Exploring the Affordances of Digital Toys for Young Children's Active Play

Yuehao Wang

Design Lab, School of Design, Queensland University of Technology (QUT), yuehao.wang@hdr.qut.edu.au

Nicole E. M. Vickery

Design Lab, School of Design, QUT, n1.mcmahon@qut.edu.au

Dannielle Tarlinton

Design Lab, School of Design, QUT, dannielle.tarlinton@hdr.qut.edu.au

Bernd Ploderer

Faculty of Science and Engineering, QUT, b.ploderer@qut.edu.au

Linda Knight

Early Childhood Education, Digital Media & Creative Practice (Education), RMIT University, linda.knight@rmit.edu.au

Alethea Blackler

Design Lab, School of Design, QUT, a.blackler@qut.edu.au

Peta Wyeth

Faculty of Science and Engineering, QUT, peta.wyeth@qut.edu.au

This paper reviewed 66 commercial digital toys for young children's (3 to 5 years old) active play, aiming to explore their features, affordances, and play activities they facilitate. Results show active play is invited predominantly through physical affordances. Digital features can act as prompts, provide feedback, and engage attention. For HCI researchers this paper contributes insights into gaps and design opportunities: 1) many digital toys target broader age groups, and more work is needed to consider young children's developmental abilities and interests in the design; 2) many digital toys do not elicit direct physical/digital responses from children's physical and embodied inputs; and 3) future research can design play sequences through providing age-appropriate affordances, prompts, and feedback that encourage active play, without restricting children's imagination and free play. The outcomes of this study can inform the design of new digital toys for children's active play, to benefit their motor skills development.

CCS CONCEPTS • Human-centred computing • Human computer interaction (HCI) • Interaction devices

Additional Keywords and Phrases: Active play, Digital toys, Children, Tangible Embedded Embodied Interactions, Motor skills, Interaction design

1 INTRODUCTION

Adequate participation in physical activities is important for pre-schoolers' health and development [14], both physically and cognitively. For pre-schoolers, they should be active for at least three hours each day including one hour of energetic play [18], including running, skipping, and jumping [23] . Play is central to children's development [56], and many activities that children engage in take the form of play [90]. Rather than having a serious or practical purpose, play is when children emerging in an activity that is enjoyable, recreative [84], spontaneous, and intrinsically motivated [86]. Early childhood professionals, researchers, and caregivers argue that play is the mechanism for young children to interact with their surroundings [67]. Young children also engage in physical activities primarily in the form of play, particularly active play [18]. In fact, active play has been promoted as an intervention for children's increasingly sedentary lifestyles [1]. However, studies of children and active play identify a variety of barriers that influence traditional active play, including limited opportunities [12, 41, 49, 76, 80]. The COVID-19 pandemic has also made the situation worse [62]. Restrictions such as lockdowns and social distancing have changed how, when, and where children are active [18].

A noticeable change in children's play during the COVID-19 pandemic is that they have spent less time on outdoor physical activities [42], and time spent on indoor activities such as playing videogames on mobile devices or playing with toys has increased. These types of indoor play activities tend to have an 'object focus' [79], meaning that children gain meaningful play experience through exploration of objects such as manipulation of toys. Toys are broadly defined as any objects that children use in their play [83]. Toys can inspire children to come up with game ideas [64]; toys can maintain children's play by sustaining their engagement; and furthermore, toys can also enrich children's play experience.

Digital toys are changing the landscape of how children play [20]. Digital toys can share the characteristics of traditional toys, relying on tangible manipulation of physical objects [13, 20]. They are also augmented by technology [8], which better attract children's interests by incorporating digital features. Certain digital toys that facilitate tangible and embodied interactions can also encourage young children's active play [87]. This is because such interactions can leverage children's bodily movements to allow them to act upon objects and to move within spaces [3]. Several HCI studies have previously reviewed digital toys in relation to children's physical forms of behaviour. These studies have been targeting different aspects of child development, such as decision making [35], problem solving [75], or physical activity [16].

The study presented in this paper examined the potential of digital toys to facilitate active play, aiming to discover the types of play and motor skills that the toys afford, as well as the applied digital and physical features and their affordances. Affordances provide clues for children to discover the possible ways to interact with a digital toy [31]. Clues can be conveyed through the toy's properties such as materials [61]. For example, when children see a squishy and bouncy ball, they may throw it towards the floor. Clues can also be inserted into designs deliberately [61] and communicated through prompts, which lead children to discover more activities they can engage in with a toy. This study aims to answer the research question of how affordances can enable digital toys to invite young children (3 to 5 years old) to engage in physically active play at moderate to vigorous intensity levels. Moderate to vigorous intensity physical activity is commonly recommended for health benefits. This type of activity usually involves moderate to vigorous bursts of high energy that makes children "huff and puff" [18].

This study forms a part of a larger research project that aims to establish a framework for engaging young children in active play through tangible embedded embodied interactions (TEIs). TEIs are designs that couple physical and embodied interactions with some forms of digital information [36]. We have previously identified that digital toys can be classified as TEIs [87], emphasising the alignment of the toys' digital responses with children's physical movements. These digital toys are digitally enhanced physical objects, where children interact with them through play behaviours such as running, pushing, or riding. Therefore, screen-based physical-digital play technologies such as exergames or bodily-controlled video games are excluded from our study.

We first discuss the relevant literature centred on active play and children's development, digital materiality and how it impacts children's play, and digital toys and their affordances. We then present our study, which analyses 66 digital toys that are currently available to children and families in online stores and local department stores in Australia. We discuss their purposes, the types of interactions they facilitate, digital and physical features and their affordances, and identify key design elements to inform future designs of digital toys for active play.

2 BACKGROUND

2.1 Active play in early childhood development

Preschool children are at an important developmental stage. From ages three to five, children experience remarkable changes in their physical and psychological growth [55]. Sufficient participation in physical activity is critical to shape young children's development [15]. This is because children build key motor skills through movements [78], which lays the foundations for their physical, social, cognitive, and emotional development.

Mastering motor skills during early childhood is critical to children's overall development [52]. This includes two main types [26]: fine motor skills and gross motor skills. Fine motor skills relate to small muscle movements, which involve precise movements of the hands, face, and feet. These skills can be facilitated through actions such as toggling or pressing buttons. Gross motor skills relate to actions of large muscle groups and whole-body movements or movements of large body segments. More specifically, gross motor skills commonly include locomotor skills (e.g., running, jumping, hopping) and object control skills (e.g., catching, kicking, throwing) [85]. In addition, gross motor skills can also be developed in body management activities [78] such as balancing, landing, and stretching. A child's ability to perform fine and gross motor skills during early childhood correlates with later participation in physical activity and helps to maintain an active lifestyle [52, 70, 89]. Additionally, acquiring a range of motor skills is also essential for school readiness. If a child does not develop these motor skills, they will struggle to engage in activities required during formal education, impacting their abilities to achieve academically, socialise with peers, and experience school life [78]. Therefore, children's motor skills should be developed through prioritising physical activity by scheduling opportunities for them to play [71].

Active play is considered as the "child version" of physical activity during early childhood [63]. Active play makes unique contributions in increasing young children's physical activity levels [12], unlike other structured forms of physical activity such as exercise-based activities [11]. Active play draws from the characteristics of play and physical activity, which involves activities that are unstructured, freely chosen, fun, and intrinsically motivating [12, 63, 84]. Children's cognitive abilities can also be developed through active play [78], where they develop their problem-solving abilities by learning about objects, ideas, and concepts [37]. Furthermore, participating in active play activities can trigger the emergence of symbolic thought, which allows children to use one thing to stand for another (e.g., in pretend play). This enables children to construct more complex ways of thinking.

Children's active play behaviours progress as they grow up [37], because children at different ages have vastly different physical and cognitive abilities. For example, infants engage in active play primarily through exploration of the body, such as touching and manipulating their fingers and feet. While for 3-5-year-olds, their active play shifts from body-focus to object-focus, as they have improved fine and gross motor skills and cognitive abilities. This means that ‘objects’ play a more important role in 3-5-year-olds’ active play. They can use objects to engage in object-control activities (e.g., kicking a ball) [78], locomotor activities (e.g., skipping a rope), and body management activities (e.g., climbing on a climbing frame).

2.2 The role of materiality in young children’s active play

Materiality has substantial impacts on children’s actions and understanding [74]. Through direct manipulation of physical objects, the materials of an object can support children’s imagination and play by providing sensory-rich experiences [60, 65], and aid children’s physical and cognitive development [66]. For example, children play with wooden blocks by stacking and constructing. These types of manipulations may support children’s learning around arrangement and balance. Therefore, diverse and sensory-rich materials are crucial to better support children’s active play.

The increased use of technologies enables young children’s play to be complex [57]. The complexity is reflected in the increasingly blurred boundaries of physical and digital play. Young children’s active play experience has also changed with interactive digital technologies being incorporated. For instance, Pokémon Go is a popular augmented reality mobile game that embeds game play in the physical world [2]. Pokémon Go transforms traditional locomotor movements (e.g., running, walking, marching) into a digital context (the game world), encouraging children to move in the physical world to find new Pokémon, and collect steps to hatch eggs. Using digital rewards for physical activity better attracts children’s interests by adding a playful dimension.

The development of interactive technologies has prompted the terminology of “digital materiality” [4, 54], which attempts to understand digital content and technologies in relation to materiality. Digital materiality refers to the properties of technologies that are intangible (e.g., audio, songs, media characters) [50], emphasising the properties’ performativity: the capability that a certain property provides with people to perform some actions. Digital and physical materiality in children’s play should not be considered as two separate things [4]. Previous studies have attempted to describe the relationship between the material and digital. For example, Marsh utilised the notion of “connected play” to describe how the Internet of Toys transformed across the physical/virtual continuum [57]. Therefore, it is important to recognise that digital materiality has been embedded in the practice of technology design.

Digital and physical materiality are entangled [4], and tangible embedded embodied interactions (TEIs) reflect the entanglement in a large extent. TEIs couple physical objects with digital information [36], allowing people to physically manipulate the objects through bodily interactions. Through physical manipulations, the associated digital responses are triggered, which in turn inform how the physical objects should be further manipulated. TEIs emphasise tangibility and embodiment [29], which support users to interact with technologies intuitively by allowing users’ digital actions to be comparable to similar actions in the real world.

2.3 Affordances of digital toys

Physical objects play an important role in TEIs [36], as they serve both as the representation and manipulation of digital data. With physical objects, people explore the possible actions to perform with these objects based on their affordances [31]. Affordances are associated with clues, and through interpretation of clues, people can discover possible actions. Clues can be natural clues and deliberate clues [61]. Natural clues refer to inherent properties of objects, such as size, shape, or material. For instance, if we see a knife with a sharp dihedral angle and an edge, we know it can afford cutting or scraping. Affordances associated with natural clues are referred to as physical affordances [21]. On the other hand, deliberate clues are information that is incorporated into designs to direct people to discover the possible actions [61]. If we see a scroll bar in a webpage, we know that is scrollable and we can navigate up and down through scrolling. The scroll bar is symbolic [30], and is an example of deliberate clues. People discover deliberate clues based on their previous experience with similar things [10]. Affordances relating to deliberate clues are described as perceived affordances [10, 40].

It is not unusual for a complex action to comprise a series of affordances [30]. Commonly, a complex action consists of several sub-actions. One sub-action can act as the context for another action, where affordances can be nested within one another [30, 88]. For instance, a light switch affords being toggled, and this affordance can be nested within the switch's ability to turn on the lights. Moreover, one sub-action can also provide indications to lead to another action, where their affordances are sequential [30]. With a light switch, it's shape (natural clue) may reveal that it is also togglable.

Digital play has become a common type of play [58], and the resources available for children to play with have changed. The increasing popularity of digital toys among children is one of the noticeable changes [13]. Digital toys are incorporated with both physical and digital components, sharing the characteristics of both traditional toys (e.g., dress up toys, construction toys) and computing devices (e.g., game consoles, tablets, mobile phones) [8]. Affordances are worth exploration when designing digital toys for active play. This is because various current designs may not be properly engaged with by children [87], compared to their initial design intentions. In relation to affordances, improperly engagement with digital toys is associated with hidden or false affordances: children may be unable to perform certain behaviours in line with designers' intentions due to mis-constructed or absence of affordances.

3 METHOD

The purpose of this study is to explore commercial digital toys for young children and families within Australia, aiming to discover their physical and digital features, and the types of play and motor skills they afford. Focus is placed on the relationship between the applied features and their affordances.

3.1 Selection of toys

A series of criteria was developed to guide the exploration of commercial digital toys:

- The toy is augmented by technology and can potentially encourage bodily interactions.
- It is inclusive to young children (3 to 5 years old) to play with and is currently available for purchase within Australia.
- It is intentionally or implicitly designed for increasing physical activity or facilitating active play.

The study began by examining online catalogues, toy stores and department stores (e.g., Target, Toyworld) for toys that would adhere to the criteria outlined above. From there, we expanded our searches by also exploring typical makers of children's toys such as LeapFrog and Vtech Electronics. As each eligible digital toy was identified, it was logged into a spreadsheet with information about the toy's target age group, purpose, digital and physical components, and a description of how the toy is used or interacted with. We also acquired some of the eligible toys for closer observation and to comprehend the information logged into the spreadsheet.

3.2 Coding scheme

Both deductive and inductive thematic analysis were conducted on the information captured in the spreadsheet. Inductive thematic analysis was conducted to investigate the digital and physical features of digital toys; while deductive thematic analysis was to analyse the toys' affordances and the types of play and motor skills they afford. Tables 1 to 4 detail the coding scheme that was developed for the thematic analysis. The coding was led by the first author, who is an HCI researcher working with young children. All toys were analysed by applying the coding scheme to the spreadsheet which captured information about each toy. The analysis was conducted using ATLAS.ti web tool [32]. All codes and their application were discussed and refined through regular meetings with all other authors.

Three codes were developed for the types of play activities that could be facilitated by digital toys (Table 1). Pretend play is considered as a stand-alone category because such activities could incorporate a combination of fine and gross motor skills.

Table 1: The codes developed for the types of play activities facilitated by the digital toys

Code	Description	Example
Gross Motor Activity	Gross motor activities involve actions of large muscle groups that involve movements of whole body or large body segments [26].	Tuff Tools L&S Power Mower [7]. A toy that looks like a realistic lawn mower. When children push the mower, they can perform gross motor activities (e.g., pushing and walking).
Fine Motor Activity	Fine motor activities are actions of small muscle groups that enable precise movements of the hands, face, and feet [26].	Lettersaurus [46]. An alphabet dinosaur toy that allowed children to explore letter names and sounds by pressing on different buttons.
Pretend Play	Pretend play is a form of play where children take on roles to assign action to symbolic objects [33].	Scoop & Learn Ice Cream Cart [48] (Figure 1). A pretend play set where children can pretend to order and make ice creams in a variety of imaginative combinations.

Figure 1: The LeapFrog Scoop & Learn Ice Cream Cart, (1) pushing handle, (2) toy set-up, (3) 'ice cream ingredients' that can be interacted with through fine motor interactions.

Physical components (Table 2) and digital features (Table 3) codes were captured from each product's description, image, and the listed components. Each toy was only coded in one category of physical components based on the primary interaction it may facilitate. The primary interaction is indicated by the metaphor that the toy utilised. Metaphors can invoke metaphorical links [29], which enable children's interactions with the toy to be comparable to similar actions in the real world. For instance, the LeapFrog Pick Up & Vacuum [47] was coded as a push along toy, because pushing and pulling are the primary actions to use a real vacuum cleaner. The Scoop & Learn Ice Cream Cart [48] (Figure 1) as another example, it also has a handle that children can use to push or pull it along. Yet, because it mimics real-world ice cream carts by including varieties of components such as ‘order cards’ or ‘ice cream toppings’, children are most likely to engage in pretend play. Therefore, the ice cream cart was coded as pretend play set instead of push-along toy. As for digital features, each toy can be coded in more than categories because it was common for the toys to provide multiple forms of digital responses.

Table 2: The codes developed for physical components of the physical toys

Code	Description	Example
Ball	General ball toys or sports-related balls such as soccer, basketball, or bowling ball.	VTech Bright Lights Soccer Ball [25]. An educational ball toy that supports learning around colours, phrases, and sportsmanship.
Mat	Floor mats, including dance mats, music mats, or other types of play mats.	LeapFrog Learn and Groove Mat [45] (Figure 2). An educational musical mat that encourages children’s movements.
Small Toy/Prop	Toys or props that are portable and in smaller sizes.	Educational Insights Magic Moves Electronic Wand [38]. A talking toy wand that gives directions to children.
Pretend Play Set	Toys used for role play including household tools, and pets/animals.	Scoop & Learn Ice Cream Cart [48] (Figure 1).
Push-along Toy	Toys with handles or leashes that children can push or pull them around.	LeapFrog Pick Up & Count Vacuum [47]. A toy vacuum that can pretend real-life vacuum cleaners.
Ride-on Toy	Toys that children can ride on, including bikes and scooters, toy vehicles, or metaphorical animals such as horses.	Fisher-Price Music Parade Ride On [5]. A ride-on toy that has marching tunes and reviving sounds.
Sports Toy	Traditional sports-related toys and sports equipment.	VTech 3-in-1 Sports Centre [24] (Figure 3). A smart sports centre that responds to children scoring baskets or making goals with cheerful sounds and phrases.
Wearable	‘Kid friendly’ smart watches, fitness trackers, and augmented clothing that children can wear.	LeapFrog LeapBand [44]. A wearable activity tracker that encourages active play and healthy habits with challenges.

Table 3: The codes developed for digital features of the digital toys

Code	Description
Audio	
Music/Songs	Music or songs.
Voice Clips/Instructions	Instructional or pretend play voice clips.
Pretend Play Sound	Sounds that reinforce pretend play such as engine revving or ‘clip clop’ sounds.
Visual	
Flashing Lights	Where lights were flashing, pulsing, and alternating between colours.
Light-up Buttons	Buttons that light up.
Light-up Interfaces	Such as the LED interfaces on smart watches, or the score boards on sports technology.
Movement	
Spinning/Vibrating/Oscillating	Components of the toy that can spin or rotate; or vibrate or move up and down.
Real-life Movements	Movements that mimic the ‘real world’ object.

Figure 2: The LeapFrog Learn & Groove Musical Mat

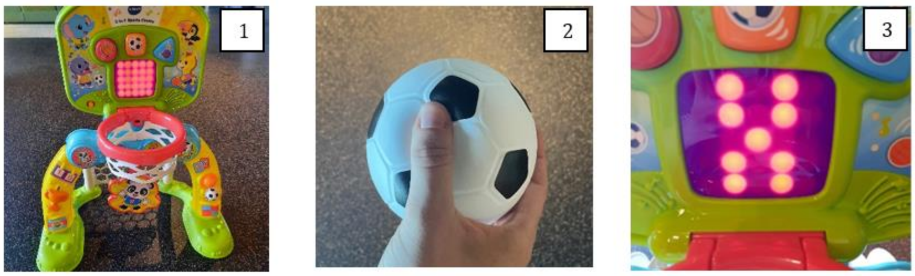


Figure 3: The VTech 3-in-1 Sports Centre, (1) toy set-up, (2) soccer ball, (3) light-up LED screen that can display scores in response to children kicking goals.

Coding heuristics for affordances were developed based on a review of relevant literature. Six types of affordances were recognised and were used to deductively code and analyse the digital toys (Table 4).

Table 4: The codes developed for affordances

Type of Affordance	**Description**	**Example**
Physical Affordances	Actions determined by physical and material properties [31]. Indicated by natural clues [21].	Giddy-Up and Play Activity Toy [22]. A soft hobby horse that invites children to pat, pull, and climb on. Its soft and squishy material affords children to squeeze and cuddle.
Perceived Affordances	Actions determined by prior experience with similar things [10]. Learned conventions [61]. Indicated by deliberate clues [21].	LeapFrog Learn and Groove Mat [45]. It provides voice instructions to direct children's movements. Voice instructions act as deliberate clues.
Nested Affordances	One affordance serves as context for another one [88].	Toysmith Flashing Skip Ball [82]. Children put one foot through its hoop, which provides context for them to perform skipping.
Sequential Affordances	"Acting on a perceptible affordance leads to information indicating new affordance" [30].	No toys were identified in this study that presented sequential affordances.
Hidden Affordances	Affordances that do not convey its existence through perception [30].	Sunlin Dance Mat [77]. The mat is advertised to encourage collaboration. However, it is not conveyed through its design.

Type of Affordance	Description	Example
False Affordances	Mis-constructed affordances that convey inappropriate actions [30].	LeapFrog Learn and Groove Mat [45]. There are four round components on the control panel. Three are mode indicators and the other one is a pressable button to change modes. Children may get confused of their functions because their designs are not distinguishable.
	Actions performed differently from designers' intentions or no actions at all [17].	

4 RESULTS

Sixty-six digital toys were identified as having the potential to facilitate active play for 3–5-year-olds. In this section, we outline the results of our thematic analysis centred on identifying the digital and physical features and their affordances, and the types of active play activities that each digital toy affords.

Each toy was firstly categorised based on its primary physical components, as described in Table 2. Table 5 shows the frequency of each type of the digital toys. Based on the results, sports toy, push-along toy, and small toy/prop are three of the most common toy types. Then we captured the co-occurrences of each type of digital toys with each type of play activity, including fine motor activity (FMA), gross motor activity (GMA), and pretend play (PP). Co-occurrences were also captured of each type of digital toys with each type of affordances, including physical affordances (PHA) and perceived affordances (PEA). Results of the co-occurrences are presented in Table 5. Hidden (4/66, 6%), false (3/66, 4%), nested (2/66, 3%), and sequential (0/66, 0%) affordances were disregarded from this co-occurrence analysis because they had very small sample sizes, which were not representative.

Table 5: Types of physical components and their frequencies; and their co-occurrences with different types of activities and affordances.

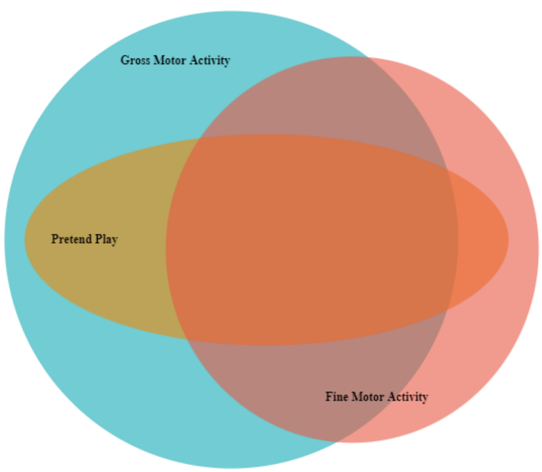
Toy Types	Co-occurrences								
	Play Activities			***Affordances***					
				PHA				PEA	
	FMA	*GMA*	*PP*	*Material*	*Size*	*Shape*	*Layout*	*Visual*	*Verbal*
Ball (5)	1	5	1	4	4	4	0	0	0
Mat (8)	4	7	3	0	8	0	8	3	8
Sports Toy (11)	2	10	0	1	4	9	0	2	2
Push-along Toy (11)	5	11	10	1	0	11	0	4	2
Ride-on Toy (7)	3	7	6	1	7	7	0	3	0
Small Toy/Prop (11)	11	6	2	1	8	7	0	4	2
Pretend Play Set (6)	5	4	6	0	0	6	0	4	3
Wearable (7)	6	7	1	0	0	7	1	7	1
Total	**37**	**57**	**28**	**8**	**31**	**51**	**9**	**27**	**18**

Section 4.1 to Section 4.3 present detailed results that elaborate on the co-occurrences listed in Table 5, in the aspects of types of play and motor skills, physical components in relation to physical affordances, as well as digital features and perceived affordances.

4.1 Types of Play activities

From Table 5, thirty-seven digital toys were identified to have the potential to facilitate fine motor activities, where small toys/props were the most common type to facilitate such activities. For example, Lettersaurus [46] is an educational toy that teaches children about alphabets. Children can engage in fine motor activities by pressing on different buttons to explore letter names and sounds. Second, fifty-seven digital toys can invite gross motor activities, which were most commonly invited by push-along toys and sports toys. For example, the VTech 3-in-1 Sports Centre [24] (Figure 3) can engage children's gross motor skills by prompting them to score baskets or kick goals. Lastly, twenty-eight digital toys can encourage pretend play, and push-along toys, ride-on toys, and pretend play sets can commonly invite such play. The LeapFrog Pick Up & Count Vacuum [47] is an example.

The majority of digital toys (63/66, 95%) can be used for different types of activities and play, as indicated by the overlaps in Figure 4. For example, AlphaPup [43] is a toy dog with letter buttons that is designed to teach children letters. Children may press the buttons (fine motor movements) to learn alphabets. It also has a leash attached, which allows children to pull the toy around (gross motor movements). AlphaPup was coded for both fine motor activity and gross motor activity. Furthermore, it is worth noting that no digital toys were identified to only facilitate pretend play. Toys that relate to pretend play also invite fine motor activities (19/66, 29%), gross motor activities (25/66, 38%), or both fine and gross motor activities (16/66, 24%).



Description	Frequency
Facilitating both pretend play and fine motor activities	19
Facilitating both pretend play and gross motor activities	25
Facilitating both fine and gross motor activities	31
Facilitating fine and gross motor activities and pretend play	16
Facilitating only fine motor activities	37
Facilitating only gross motor activities	57
Facilitating only pretend play	28

Figure 4: Types of play activities and frequencies. The overlaps between gross motor activity, fine motor activity, and pretend play show that most digital toys can be used for multiple play activities.

4.2 Physical properties and physical affordances

Physical affordances were provided by physical properties of the toy, which convey information about how children can interact with it. Physical affordances identified in this study are relating to the toy's material, size, shape, and layout/presentation, as described in Table 6. Based on the results presented in Table 5, size and shape were two of the most frequently captured physical properties. Size plays an important role in communicating physical affordances, especially in mat-based toys, ride-on toys, and small toys/props. However, push-along toys, pretend play sets, and wearables did not rely on size to afford the play activities that they may invite.

The impact of shape was not observed from mat-based toys in this study. While on the other hand, shape was a common determinant of other types of digital toys to engage children in play activities, which was captured from push-along toys the most frequently. Moreover, layout/presentation and material showed predominance power in certain types of digital toys. More specifically, mat-based toys rely on layout/presentation to invite children in play activities. The LeapFrog Learn and Groove Mat [45] (Figure 2) is an example, as described in Table 6. Additionally, in terms of material, ball toys are typically made of squishy and bouncy materials, which may engage children in various activities such as throwing the ball towards the floor and catching it when bounced up.

Table 6: Types and frequencies of physical properties that inform physical affordances

Type	Description
Material (8)	Soft, squishy, or bouncy materials that are commonly seen in toy pets and bouncy balls.
Size (31)	Where the size of a digital toy is a determinant of possible actions to perform, including playmats that are usually in lager size so that children can stand and play on top; and small and portable toys that children can hold in their hands and form their own types of play.
Shape (51)	The shape of some components of a digital toy informs possible actions to perform, such as push and pull toys that are usually incorporated with handles; ride-on toys that have seat pads; small toys such as balls that are in round shapes so that children can hold in hands; and skipping ropes that children can skip over.
Layout/Presentation (9)	The graphical design of a digital toy is an indicator of potential actions. For example, the LeapFrog Learn and Groove Mat [45] (Figure 2) is designed with ten coloured circles, which can inform children to stomp/step on different circles to hear different sounds.

4.3 Digital Features and Perceived Affordances

Digital features of digital toys were analysed to identify their roles in children's interactions with the toys. Digital features can act as prompts to direct children to engage in activities; they can provide feedback in response to children's interactions; and/or engage children's attention. Table 7 shows the frequencies of each type of digital features as described in Table 3, and also details the frequencies of each type of digital features acting as prompts, providing feedback, and engaging attention.

Thirty-eight digital features were identified to provide prompts to direct children's interactions, which include visual and verbal prompts. Prompts convey information of a digital toy's perceived affordances. Visual prompts were frequently captured from toys with light-up interfaces, which can be communicated through animations, graphics, and texts. In this study, these prompts were commonly observed from wearables. For example, the LeapFrog LeapBand [44] allows children to keep virtual pets, and the more active they are, the more their pets can grow. Virtual pets are presented to children in the form of animations, and different animations can provide prompts for children to unlock more features about raising their pets. On the other hand, verbal prompts were frequently captured from mat-based toys, which were commonly conveyed through music/songs, and voice clips/instructions.

Fifty-seven digital features can provide feedback to children's interactions, which were commonly presented through light-up interfaces and flashing lights, as well as pretend play sound. For example, the light up rain boots

[51] can respond to children's walking/running/jumping/stomping with flashing lights. Flashing lights act as feedback in this example. Lastly, seventy-eight digital features were observed to engage children's attention. Such digital features were commonly in the forms of flashing lights and pretend play sound.

Table 7: Types of Digital Features and frequencies. Digital features can act as prompts, provide feedback, and engage children's attention.

Digital Feature	**Frequency**			**Overlap**
	Prompts	***Feedback***	***Attention***	
		Visual		
Light-up Buttons (8)	1	1	6	No overlaps captured.
Light-up Interfaces (12)	11	12	0	All light-up interfaces can convey feedback; 11 of them can also act as prompts.
Flashing Lights (24)	8	12	24	All flashing lights can engage children's attention; 8 of them act as prompts; 12 provide feedback; 6 of them can act as prompts and provide feedback.
		Audio		
Music/Songs (28)	9	6	13	No overlaps captured.
Voice Clips/Instructions (15)	9	6	0	No overlaps captured.
Pretend Play Sound (20)	0	11	20	All pretend play sounds can engage children's attention; 11 of them can also provide feedback.
		Movement		
Spinning/Vibrating/ Oscillating (10)	0	2	8	No overlaps captured.
Real-life Movements (8)	0	7	8	All real-life movements can engage children's attention, 7 of them can also provide feedback.
Total	**38**	**57**	**78**	

5 DISCUSSION

This study examined sixty-six commercial digital toys that can encourage young children's physically active play, either as an intentional design choice, or as a more implicit aspect. The purpose of this study is to explore the associations between the affordances of the digital toys' physical and digital features, and the types of play activities they afford.

The digital toys examined in this study tend to target much broader user age groups, where many toys are also inclusive to children younger than 3 years or older than 5 years. Targeting broader age groups may lead to the digital toys facilitating limited types of play activities. This is because children experience dramatic development changes both physically and cognitively since infancy [37], meaning they have vastly different abilities even with one year age difference. Limitations also apply when considering the physical features of a toy, because toys for children of one age may have some features not suitable for another. For instance, a common reason that excludes children at certain ages to play with certain toys is when the toys have small components and there is a chance that younger children may swallow them. The results highlight an opportunity to design digital toys specifically for 3- to 5-year-olds' physically active play, that meet their developmental abilities and interests.

5.1 Design opportunities for enhancing active play activities

Fifty-seven digital toys were identified in this study to have the potential to encourage active play by inviting gross motor activities. However, we argue that there is still a lack of design of such digital toys. First, even though many digital toys have the potential to engage children in gross motor activities, it is not their primary focus. For example, the Scoop & Learn Ice Cream Cart (S&L ICC) (Figure 1) may have the potential to create vigorous active play because it has a pushing handle that allows for gross motor movements such as pushing and walking/running. However, since the primary focuses of the S&L ICC are about pretend play and education about colours and numbers [48], children may neglect the pushing handle of the ice cream cart. Instead, they may engage in pretend play by scooping 'ice cream' and inputting 'order cards', which are mostly fine motor inputs. Hence, we highlight designing for active play by inviting gross motor activities as an opportunity for future HCI research. In particular, children could benefit from toys that invite gross motor play activities through clues and feedback such as lights and sounds triggered by quick sprints, jumping, or other intense bursts of active play.

Second, children may not perform the gross motor activities as prompted by the digital toys when there is no direct digital feedback. For example, the Educational Insights Magic Moves Electronic Wand [38] requires children to switch it on, and then it gives children directions to engage in a range of different gross motor movements. However, it continues to give new instructions whether children perform the previously instructed activities or not; and it does not respond with any feedback when children perform the correct movements. We see two opportunities for HCI researchers here. On the one hand, there is an opportunity to enhance the understanding of the analysis presented in this paper through observational research on how children use and appropriate digital toys in unintended ways. On the other hand, there is an opportunity to work out and design play sequences through cycles of affordances and feedback that encourage active play, without restricting the imagination and free play of children through overly didactic instructions and feedback.

5.2 Considering physical affordances for designing digital toys

HCI researchers are interested in designing digital toys that can exploit the physical and material properties [31] to encourage active play. Results presented in Table 6 indicate that size and shape are two dominant properties that relate to physical affordances of a digital toy, which convey information about the types of play activities that children can engage in with the toy.

Size is an important property that impacts a toy's physical affordance and its ability to facilitate gross motor activities. When a toy is in a size that can afford a child's whole-body movements or movements of large-body segments, it can facilitate gross motor activities by inviting the child to stand, climb, sit, or ride. It is evident that when digital toys are in smaller sizes that cannot physically afford bodily movements, they need to rely on other physical or digital properties to invite gross motor activities. For example, the LeapFrog Learn and Groove Mat [45] (Figure 2) is a playmat that encourages children's movements by prompting them to step on different circles on the mat. The mat provides a wide surface so that children can perform various gross motor movements on it, such as stomping, jumping, and crawling. Yet, the Educational Insights Magic Moves Electronic Wand (the wand) [38] can be handheld (smaller in size). The wand itself cannot physically afford children's gross motor movements, however, it provides voice instructions to direct children to perform specific movements. In this example, the wand relies on digital outputs to encourage vigorous movements. In comparison, fine motor movements are usually performed in limited spaces because they typically only involve finger or hand movements. Physical components related to such movements identified in this study are varieties of buttons, portable toys such as toy dogs, and components of playsets that facilitate pretend play.

The shape of a toy is also an important physical property to engage children in gross motor activities such as throwing and catching, pushing and pulling, or kicking. For example, ride-on toys are usually in the shape of vehicles (e.g., cars, trains, bikes), or they can be in the form of some real-life animals (e.g., horses). These specific shapes not only physically afford children's bodily movements, but also allow for mimicry and pretend play, which further contribute to children's intuitive use of toys [19]. This is because when the shapes are familiar to children, they may subconsciously apply their experiential knowledge based on past experience in 'real life' [9]. A push-along toy is another example, which is typically incorporated with a handle or a leash. The shapes of handles and leashes can afford gross motor movements including pushing, pulling, and walking. Therefore, to engage children in gross motor activities, a digital toy should either be in a shape that can physically afford bodily movements (e.g., riding on), or it is incorporated with some physical components (e.g., leashes and handles) that can afford gross motor movements (e.g., pushing and pulling).

5.3 Harnessing digital features and perceived affordances

5.3.1Digital outputs as feedback

The results presented in Table 7 show that the examined digital toys typically incorporated digital features in the form of audio (e.g., music, voice instruction), light (e.g., blinking LED light), and movement (e.g., vibration, spinning). These digital features can provide feedback to children's inputs, which can be an important tool for communication between children and the toys. It is common for a toy to provide more than one form of digital feedback. For example, the VTech 3-in-1 Sports Centre [24](Figure 3) responds to children scoring baskets or kicking goals with both cheerful sounds (in the form of audio) and LED scores (in the form of visual), which can engage children's attention and can be more persuasive [53].

For HCI researchers it is important to remember that digital feedback needs to be appropriate to the child's age. The feedback identified in this study relied largely on the child's senses (i.e., touch, sight, and hearing), rather than on written or visual instructions. This is because 3 to 5 years old children have minimal or developing literacy skills [78]. Feedback was commonly presented through the forms of audio and visual. Audio-based feedback included music and songs, pretend play sounds, and voice clips. Music and songs may engage children in active play as they experiment with how to move their bodies with the rhythm of the music [78]. The Musical Hop Skipper is an example; when it is switched on, music plays, and the arms of the toy begin to spin. Children can then jump over the spinning arms in time with the music, therefore getting active. On the other hand, visual-based feedback was commonly communicated through light-up interfaces. Light-up interfaces include graphical user interfaces and simple LED boards, and children need to use their literacy skills to make sense of such feedback. Digital toys designed with light-up interfaces are usually more complex in terms of functionality. Such toys usually incorporate games, challenges, or have different levels of difficulties, and most of them are wearables such as 'kid-friendly' smart watches.

There are several gaps and opportunities identified in terms of providing digital feedback to encourage children's active play. First, digital toys examined do not elicit a digital response directly from children's physical and embodied inputs. This means they do not reinforce children's development of physical activity competencies (gross motor skills, and to a lesser degree fine motor skills). This is further supported by the fact that movement-based feedback (e.g., spinning, vibration) appears to be used to reinforce the pretend play qualities of toys, as opposed to encouraging embodied interaction. For example, the inner housing of the LeapFrog Pick Up & Count Vacuum [47] spins around to emulate the inner workings of a vacuum cleaner (Figure 5), making the child believe they are vacuuming. Hence, more work is needed to design digital toys that map physical inputs and digital information [27], and that provide appropriate feedback to children to communicate this information.

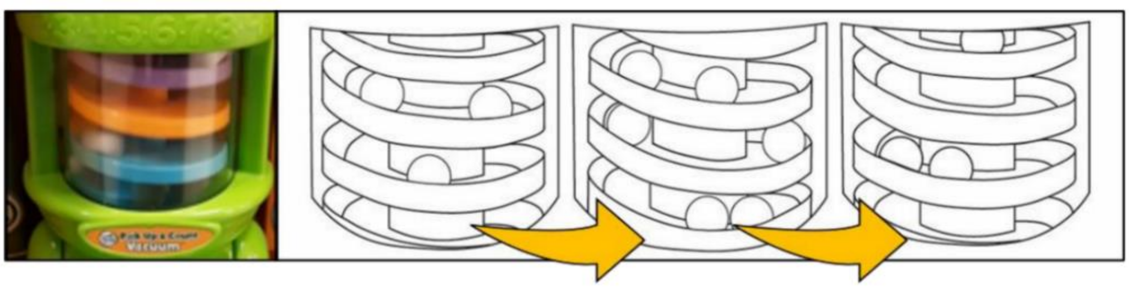


Figure 5: The LeapFrog Pick Up & Count Vacuum's inner housing rotates in order to emulate a real vacuum cleaner

Second, visual-based feedback such as light and visual stimuli can attract children's attention [53, 69], however, the misuse of lights can be problematic. For example, flashing lights are commonly captured in this study. Flashing lights of between 1 and 65 Hz (particularly red lights) can be an issue for children who are photosensitive, potential causing seizures [28, 68]. An example of this is the Hello Sunshine Light Up Sensory Ball [6] (Figure 6), which has rapid flashing red and blue lights inside of it. Based on the literature around photosensitivity [28, 68], HCI researchers need to be careful in using high frequency flashing lights in their design and perhaps avoid them altogether.

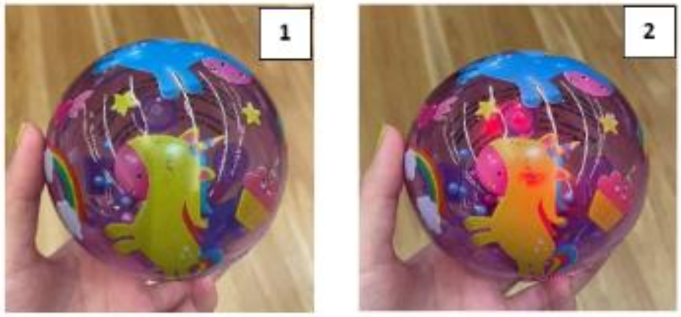


Figure 6: The Hello Sunshine Light Up Sensory Ball, (1) with lights turned off, (2) with flashing light.

5.3.2Digital outputs as prompts to explore possible interactions and pretend play

HCI researchers interested in designing more complex digital toys, which creates digital outputs that prompt children to discover and explore possible interactions. Our study showed that many of the more complex toys relied on perceived affordances, which provide deliberate clues [21] or prompts to encourage possible interactions. A prompt is a deliberate message to encourage someone to perform certain behaviours in a particular situation [34, 72]. HCI researchers have studied prompts in wide range of contexts, e.g., to support people with dementia [59], to help students' knowledge acquisition and learning [81], or in the context of persuasive computing to support people in changing their behaviours [39].

Thirty-six digital toys were identified to have perceived affordances through visual and verbal prompts. Visual prompts are presented in the forms of texts, graphics, animations, and lights; while verbal prompts identified in this study are through music and songs, pretend play sounds, and voice instructions or voice clips. Visual and verbal prompts are commonly presented together, which can be more persuasive [53]. An example is the FAO Schwarz – Toy Dance Mixer Rhythm Step Playmat [73] (the playmat), which can facilitate a beat rhythm game. The playmat has an instruction panel (Figure 7), and children need to step on the correct circle on the playmat as the buttons light up. In this example, children perceive the meaning of the light-up buttons (visual prompt) and know which circle to step on to keep the beat (verbal prompt).

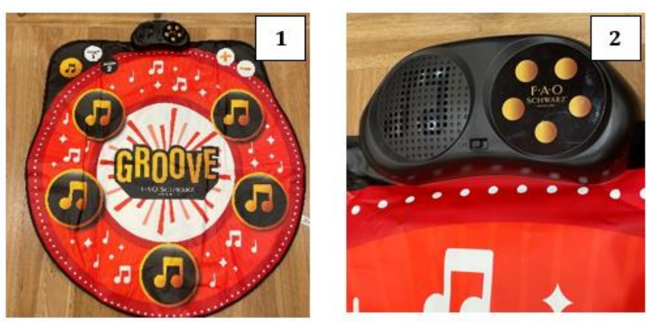


Figure 7: The FAO Schwarz – Toy Dance Mixer Rhythm Step Playmat, (1) the toy set-up, (2) the instruction panel.

Digital prompts also provide opportunities to invite pretend play, e.g., through sounds related to the child's prior experience with similar scenarios in their real life. Pretend play sounds are sounds that reinforce pretend play such as engine revving or 'clip clop' sounds. These sounds usually do not provide strong prompting power compared to voice instructions that directly tell children what to do. Instead, these sounds may trigger children's memory of similar situations in their real life, therefore guiding children's actions. For example, with the Scoop and Learn Ice Cream Cart [48] (Figure 1), children who have purchased ice cream in 'real life' may find it easier to play with this playset. Furthermore, such sounds can also provide feedback to reinforce desirable actions (e.g., cheerful sounds, bingo sounds). Given the importance of pretend play for children in this age group, harnessing sounds for pretend play constitutes an interesting area for further investigation.

5.4 Limitation

A limitation of this study is that we focused primarily on digital toys that are commercially available in Australia. Our intention was that children and families can easily access these toys from online or in-store purchase, meaning that these toys were more likely to be widely used. This limitation also provides opportunities for future reviews of digital toys from international stores such as Amazon, which has been experiencing increased popularity in Australia.

6 CONCLUSION

The study explored sixty-six commercial digital toys for young children's (3 to 5 years old) active play. The aim of this study was to uncover the relationships between the toys' physical and perceived affordances, and the types of play activities and motor skills they invite. Results indicate that majority of the digital toys rely on physical affordances to engage children in active play, particularly the physical affordances relating to size and shape. Some digital toys also presented perceived affordances through visual and verbal prompts to direct children to discover more activities to engage in with the toys.

We identify gaps and highlight the design opportunities for future research to design new and innovative digital toys for young children's active play. First, more work is needed to design digital toys that target young children's developmental capabilities and interests, by applying age-appropriate digital and physical features. Second, even though many digital toys in this study can potentially invite active play, it was not reinforced through their physical and perceived affordances, which relate to their physical and digital features. In terms of physical affordances, future designs should regard size and shape as two important physical considerations. In terms of perceived properties, future designs should provide visual and/or verbal prompts to direct children's engagement with the toys without restricting their imagination and free play; and provide direct feedback in response to children's physical and embodied interactions.

ACKNOWLEDGMENTS

This research was funded by the Australian Research Council (grant DP200100723). The authors would also like to acknowledge and thank Professor Stewart Trost for his support in this project.

REFERENCES

[1] Stephanie A. Alexander, Katherine L. Frohlich and Caroline； Fusco. 2014. Active Play May Be Lots of Fun, but It's Certainly Not Frivolous': The Emergence of Active Play as a Health Practice in Canadian Public Health. *Sociol Health Illn* 36, 8, Sociology of Health & Illness. http://dx.doi.org/10.1111/1467-9566.12158

[2] Tim Althoff, Ryen W White and Eric Horvitz. 2016. Influence of Pokémon Go on Physical Activity: Study and Implications. *Journal of Medical Internet Research* 18, 12, e315. http://dx.doi.org/10.2196/jmir.6759

[3] Alissa N. Antle, Greg Corness and Milena Droumeva. 2009. Human-Computer-Intuition? Exploring the Cognitive Basis for Intuition in Embodied Interaction. *International Journal of Arts and Technology* 2, 3, 235. http://dx.doi.org/10.1504/IJART.2009.028927
[4] Elisenda Ardevol, Debora Lanzeni and Sarah Pink. 2016. *Digital Materialities; Design and Anthropology*.
[5] Toyworld Bendigo. 2022. Fisher-Price Music Parade Ride On Retrieved from https://www.toyworld.com.au/products/fisher-price-little-people-music-parade-ride-on.
[6] Toyworld Bendigo. 2022. Hello Sunshine Sensory Light up Balls. Retrieved from https://toyworldbendigo.com.au/collections/preschool/products/hello-sunshine-sensory-light-up-balls.
[7] Toyworld Bendigo. 2022. Tuff Tools L&S Power Mower. Retrieved from https://www.toyworld.com.au/products/tuff-tools-light-and-sound-power-mower.
[8] Liam; Mascheroni Berriman, Giovanna. 2019. Exploring the Affordances of Smart Toys and Connected Play in Practice. *New Media & Society* 21, 4, 797-814. http://dx.doi.org/10.1177/1461444818807119
[9] Alethea Blackler. 2006. Intuitive Interaction with Complex Artefacts. thesis. Queensland University of Technology,
[10] Alethea Blackler, Vesna Popovic and Doug Mahar. 2010. Investigating Users' Intuitive Interaction with Complex Artefacts. *Applied Ergonomics* 41, 1, 72-92. http://dx.doi.org/10.1016/j.apergo.2009.04.010
[11] Boudewijn Boon, Marco Rozendaal, Marry Heuvel-Eibrink and J. Net. 2016. Playscapes: A Design Perspective on Young Children's Physical Play. In *Proceedings of* 181-189. http://dx.doi.org/10.1145/2930674.2930713
[12] Rowan Brockman, Russell Jago and Kenneth R Fox. 2011. Children's Active Play: Self-Reported Motivators, Barriers and Facilitators. *BMC Public Health* 11, 1, 461. http://dx.doi.org/10.1186/1471-2458-11-461
[13] Kursat Cagiltay, Nuri Kara and Cansu Cigdem Aydin. 2014. Smart Toy Based Learning. In *Handbook of Research on Educational Communications and Technology*, J. Michael; Merrill Spector, M. David; Elen, Jan Ed. Springer New York, New York, NY, 703-711. http://dx.doi.org/10.1007/978-1-4614-3185-5_56
[14] Valerie Carson, Stephen Hunter, Nicholas Kuzik and Sandra A. Wiebe. 2016. Systematic Review of Physical Activity and Cognitive Development in Early Childhood. *Journal of Science and Medicine in Sport* 19, 7, 573-578. http://dx.doi.org/10.1016/j.jsams.2015.07.011
[15] Li Kheng Chai, Kelly Rice-McNeil and Stewart G. Trost. 2020. Patterns and Correlates of Sedentary Behavior in Children Attending Family Child Care. *International Journal of Environmental Research and Public Health* 17, 2, 549. http://dx.doi.org/10.3390/ijerph17020549
[16] Franceli L. Cibrian, Monica Tentori and Ana I. Martínez-García. 2016. Hunting Relics: A Persuasive Exergame to Promote Collective Exercise in Young Children. *International Journal of Human–Computer Interaction* 32, 3, 277-294. http://dx.doi.org/10.1080/10447318.2016.1136180
[17] Javier de la Fuente, Stephanie Gustafson and Colleen Twomey. 2015. An Affordance-Based Methodology for Package Design. *Packaging Technology and Science* 28, 2, 157-171. http://dx.doi.org/10.1002/pts.2087
[18] Australia Government Department of Health. 2021. Australian 24-Hour Movement Guidelines for Infants, Toddlers and Pre-Schoolers (Birth to 5 Years). . Retrieved 2022 from https://www.health.gov.au/health-topics/physical-activity-and-exercise/physical-activity-and-exercise-guidelines-for-all-australians/for-infants-toddlers-and-preschoolers-birth-to-5-years#:~:text=For%20preschoolers%20(3%20to%205%20years),-For%20preschoolers%2C%20we&text=preschoolers%2C%20we%20recommend%3A-,not%20restraining%20them%20for%20more%20than%201%20hour%20at%20a,per%20day%20%E2%80%93%20less%20is%20better.
[19] Shital Desai, Alethea Blackler and Vesna Popovic. 2015. Intuitive Use of Tangible Toys. In *Proceedings of* IASDR The International Association of Societies of Design Research.
[20] Rebecca A. Dore, Jennifer M. Zosh and Kathy Hirsh-Pasek. 2017. Plugging into Word Learning: The Role of Electronic Toys and Digital Media in Language Development. In *Cognitive Development in Digital Contexts*, Elsevier, 75-91. http://dx.doi.org/10.1016/B978-0-12-809481-5.00004-3
[21] Dobromir Dotov, Lin Nie and Matthieu De Wit. 2012. Understanding Affordances: History and Contemporary Development of Gibson's Central Concept. *Avant* 3, 28-39.
[22] Melissa & Doug. 2022. Giddy-up and Play Activity Toy Retrieved from https://www.melissaanddoug.com/giddy-up-and-play-activity-toy/9222.html.
[23] Molly Driediger, Leigh M. Vanderloo, Stephanie Truelove, Brianne A. Bruijns and Patricia Tucker. 2018. Encouraging Kids to Hop, Skip, and Jump: Emphasizing the Need for Higher-Intensity Physical Activity in Childcare 7, 3. http://dx.doi.org/Journal of Sport and Health Science
[24] VTech Electronics. 2022. 3-in-1 Sports Centre. Retrieved from
[25] VTech Electronics. 2022. Bright Lights Soccer Ball. Retrieved from https://www.vtechkids.com/product/detail/18417/Bright_Lights_Soccer_Ball___.
[26] Elena Escolano-Pérez, Maria Luisa Herrero-Nivela and José Luis Losada. 2020. Association between Preschoolers' Specific Fine (but Not Gross) Motor Skills and Later Academic Competencies: Educational Implications. *Frontiers in Psychology* 11.
[27] Ylva Fernaeus, Jakob Tholander and Martin Jonsson. 2008. Beyond Representations: Towards an Action-Centric Perspective on Tangible Interaction. *Int. J. Arts and Technology Int. J. Arts and Technology* 14, 249-267. http://dx.doi.org/10.1504/IJART.2008.022362
[28] Robert S. Fisher, Graham Harding and Giuseppe Erba. 2005. Photic- and Pattern-Induced Seizures: A Review for the Epilepsy Foundation of America Working Group. *Epilepsia* 46, 9, 1426-1441. http://dx.doi.org/10.1111/j.1528-1167.2005.31405.x
[29] KennethP. Fishkin. 2004. A Taxonomy for and Analysis of Tangible Interfaces. *Personal and Ubiquitous Computing* 8, 5. http://dx.doi.org/10.1007/s00779-004-0297-4
[30] William Gaver. 1991. Technology Affordances. In *Proceedings of Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 79-84. http://dx.doi.org/10.1145/108844.108856
[31] James J. Gibson. 2014. The Theory of Affordances. In *The Ecological Approach to Visual Perception*, Psychology Press, 18.
[32] Scientific Software Development GmbH. 2022. Atlas.Ti. Retrieved from https://atlasti.com/.
[33] Tonya R. Hammer. 2011. Pretend Play. In *Encyclopedia of Child Behavior and Development*, Sam; Naglieri Goldstein, Jack A. Ed. Springer US, Boston, MA, 1157-1157.
[34] Thomas Herrmann and Jan Nierhoff. 2017. Prompting – a Feature of General Relevance in Hci-Supported Task Workflows. In *Proceedings of* Springer International Publishing, Cham, 123-129. http://dx.doi.org/10.1007/978-3-319-58750-9_17
[35] Alexis Hiniker, Bongshin Lee, Kiley Sobel and Eun Kyoung Choe. 2017. Plan & Play: Supporting Intentional Media Use in Early Childhood. In *Proceedings of IDC '17: Interaction Design and Children*. ACM, 85-95. http://dx.doi.org/10.1145/3078072.3079752

[36] Eva Hornecker and Jacob Buur. 2006. Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction. In *Proceedings of* ACM Press, New York NY, 437–446.
[37] Justine Howard and Karen McInnes. 2013. *The Essence of Play: A Practice Companion for Professionals Working with Children and Young People*. Routledge, Abingdon, Oxon ;.
[38] Educational Insights. 2022. Magic Moves Electronic Wand. Retrieved from https://www.educationalinsights.com/magic-moves-electronic-wand.
[39] Stephen S. Intille. 2004. A New Research Challenge: Persuasive Technology to Motivate Healthy Aging. *IEEE transactions on information technology in biomedicine: a publication of the IEEE Engineering in Medicine and Biology Society* 8, 3, 235-237. http://dx.doi.org/10.1109/titb.2004.835531
[40] Linderoth Jonas. 2011. Beyond the Digital Divide: An Ecological Approach to Gameplay.
[41] Gregg Kottyan, Leah Kottyan, Nicholas M. Edwards and Ndidi I. Unaka. 2014. Assessment of Active Play, Inactivity and Perceived Barriers in an Inner City Neighborhood. *Journal of Community Health* 39, 3, 538-544. http://dx.doi.org/10.1007/s10900-013-9794-6
[42] Anastasia Kourti, Androniki Stavridou, Eleni Panagouli and Theodora Psaltopoulou. 2021. Play Behaviors in Children During the Covid-19 Pandemic: A Review of the Literature. *Children* 8, 8, 706. http://dx.doi.org/10.3390/children8080706
[43] Inc LeapFrog Enterprises. 2022. Alphapup. Retrieved from https://store.leapfrog.com/en-au/store/p/alphapup/_/A-prod19241.
[44] Inc LeapFrog Enterprises. 2022. Leapband. Retrieved from https://store.leapfrog.com/en-us/store/p/leapband/_/A-prod19263.
[45] Inc LeapFrog Enterprises. 2022. Learn & Groove Musical Mat. Retrieved from https://store.leapfrog.com/en-us/store/p/learn-groove-musical-mat/_/A-prod19310.
[46] Inc LeapFrog Enterprises. 2022. Lettersaurus. Retrieved from https://store.leapfrog.com/en-us/store/p/lettersaurus/_/A-prod80-607400.
[47] Inc LeapFrog Enterprises. 2022. Pick up & Count Vacuum. Retrieved from https://store.leapfrog.com/en-au/store/p/pick-up-count-vacuum/_/A-prod80-611000.
[48] Inc LeapFrog Enterprises. 2022. Scoop & Learn Ice Cream Cart. Retrieved from https://store.leapfrog.com/en-us/store/p/scoop-learn-ice-cream-cart-deluxe/_/A-prod80-600761.
[49] Shoo Thien Lee, Jyh Eiin Wong, Wei Wen Ong and Mohd Noor Ismail. 2016. Physical Activity Pattern of Malaysian Preschoolers: Environment, Barriers, and Motivators for Active Play. *Asia Pacific Journal of Public Health* 28, 5_suppl, 21S-34S. http://dx.doi.org/10.1177/1010539516638155
[50] Paul M. Leonardi. 2010. Digital Materiality? How Artifacts without Matter, Matter. *First Monday* 15, 6. http://dx.doi.org/10.5210/fm.v15i6.3036
[51] Woolworths Group Limited. 2022. K-D Kids Glitter Light up Rainboots. Retrieved from https://www.bigw.com.au/product/k-d-kids-glitter-light-up-rainboots-purple-size-12/p/1419997?region_id=444444&gclid=EAIaIQobChMI--nbqrq5-AIViiRgCh01GwVZEAQYBSABEgLD4vD_BwE&gclsrc=aw.ds.
[52] Anne Lindsay, Angela Starrett, Ali Brian and Teresa Byington. 2020. Preschoolers Build Fundamental Motor Skills Critical to an Active Lifestyle: The All 4 Kids© Intervention Study. *International Journal of Environmental Research and Public Health* 17, 3098. http://dx.doi.org/10.3390/ijerph17093098
[53] Geke Dina Simone Ludden. 2013. Designing Feedback: Multimodality and Specificity. In *Proceedings of 5th World Conference on Design Research, IASDR 2013: Consilience and innovation in design*. IASDR.
[54] M Madianou and D Miller. 2018. Polymedia: Towards a New Theory of Digital Media in Interpersonal Communication / Transl. From Eng. A. Paukova, V. Chumakova. *Monitoring Obshchestvennogo Mneniya: Ekonomichekie i Sotsial'nye Peremeny / The Monitoring of Public Opinion: Economic and Social Changes Journal* 143.
[55] Clover Maitland, Leanne Lester, Stewart G. Trost and Michael Rosenberg. 2020. The Influence of the Early Childhood Education and Care Environment on Young Children's Physical Activity: Development and Reliability of the Playce Study Environmental Audit and Educator Survey. *International Journal of Environmental Research and Public Health* 17, 7, 2497. http://dx.doi.org/10.3390/ijerph17072497
[56] P. Markopoulos. 2008. *Evaluating Children's Interactive Products: Principles and Practices for Interaction Designers*. Morgan Kaufmann, Amsterdam ; Boston.
[57] Jackie Marsh. 2017. The Internet of Toys: A Posthuman and Multimodal Analysis of Connected Play. *Teachers College Record* 119, 12, 1-32. http://dx.doi.org/10.1177/016146811711901206
[58] Jackie Marsh, Lydia Plowman, Dylan Yamada-Rice and Julia Bishop. 2016. Digital Play: A New Classification. *Early Years* 36, 3, 242-253. http://dx.doi.org/10.1080/09575146.2016.1167675
[59] Alex Mihailidis, Jennifer N. Boger and Tammy Craig. 2008. The Coach Prompting System to Assist Older Adults with Dementia through Handwashing: An Efficacy Study. *BMC Geriatrics* 8, 1, 28. http://dx.doi.org/10.1186/1471-2318-8-28
[60] Maria Montessori, J. McV. Hunt and Jaan Valsiner. 2017. *The Montessori Method* (1). Routledge,
[61] Donald A Norman. 1999. Affordance, Conventions, and Design, 5.
[62] Anthony D. Okely, Katharina E. Kariippanon and Hongyan Guan. 2021. Global Effect of Covid-19 Pandemic on Physical Activity, Sedentary Behaviour and Sleep among 3- to 5-Year-Old Children: A Longitudinal Study of 14 Countries. *BMC Public Health* 21, 1, 940. http://dx.doi.org/10.1186/s12889-021-10852-3
[63] Anni Pakarinen, Lea Hautala and Lotta Hamari. 2020. The Association between the Preference for Active Play and Neurological Development in Toddlers: A Register-Based Study. *International Journal of Environmental Research and Public Health* 17, 7, 2525. http://dx.doi.org/10.3390/ijerph17072525
[64] A. D. Pellegrini and David F. Bjorklund. 2004. The Ontogeny and Phylogeny of Children's Object and Fantasy Play. *Human Nature* 15, 1, 23-43. http://dx.doi.org/10.1007/s12110-004-1002-z
[65] Louisa Penfold. 2019. Material Matters in Children's Creative Learning. *Journal of Design and Science*.
[66] Jean Piaget. 1964. Part I: Cognitive Development in Children: Piaget Development and Learning. *Journal of Research in Science Teaching* 2, 3, 176-186. http://dx.doi.org/10.1002/tea.3660020306
[67] Ingrid Pramling-Samuelsson and Marilyn Fleer. 2009. *Play and Learning in Early Childhood Settings: International Perspectives*. Springer Netherlands, Dordrecht.
[68] Manish Prasad, Michelle Arora and Ishaq Abu-Arafeh. 2012. 3d Movies and Risk of Seizures in Patients with Photosensitive Epilepsy. *Seizure* 21, 1, 49-50. http://dx.doi.org/10.1016/j.seizure.2011.08.012

[69] Mitchel Resnick, Fred Martin and Robert Berg. 1998. Digital Manipulatives: New Toys to Think With.
[70] Lindsay Roach and Melanie Keats. 2018. Skill-Based and Planned Active Play Versus Free-Play Effects on Fundamental Movement Skills in Preschoolers. *Perceptual and motor skills* 125, 4, 651–668. http://dx.doi.org/10.1177/0031512518773281
[71] Steve Sanders. 2015. *Encouraging Physical Activity in Preschoolers*. Gryphon House, Inc, Lewisville, NC.
[72] Kjeld Schmidt and Liam Bannon. 1992. Taking Cscw Seriously. *Computer Supported Cooperative Work (CSCW)* 1, 1, Computer Supported Cooperative Work (CSCW). http://dx.doi.org/10.1007/BF00752449
[73] FAO Schwarz. 2022. Dance Mixer Rhythm Step Playmat. Retrieved from https://faoschwarz.com/products/dance-mixer-rhythm-step-playmat.
[74] Jinsil Hwaryoung Seo, Janelle Arita, Sharon Chu and Francis Quek. 2015. Material Significance of Tangibles for Young Children. In *Proceedings of TEI '15: Ninth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Stanford California USA, 53-56. http://dx.doi.org/10.1145/2677199.2680583
[75] Suleman Shahid, Emiel Krahmer Krahmer and Marc Swerts. 2014. Child–Robot Interaction across Cultures: How Does Playing a Game with a Social Robot Compare to Playing a Game Alone or with a Friend? *Computers in Human Behavior* 40, 86-100. http://dx.doi.org/10.1016/j.chb.2014.07.043
[76] Rune Storli and Trond Løge Hagen. 2010. Affordances in Outdoor Environments and Children's Physically Active Play in Pre-School. *European Early Childhood Education Research Journal - EUR EARLY CHILD EDUC RES J* 18, 445-456. http://dx.doi.org/10.1080/1350293X.2010.525923
[77] Ltd. SunLin Electronic Co. 2022. Sunlin Dance Mat. Retrieved from https://www.amazon.com/SUNLIN-Dance-Mat-Adjustable-Built/dp/B08PF4T8W1.
[78] Tania Swift. 2017. *Learning through Movement and Active Play in the Early Years: A Practical Resource for Professionals and Teachers*. Jessica Kingsley Publishers, London.
[79] Kathleen Tait. 2017. The First 2 Years of Life: A Developmental Psychology Orientation to Child Development and Play. In *Multidisciplinary Perspectives on Play from Birth and Beyond*, Lynch; Pike Lynch, Deborah; à Beckett, Cynthia Ed. Springer Singapore, Singapore, 39-59. http://dx.doi.org/10.1007/978-981-10-2643-0_3
[80] Pooja S. Tandon, Brian E. Saelens and Dimitri A. Christakis. 2015. Active Play Opportunities at Child Care. *Pediatrics* 135, 6, e1425-e1431. http://dx.doi.org/10.1542/peds.2014-2750
[81] Hubertina Thillmann, Josef Künsting and Joachim Wirth. 2009. Is It Merely a Question of "What" to Prompt or Also "When" to Prompt? *Zeitschrift für Pädagogische Psychologie* 23, 2, 105-115. http://dx.doi.org/10.1024/1010-0652.23.2.105
[82] Toysmith. 2022. Flashing Skip Ball. Retrieved from https://www.amazon.com.au/Toysmith-Flashing-Purple-Complete-Bundle/dp/B071R4ZFJB.
[83] Jeffrey Trawick-Smith, Jennifer Wolff and Marley Koschel. 2015. Effects of Toys on the Play Quality of Preschool Children: Influence of Gender, Ethnicity, and Socioeconomic Status. *Early Childhood Education Journal* 43, 4, 249-256. http://dx.doi.org/10.1007/s10643-014-0644-7
[84] Stephanie Truelove, Leigh M. Vanderloo and Patricia Tucker. 2017. Defining and Measuring Active Play among Young Children: A Systematic Review. *Journal of Physical Activity and Health* 14, 2, 155-166. http://dx.doi.org/10.1123/jpah.2016-0195
[85] Dale Ulrich. 2000. *Test of Gross Motor Development-2*.
[86] Irina Verenikina, Pauline Harris and Pauline Lysaght. 2003. Child's Play: Computer Games, Theories of Play and Children's Development. In *Proceedings of* Australian Computer Society, Inc., AUS, 99–106.
[87] Nicole Vickery, Dannielle Tarlinton, Yuehao Wang and Alethea Blackler. 2022. Digital Toys as Tangible, Embodied, Embedded Interactions In *Proceedings of Design Research Society 2022*. Guggenheim Museum Bilbao.
[88] Jeffrey B. Wagman and Thomas A. Stoffregen. 2020. It Doesn't Add Up: Nested Affordances for Reaching Are Perceived as a Complex Particular. *Attention, Perception, & Psychophysics* 82, 8, 3832-3841. http://dx.doi.org/10.3758/s13414-020-02108-w
[89] Kristin Wick, Claudia S. Leeger-Aschmann, Nico D. Monn, Thomas Radtke and Laura V. Ott. 2017. Interventions to Promote Fundamental Movement Skills in Childcare and Kindergarten: A Systematic Review and Meta-Analysis. *Sports Medicine* 47, 10, 2045-2068. http://dx.doi.org/10.1007/s40279-017-0723-1
[90] Diana Xu, Emanuela Mazzone and Stuart Macfarlane. 2005. Informant Design with Children- Designing Children's Tangible Technology.