some considering exploratory actions to fall outside the scope of play entirely (Lillard, 2015).

What the material world offers: Rich vs. impoverished information—Perception-action accounts describe objects and surfaces as rich in information that specifies affordances for actions (E. J. Gibson, 1982; E. J. Gibson & Pick, 2000). Developmentally, the challenge for infants is to harness their emerging manual skills to explore, register and use this information to act adaptively in the world. In contrast, cognitive-developmental and sociocultural views of play implicitly characterize the material world as impoverished. Infants construct meaning about the world through their nascent mental structures (Piaget, 1952). Top-down schema constrain what infants can do with objects and what they understand about the object world. Given diverging positions about the kinds of information embodied by in the environment, it is unsurprising that one position (i.e., perception-action theory) would predict that early object manipulation and play would be specific and discriminating, whereas others (i.e., cognitive-developmental, sociocultural theory) would not.

Solitary Scientist versus Social Partner—Researchers from a perception-action approach treat infants as solitary scientists. In contrast, researchers of play build on

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Vygotsky's sociocultural theory and consider knowledge to reside with experienced members of a culture who support infant learning through a process of co-construction and guided participation (e.g., Rogoff, 1990, 2003). Social partners provide information and encourage children to interact with objects (whether at real or imagined planes) through direct instruction, hands on guidance, and simply by modeling actions with objects on a regular basis. Indeed, adults interact with hundreds of objects over the course of a day, offering infants opportunities to watch what can be done with specific objects. They often join their children who struggle with everyday actions like zipping coats, opening yogurt cups, and so on. In short, according to sociocultural theory, developments in object manipulation (just as in pretend play) cannot be divorced from the social environment in which children develop.

Methodological Divides

Diverging theoretical perspectives have shaped researchers' methodological choices, further separating studies on children's actual and imagined use of objects. Methodological differences span study design and approach to behavioral coding.

Controlled Studies versus Naturalistic Design—Perception-action researchers rigorously control materials and room set up, down to the precise positioning of objects relative to infants' hands. Researchers typically seat infants at a table, in a pristine environment devoid of distractions, and instruct caregivers to not interact with their children during testing. Researchers systematically vary objects and surfaces from trial to trial to isolate a particular feature or material property of empirical interest. Focus is on the details of infants' manual actions with objects of different shapes, textures, sizes, and so forth (e.g., Bourgeois et al., 2005; Palmer, 1989; Rachwani et al., 2020a).

In contrast, researchers from a cognitive-developmental tradition choose materials that allow children to engage in a range of play behaviors, and typically present several objects (toys) simultaneously. They do not vary the material properties of objects in a controlled fashion, but rather code behaviors into broad categories of play. For example, researchers might present infants with animals, dolls, vehicles, and miniature replicas of cultural artifacts (e.g., cups, saucers, combs) to examine how infants construct scenarios involving more than one object and whether infants engage in functional (nonsymbolic) or symbolic play at different levels (e.g., Bigelow et al., 2004; Bornstein & Tamis-LeMonda, 1995; Quinn et al., 2018). Moreover, research on the social context of play is likely to be naturalistic, allowing dyads to interact with objects however they wish. Thus, experimental rigor is often exchanged in favor of ecological validity.

Behavioral Coding: Intention versus Process—Researchers from cognitive and socio-cultural traditions typically code infants' intended action or inferred end-goal, rather than specifying the actions that children implement during play. Thus, they do not distinguish between unsuccessful and successful attempts. For example, a toddler who attempts to pour from a toy teapot into a cup would be coded as engaging in "pretend play" whether or not the teacup falls over as the toddler pours. Similarly, an infant who tries to stack blocks would be coded as playing non-symbolically, whether or not the tower

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collapsed. In contrast, researchers from a perception-action perspective carefully describe manual actions (e.g., hand placement, bimanual coordination, grip modification, stabilizing actions; Kimmerle et al., 2010). Moreover, they distinguish actions from implementation of the end goal: a toddler may display a pulling motion on a zippered pouch, but misplacement of the stabilizing hand will result in a failed attempt (Rachwani et al, 2020a).

Bridging the Divide

While granting differences in theoretical and methodological approaches, we aim to reassess the dynamic between children's actual and imagined use of objects. Guided by an embodied or grounded cognition perspective in which action and thought are viewed to be integrated and co-dependent (Barsalou, 2008; Lakoff & Johnson, 1980), we showcase parallels and interdependencies in developments of object manipulation and play. Our overarching goal is to surmount the artificial divide and offer a unified account of how advances in children's real and imagined use of objects both parallel and interweave with one another.

Parallels in the Dual Planes: Distancing in Object Interactions

Real and imagined interactions with objects are characterized by developmental parallels in how children: a) gradually move beyond the designed functions of objects, b) extend beyond the self, and c) transcend the here and now to encompass future points in time and space.

Distancing in Time and Space—Actions with objects become distanced in time and space as children develop skills in visual-manual integration, planning, and prospective control. Such developments allow infants to anticipate (for example) the grips that will most effectively accomplish a goal, (McCarty et al., 2001) and how to orient objects to fit into apertures (Jung et al., 2015; 2018). Pretend play as well, is marked by growth in prospective control and planning. For example, acts of pretense at the start of the second year are fleeting and brief, with little evidence of planning. Each action occurs in isolation of the next, with little evidence of laying out a story. In contrast, 18-month to 24-month-old toddlers exhibit multi-step sequences of pretend play that follow a logical order marked by planning. For example, an infant might pretend to drink from a cup, and then suggest "baby cup" in advance of feeding a doll, while handing cups and spoons to daddy as well. In doing so, the toddler must alter the orientation of spoons and cups to accommodate doll and dad's position in space. 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 objects happen to be nearby (McCune-Nicolich, 1981).

Distancing from an Object's Intended Purpose—Infants' interactions with objects at real and imagined planes shift from the use of objects as designed to using objects flexibly and imaginatively. Children's novel application of objects beyond their intended purpose lies at the core of creativity and divergent thinking (Bruner, 1978). For example, a 12-month-old might push cars and trucks along the floor while playing, but fail to imagine the affordance that rectangular blocks offer as pretend cars. Midway through the second year and into the third year, as children understand that objects can stand for other things (DeLoache, 2004), they creatively substitute objects for other objects. Blocks, sticks, and pencils can serve

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as cars, and empty tissue boxes as garages. Thus, pretend play shifts from understanding what people typically do with specific objects to being freed from conventional usages. By around 3.5 years of age, children's distancing heightens: they can now substitute objects that dramatically differ in size and shape 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 et al., 2016).

Similarly, developments in tool use reveal growing distancing of objects from their intended design. Initially, infants rigidly adhere to the common uses of tools, displaying "functional fixedness" (Duncker, 1945). As a result, they have difficulty considering alternative uses of objects. For example, 12-month-old infants fail to understand that the long handle of a spoon can be inserted into a small aperture to light up a box. Instead, they insist on grasping the spoon's handle as they would to eat, which prevents them from using the spoon to illuminate the box. By 18 months of age, infants accomplish the goal by flipping the spoon to insert the slim handle into the hole (Barrett et al., 2007).

Distancing from the Self—Finally, actions with objects become increasingly distanced from the self. The progression from self-to-other directed pretend play exemplifies such decentering (Piaget, 1952; Werner & Kaplan, 1963). Infants direct their first pretend acts toward the self, simulating familiar activities such as eating, washing up, and going to sleep. Several months later, pretend play becomes increasingly independent of the child's own sensorimotor actions, with infants feeding teddy, mommy, and so on. Still later, toddlers engage in vicarious play, in which inanimate objects are made to act, such as when teddy combs its own hair, cries after falling down, or talks on a phone (e.g., Fenson & Ramsay, 1980; Tamis-LeMonda & Bornstein, 1993, 1996).

The movement from self-directed to other-directed actions likewise holds for everyday tasks. Infants often have an easier time engaging in self- than other-directed tool use. For instance, they effectively grip and orient a spoon to feed themselves months before they effectively do so to feed others (McCarty et al., 2001). Cognitive development, however, also contributes, as evidenced in the ability to anticipate which grips will be most comfortable given more complex task goals.

Motor Skill Demands Constrain Play

Motor skills determine what infants can do with objects. Such constraints extend to nonsymbolic (functional) and symbolic forms of play. For example, interlocking blocks such as Duplo requires much more than a goal to build an imaginary house. Infants must bring the correct sides of bricks together; align the studs of one brick with the holes of another; and press down with sufficient force to interlock (Kaplan et al., 2018). The perceptual and biomechanical requirements to implement the designed actions of toys mean that many forms of object play require months or even years of practice.

Similarly, the requirements of pretend play extend well beyond skills of mental representation. Children must be able to successfully implement complex motor actions to effectively string together multiple actions in the service of elaborate pretend scenarios. For example, a spoon that knocks over a cup during stirring may disrupt play and prevent the

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smooth execution of actions—stirring, pouring, drinking, and so on. Essentially, successful implementation of motor actions allows infants to move to the next segment of the story.

Cognitive Load—Additionally, cognitive load theory (Boudreau & Bushnell, 2000; Cameron et al., 2016; Sweller, 2011) would suggest that cognitive or attentional capacities regulate motor skill during young children's real and imagined use of objects. In tasks that involve the real use of objects, when motor demands (i.e., hand positioning) increase, infants' cognitive (discrimination) performance suffers. Conversely, when cognitive (i.e., means-end problem solving) demands increase, infants' motor performance (i.e., reaching) is compromised (Boudreau & Bushnell, 2000). By the same token, as children deploy more attentional resources to implement a motor action, fewer resources may be available to execute cognitively demanding tasks, such as sequencing multiple, complex actions during pretend play. Insights into such tradeoffs can be gleaned by studying the "how" of object use across real and imagined planes

Play as Practice and Practice as Play

The longstanding dichotomy between children's real and imagined use of objects—and corresponding siloed literatures—ignores the synergistic connection and blurred boundaries between the two. Infants' play with objects helps them refine motor skills and vice versa. For example, exploratory play in young infants (banging, fingering, rotating, and so on) provides essential practice for the skilled use of cultural artifacts and tools, such as containers, zippers, and spoons. Indeed, perception-action theory suggests that complex and instrumental actions with objects arise from infants' exploration of objects and surfaces and their combination during everyday play (Gibson & Pick, 2000; Lockman, 2000). In turn, infants incorporate what they learn from their everyday practice with cultural artifacts and tools into their play. Reciprocally, play with replicas of everyday objects and tools further refines the motor skills required by the activities of daily living such getting dressed, eating, bathing, and toileting.

In short, we reject the idea that pretense play supplants "simple" manipulation evoked by an object's material properties as children become less beholden to the rules of reality. Rather, object interactions at real and imagined planes reciprocally and continuously advance one another from infancy onward. We illustrate with examples of co-dependencies between infant play and the use of tools and everyday artifacts.

Exploratory Play as Practice for the Use of Tools and Artifacts

We propose developmental continuity between the processes that underlie exploratory play in infancy and the expanded use of tools and cultural artifacts in childhood. This idea runs counter to longstanding accounts of tool use as an index of cognitive representation in humans and animals (Bates, 1979; Kohler, 1929; Piaget, 1952), and similarly counters the characterization of pretend play as a privileged form of object engagement. Indeed, the notion of "play as practice" (Groos, 1898) suggests that play scaffolds' children's learning of complex bio-mechanical skills required to implement just about any motor action.

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Human Research on Tool Use—Tool use is built from the sensorimotor routines that organisms recruit to explore and act on the world (Kahrs et al., 2014; Lockman 2000; Lockman & Kahrs, 2017). Indeed, the long period of developmental time during which infants relate objects and surfaces during play provides practice with a key requirement of tool use: an object, natural or manufactured, must interact with another object or surface in a targeted way to effect a particular change in the environment. Moreover, tool use requires not only recognizing how objects and/or surfaces must interact to yield desired effects, but skill in implementing the required actions (Kahrs & Lockman, 2014). As infants play with objects in real time, they gain control of the motor skills that they will incorporate into tool use over developmental time.

The path from object banging to percussive tool use (i.e., hammering) during early childhood illustrates this developmental progression. During object play, young infants often display bursts of repetitive manual activity in which they bang objects against surfaces. Historically, this high-energy motor stereotypy received little attention in the developmental literature other than being considered a marker at later ages of developmental delay (Gesell & Amatruda, 1941; see Thelen, 1981). However, infants' repetitive banging during play prepares the manual system for percussive tool use. When researchers use motion tracking to record infants' arm trajectories in real time during bouts of object banging (see Figure 2), they find that bouts of object banging become more consistent, controlled, slower and straighter from late in the first year through the early part of the second year (Kahrs et al., 2012). This is precisely the pattern of movement that is optimal for using a pounding tool. When a handle is added to an object, mirroring the design of hammers, a similar developmental progression is found, but initially delayed, due to the increased demands associated with controlling an object through a handle (Kahrs et al., 2013; Kahrs & Lockman, 2014). Collectively, findings suggest that tool use is an outgrowth of infants' efforts to combine objects with other objects and surfaces during everyday play.

Comparative research on tool use—Comparative research likewise supports connections between juvenile's exploratory play and tool use (Lockman, 2000). The path to tool use in non-human animals follows a lengthy period of development that mirrors progressions in the play of human infants. Namely, across long expanses of developmental time, juveniles explore objects and surfaces individually; begin to combine objects with other objects or surfaces; learn about the new affordances that arise from such combinations; and finally attempt to assemble tool use from component actions. This developmental progression has been documented in non-human primate tool-using species including chimpanzees (Inoue-Nakamura & Matsuzawa, 1997; Musgrave et al., 2021), capuchin monkeys (De Resende et al, 2008), and long-tailed macaques (Tan, 2017); and non-primate species, including New Caledonian crows (Kenward et al., 2006). For example, stone play and handling over several years by long-tail macaques equips them with the ability to use a hammerstone to crack open shellfish with targeted, correctly sequenced and effective forms of percussive action (Tan, 2017). Likewise, before New Caledonian crows develop the ability to use a twig to probe for food, they engage in an extended period of "proto-probing," which enables them to learn new affordances for action and acquire skill in controlling a twig that extends from its beak (Kenward et al., 2006, but see Rutz et al., 2016).

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Collectively, studies with humans and non-humans indicate that exploratory play is foundational for later tool use, and that tool use originates across species from common processes of sensorimotor learning. Repeated play with objects, surfaces and their interrelations in real time begets motor skill learning over developmental time, and thus supports the emergence of tool use.

Engaging with Cultural Artifacts—As for tool use, practice gained during play promotes competence in the use of cultural artifacts—manufactured objects that are designed to be used in specific ways. In some cases, these so-called designed actions are transparent, and readily perceived (such as a protruding button to be pressed down). But in many instances, designed actions are opaque (think twist-off lids that arbitrarily require turns to the left to open). As design expert Donald Norman (1988/2013) has argued, human design is not synonymous with human friendly. For children, the problem is further compounded: they must discover the so-called "hidden affordance" and implement the designed action(s), despite gaps in manual skill. Nevertheless, by the time children begin formal schooling, they are expected to effectively engage with everyday artifacts.

Recent work sheds light on the tight connection between exploratory play and artifact use. Specifically, children learn to open containers (Rachwani et al., 2020b) and zippered pouches (Rachwani et al., 2020a), not through sudden insight, but through prolonged periods of exploration and play, spanning several years from infancy through early childhood (see Figure 3). During this time, children attempt a variety of non-designed actions (e.g., banging); subsequently discover the designed action associated with the hidden affordance; and repeatedly attempt to implement the designed action, even though success may be fleeting. Through extensive practice and play, children refine and sequence the component motor skills needed to discover and implement required actions. Thus, like the ontogeny of tool use, the use of everyday artifacts is rooted in reciprocal processes of exploratory play and sensorimotor learning that unfold over real and developmental time.

Everyday Practice with Tools & Artifacts: Fodder for Play

Just as play offers practice for using tools and cultural artifacts, everyday engagements with tools and artifacts shape and support all forms of play. During a single day, children are exposed to a multitude of objects that they actively explore and witness other people use. For instance, in the context of eating, children are given bottles that they need to hold and rotate, utensils that they need to grip and orient, pouches they need to open, and juice boxes that they need to unscrew or pierce with a straw. Because these so-called activities of daily living occur repeatedly throughout the day, they simultaneously function as natural instances of recurrent but spaced practice. Critically, such practice is optimally structured to promote prospective control of action, bimanual coordination, manual dexterity, grip selection and the like. In turn, such refinements in manual skill contribute to the development of complex forms of play—children gain skills needed to build complex block structures, fit puzzle pieces, and insert shapes into shape sorters.

Clearly as well, activities and routines of daily life inspire the stories of pretend play. That is, drinking from cups, eating with spoons, brushing teeth, and so on are fodder

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for children's imagined use of objects (Tamis-LeMonda & Lockman, 2020). As Harris (2021) notes, the mundane events of life allow children to both recreate events in pretend play and imagine unique alternatives to those events (such as feeding teddy and imagining what would happen if teddy throws food on the floor). Indeed, the reality-to-imagination connection explains why infants' first expressions of pretense reproduce common experiences (Bretherton, 1984). That is, infants' imaginary worlds are rife with actions that they and others repeatedly apply to common objects—stirring in toy pots, scooping pretend food into plates, and using spoons to eat.

Continuity between reality and imagination also explains how children learn to expand their early pretense bouts to situations that they have not experienced: They draw on assumptions that the pretend world follows the same constraints and regularities as reality (Gopnik & Walker, 2013; Harris, 2021). That is pretend play abides by physical laws, such that although a toy teapot is empty, accidentally tipping it over will cause hot water to soak the tablecloth.

Pretend Play as Practice in the Use of Real Tools and Artifacts

Cycling back to play as practice, children's proclivity to enact everyday routines in pretend play further facilitates their discovery and implementation of the designed actions of objects generally. As children zip toy purses, untwist lids of toy bottles, and stir in replica teapots, they practice the unique manual actions relevant to engaging with conventional zippers, lids, and spoons. And practice through pretend play generalizes across cultural communities: Children of forest foragers and farmers re-enact the subsistence activities of their daily life —such as fetching water, cooking with leaves, and weaving—using miniature implements like small spears, baskets, and toy looms (Boyette, 2019; as cited in Harris, 2021; Maynard & Greenfield, 2003).

Notably, however, the suggestion that play is practice has been challenged. Chu and Shultz (2020) remark that such "activities neither prepare children for adult life nor reduce children's uncertainty about anything they were uncertain about" (pp. 332). They propose that although pretend play may be "useless" for many ends, it centrally aids thinking, because pretending allows children to generate new thoughts and plans. Although we agree that pretend play provides opportunities for innovation (a predominantly cognitive view), we believe that rejection of the view that play offers practice reinforces theoretical divides.

Moreover, the argument against play as practice rests on the lack of correlations between experience with toys and later motor skills as adults in animal and human species (Chu & Schulz, 2020). However, two problems undercut this counterargument. First, correlations necessitate sufficient variation in early experiences. Yet, infants, across age, culture, household SES, and so on, spend more than half their awake hours manipulating a wide variety of objects during bouts of play (e.g., Karasik et al., 2018). Such immense practice undoubtedly contributes to motor skill development, as supported by studies of tool use (reviewed here) and findings that training on motor skills like grasping cascades to later manual skills (Libertus et al., 2016).

Second, the assumption that play=toys rests on the idea that children privilege toys in pretense. This is not the case. Although the toy industry reaps 90+ billion dollars a year on

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toys that adults eagerly purchase for their children, from an infant's perspective (at least) there's no reason why pretend play should involve "toy keys" but not "real keys". In fact, during spontaneous play at home, 1- to 2-year-old infants manipulate toys and non-toys alike, often mixing the two in a single play bout (Herzberg et al., 2021). Immense amounts of time-distributed, varied practice manipulating objects during everyday play builds motor skills critical to tool use and the activities of daily living. In short, every action on every object (toys and non-toys alike) provides infants with practice in modifying grips, building strength, honing bimanual skills, and dynamically adjusting behaviors to fit task demands.

Socio-Cultural Contexts of Real and Imagined Object Interactions

Children's real and imagined engagements with objects are embedded within culture, and thus mediated by the social figures, practices, and institutions of that culture. In communities everywhere, caregivers guide children's interactions with objects at real and imagined planes in both ostensive and incidental ways. Indeed, caregivers: (1) structure physical environments, thereby determining which objects are accessible to infants for exploration and play, when, and where (Fletcher et al., 2021); (2) act on cultural artifacts as they engage in the activities of daily living, thereby modeling how to use objects as designed (note, this need not be intentional); and (3) jointly engage with children around objects, and in doing so, scaffold children's learning to varying degrees depending on the verbal and physical cues they offer. Although the three forms of support are universal, here we highlight how caregivers scaffold children's use of objects during "triadic" object interactions (de Barbaro, et al., 2016).

Triadic Interactions: Scaffolding Infants' Interactions with Objects.—As caregivers engage with infants around everyday objects, caregivers produce various behaviors that facilitate learning. For example, caregivers engage in "motionese" by exaggerating their manual behaviors (e.g., high amplitudes, frequent repetitions) when showing objects to infants (Brand et al., 2002). Such cues to action heighten children's attention (Koterba & Iverson, 2009), particularly to the movement of caregivers' hands (Jayaraman et al., 2013), with hands yielding information about how to act on objects in culturally relevant ways.

Additionally, caregivers sometimes take a hands-on approach as they literally go through the motions with their infants. Caregivers guide infants' hands to perform actions that are tailored to an object's physical features (e.g., jointly scratching a textured object or clasping infants' hands to jointly shake sound-producing objects, Lockman & McHale, 1989). They help young children discover and implement the hidden affordances of everyday artifacts—such as how to twist a container lid—by pointing at relevant locations (the lid), gesturing specific actions (a twist), positioning infants' hands, and stabilizing the container as infants attempt to turn the lid (Kaplan et al., 2021).

Similarly, caregivers scaffold children's play with toys through behaviors matched to children's skills, thereby operating within children's "zone of proximal development" (Fletcher et al., 2020; Quinn et al, 2018). For example, the frequency of mothers' nonsymbolic play coincides with the frequency of toddlers' nonsymbolic, and the frequency

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of mothers' symbolic play relates to infants' symbolic play at the transition to symbolic play (13 months), midway through the 2nd year when symbolic play is frequent (20 months), and at the start of the third year when symbolic play grows in complexity (e.g., Fletcher et al., 2020; Tamis-LeMonda & Bornstein, 1991). Furthermore, mothers respond to infant play with play behaviors that match or are slightly more advanced than infants' play behaviors; but rarely engage in play that is less sophisticated than what their infants are doing in the moment (Damast et al., 1996).

Cultural Contexts—Although triadic interactions are universal and afford opportunities for learning how to act on objects, their characteristics vary across cultural communities (e.g., Little et al., 2016). For example, cultural communities differ in the degree to which caregivers provide replicas of everyday artifacts to young children for play (Karasik et al., 2018; Lancy, 2016; Tamis-LeMonda & Schatz, 2019). Cultures likewise differ in the degree to which caregivers assist young children with the activities of everyday living (although this assumption has not yet been tested). Similarly, they differ in the views that caregivers hold about their role in children's play, and relatedly their tendencies to participate in play with children (e.g., Delgado-Gaitan & Trueba, 1991; Farver & Howes, 1993; Hafford, 2010; Zukow, 1989). And, caregivers from different cultural communities emphasize different modalities of input (e.g., touch, talk) as they interact with children around toys and other objects (Little et al., 2016).

Rogoff's work on "guided participation" highlights the informal ways that children learn from engaging in cultural routines (e.g., Rogoff, 1990; 2003; Rogoff et al, 1993). Observations of children in San Pedro, Guatemala, Salt Lake City, Utah, Dhol-Ki-Patti, India, and Keqiren, Turkey revealed that children learned culturally relevant skills by engaging in everyday routines with people who were skilled in the use of cultural tools and artifacts (rather than through experiences with explicit forms of teaching). Indeed, many complex skills—weaving, tailoring, hunting, fishing—involved "apprenticeship learning" as novices engage with the adults of their community.

Taken together, the inputs that adults offer young children during bouts of joint object engagement constitute rich contexts for learning — whether exploring object features with young infants, participating in bouts of pretend play with toddlers, or informally involving children in everyday routines through guided participation. Such social interactions support children's learning the designed actions of everyday objects, and present children opportunities to engage in complex forms of object play.

Conclusions

In this review, we have argued that the literatures on the development of manual skill and the development of play have remained unnecessarily siloed. We contend, however, that all forms of play, including pretense, cannot be divorced from the actions that embody play. A primary implication of this view is that the development of skilled action and the development of play are intertwined and reciprocally influence one another: Play engenders practice and skill in using objects, but just the same, practice using objects engenders

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advances in play. In our closing remarks, we consider what these conclusions mean more generally for theory and research.

At the level of theory, we advocate for a more unified, embodied account of the development of manual skill and play, in which action and thought are integrated and co-dependent (Barsalou 2008; Lakoff & Johnson, 1980; Tamis-LeMonda & Lockman, 2020). In daily life, the line between children's actions on objects and play is blurred. Children's attempts to use everyday objects seamlessly flow into play with objects and vice versa. Yet, theoretical accounts that address the development of manual skill (i.e., perception-action theory) on the one hand, and play (i.e., cognitive-developmental theory) on the other remain divided. Perception-action theory has largely eschewed the social and imagined worlds, focusing instead on environmental information immediately available to the individual. By contrast, cognitive-developmental theory has relegated discussion of action to the earliest and simplest forms of play. Instead, we maintain that there is much to be gained by dismantling this unnecessary divide.

How can this be accomplished? Perception-action approaches can be extended to address how skilled action is inherent to play, enabling discovery and practice, and even promoting imagination. Some of the work that we reviewed on the development of tool use and the detection and implementation of hidden affordances is consistent with this idea. Perception-action approaches may also be broadened to theorize about the role of social figures and culture in how young children learn to act on objects. Conversely, cognitive-developmental theory can be integrated with perception-action approaches by explicitly considering how functional and pretense play is grounded in action and motor skill. The idea that pretend play is free of motor demands and largely object-free, implicit in some cognitive-developmental accounts, mischaracterizes the "reality of pretend play". Instead, we argue that parallels and interdependencies between the development of manual skill and play pave the way for the creation of a more integrated account of children's real and imagined use of objects.

These theoretical considerations, in turn, have implications for several lines of research at the interface of manual skill and play development. First, research is needed to describe the actions that children perform with everyday objects and during bouts of play either alone or with a caregiver. In this connection, motion tracking technology and head-mounted eye-tracking (Smith et al., 2015) can illuminate how children and caregivers plan and regulate the actions that underlie everyday object interactions. Such methods promise to yield new insights into the dynamics of object manipulation and play.

Second, in keeping with the notion of play as practice and practice as play, longitudinal studies in everyday settings are needed to identify reciprocal pathways that underlie the development of manual skill and play. Descriptions of young children's interactions with objects—including how they transition between the real and imagined use of objects from moment to moment and across developmental time—require venturing into the home environment and other everyday contexts to document how and when children engage with the artifacts of their culture and the role of social partners in learning.

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Finally, to the extent that different aspects of manual skill and play share common sources of variance, new strategies for early intervention arise: Play, dosed regularly over extended periods of time, can lead to improvements in manual skill. Simultaneously, practice in applying manual skill can enhance cognitive functioning and bring forth new and more advanced forms of play. Appreciation of the importance of repeated, extensive, and varied practice for the development of manual skill and play (Adolph & Hoch, 2019), has inspired recent efforts to boost object exploration and play in infants from low socio-economic households (Clearfield, 2019) and create wearable devices for at risk pediatric populations to support appropriate movement experience throughout the day (Heathcock & Lockman, 2019; Lobo et al., 2019).

In closing, we began our review by asking how young humans learn to exploit the immense potential afforded by objects that can exist simultaneously in physical and imaginary realms. Integrative theoretical and methodological approaches can address this challenge by recognizing the ways in which the development of manual skill and play are interrelated and co-dependent.

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Fig 1.

During bouts of pretend play, toddlers sequence strings of actions to enact familiar experiences, such as pouring, stirring, pretending to drink, and then eating, behaviors traditionally attributed to their symbolic-representational abilities.

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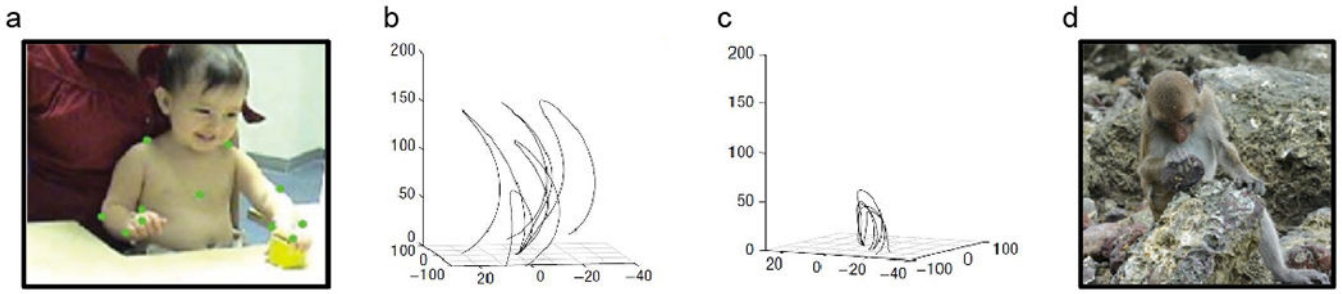

Fig 2.

(a) Infant banging a cube, green dots indicate placement of motion tracking markers. Motion tracking trajectories of five strikes for a (b) 214-day-old infant and a (c) 408-day-year-old infant. Trajectories become straighter and less variable with age. Adapted from Kahrs et al., 2012, Experimental Brain Research. Copyright 2012 by Springer Verlag (d) Long-tailed macaque using a hammerstone as a pounding tool. Photo by A. W. Y. Tan.

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Fig 3.

Cultural artifacts have designed actions that children must learn and implement in the activities of daily living. When toddlers attempt to access treats inside containers by twisting or pulling off lids and unzipping pouches, they show a prolonged developmental progression from exploration, to discovery of the designed action, to successful implementation (Rachwani et al., 2020 a, b).