

Come and Play: Interactive Theatre for Early Years

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ABSTRACT

The convergence of theatre and digital technologies can play a valuable role in theatre for early years, but, how an audience of under-5's experiences and engages with these spaces is largely unexplored. We present an interactive performance installation and demonstrate how concepts from early years practice, in particular schemas, children's repeated play patterns, can be used as a design framework. We integrated sensors and microcontrollers into objects, puppets, and scenography and invited eight groups of very young children and their grownups to explore the performance. We discuss how schemas are useful as a design and analysis tool in TEY, how schemas need to be expanded to include multi-sensory interactions with hybrid physical-digital objects, and how designers need to consider the roles of adults who scaffold interaction between very young children and their surroundings.

Author Keywords

Performance; interaction design; early years; tangible; children; theatre

ACM Classification Keywords

• Human-centered computing~Interaction design theory, concepts and paradigms

INTRODUCTION

Theatre for Early Years (TEY) refers to theatre for the under-5s and is often more challenging and experimental than other forms of children's theatre [35]. The way young children process interactions through their embodied experience calls for a performance where the senses are central to the design. For that reason alone children's theatre cannot be a simplified version of adult's theatre. Recent research in neuroscience and developmental psychology shows that babies and toddlers have a remarkable capacity to learn and comprehend much beyond what was originally thought [5,9,15]. This challenges previous assumptions about the cultural and psychological value of theatre for very young children [35]. Children at

this age engage with the world through doing, watching, touching and imitating. TEY audiences are therefore unpredictable and they have no concept of theatre conventions. However, these conventions are changing even in mainstream theatre. Interactive and immersive theatre has emerged, breaking down the barriers between audience and performer. It is more dynamic and is often preferred by TEY companies, but can be challenging and cost prohibitive [6]. An interactive format usually requires smaller audience numbers, tangible props, and spaces that can sustain curiosity, allow freedom of expression, surprise and time to play. Technologies and tangibles extend agency and imagination to an audience, and create unexpected and novel experiences that merge the tactile and the visual [10, 24, 28]. Digitally enhanced tactile objects could be a valuable addition to TEY because they appeal to young children. They encourage embodied mixed reality experiences beyond the screen and can have additional learning benefits [19].

Potential producers of TEY face multiple challenges. Interactive tangible technologies have not yet been closely investigated in TEY and many theatre practitioners do not know how to make use of them. The challenge is how to design experiences when there is very little related research, with the exception of [13,20,28]. Knowledge developed in education and psychology concerning children's cognitive development, while theoretically available, has not found broader re-use in TEY production, and by itself, would not be enough for the development of more dynamic and grounded experiences. Finally, it is a challenge to break away from the concept of theatre in education based on learning (often the motivation for TEY) and create professional children's theatre with an emphasis on aesthetic and interactive experiences[35].

In this paper we address the emerging research around TEY by first introducing how children's play patterns (or schemas) apply as a design and analytical framework for interactive props and scenography. We discuss how this approach can extend and support very young children's play and interactions. We also consider how tangible technologies can move interaction beyond on-screen, in particular how DIY technologies can potentially extend agency in TEY and how finding the right balance between the performer and child interaction, materials and aesthetics require us to reframe our thinking.

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RELATED RESEARCH

There are few examples of related research with children under four years in TEY or HCI it is largely conducted with older children within a learning context. However, an approach that draws on practices and theories in early years, interaction design and children's theatre, can help us better design tangible interaction for very young children in TEY.

Play and Exploration

Until around the age of seven, children's brains are like 'a sensory processing machine' [5]. They make meaning primarily through direct sensing and interacting with the world. Strong sensory integration is a basis for all intellectual activity [9]. Children are intrinsically motivated to play, are naturally curious and programmed to explore and master their world [37]. How they play with objects through trial and error, imitation and imagination are significant and age dependent. A one year old will usually imitate how an object is used and by two years the same object becomes disassociated from reality and its purpose becomes imaginative [33, 36]. Weininger furthers this notion by proposing that pretend play is the effect of an 'as if' situation and imagination is the 'what if' or the thinking function behind pretend play [36]. Theatre optimises the connection of the 'as if' and the 'what if' but this can become challenging in a performance with a mixed target group. Children's play can be understood through observing repeated behaviours which can be formalised in play patterns or schemas [3,4,18] (Table 1). They provide early years practitioners with a tool for analysing and making sense of what children do when playing. They are the foundation for the design framework that we will discuss further in the 'Interactive Design for Performance' section.

Interaction Design for Children

Children's toys can be endowed with lifelike qualities through their movement and sound. Ackermann points out those affordances are not enough, toys need to capture our imagination, enchant and have holding power. She recommends that designers consider the user's psychological points of view and design for 'conviviality' where there is a dialogue between the child and the smart toy [1]. This notion of 'Intelligent object' is now more realistic. Tangible 'smart' toys are now available for very young children. They are either interactive standalone plush toys or one that augments screen based interaction [24, 25]. However, toy manufacturers research have found that parents are less interested in the latter as they become more wary of mainstream media messages about the negative impact of screentime [12]. The development and availability of technologies to make physical objects interactive lies at the heart of the practical work conducted in this research.

Interactive Theatre

The experience economy and the desire for agency, physical and sensory experiences underpin the rise of interactive and immersive theatre seen in the last decade in the UK [7]. It rejects linear storytelling for the more

episodic and directors draw on contemporary culture like computer games and gamification formats to inspire interactive elements [7]. Digital technology has come to shape many aspects of performance. Projection design is now a common feature of stage aesthetics and live interactive technology is more prevalent in dance [17]. There are very few examples of this interactivity appearing in TEY. But one stand-out example is the 'cheering carpet' by children's dance company Compagnia T.P.O. Via touch sensors and motion tracking, footsteps and body movements trigger sounds and digital projections [24, 32]. When invited, the young audiences join the stage and follow the dancers' lead. Despite this demonstrating the potential for providing richer experiences and more agency for children, these technologies remain underexplored.

To the best of our knowledge, early years' practices and interactive, tangible technologies have not yet been evaluated in TEY. Next, we present our research that brings together all three areas discussed. We outline the process that led up to the performance installation by describing the creative design and application of the play pattern design framework.

INTERACTIVE DESIGN FOR PERFORMANCE

We created an interactive performance installation for toddlers (18 to 48 months) and their grownups to be staged at the Lakeside Arts Centre in Nottingham. We opted for an improvised immersive theatre approach (no script), as it allowed us to explore the freedom and spontaneity between the audience, performers, interactive prototypes and theatrical space. We used technologies available to digital DIY maker communities [11] such as the Arduino platform because it provides open source support networks and a variety of hardware solutions, given the economic and time constraints encountered by theatre makers.

Design Process, Concept & Strategy

The performance installation design aimed to explore both the novel and the familiar with the scenography/spatial design and to promote agency and whole-bodied and intimate experiences. It was designed by one of the researchers who is a professional scenographer. The design process employed an artistic working method that relies on an intuitive approach to design, the tacit knowledge of the scenographer and the application of the Schema design framework. It also included several consultations with a creative team made up of HCI researchers, arts venue personnel, an object theatre artist and the performer. The design process began with an exploration of the natural world and reflected on the sensory and tactile nature of the woods. It involved experimentation and exploration of material and visual ideas around the conceptual theme, experiments with different DIY technology, prototype iterations and employ play patterns as a design framework, which we consider in the next section. Play Patterns as a Design Framework Schemas are natural play patterns that tend to occur over and over again in children. They were

originally used by Piaget in his early research to describe the cognitive development of children under five. He was concerned with how schemas affect problem solving and operational thinking. Our research employs the Chris Athey interpretation of schema, defined as a pattern of behaviour and thinking in children [3], which has since been extended by other researchers [18, 22]. The set used here is explained in table 1. These patterns of behavior play an important role in the development of children's brain structure and understanding of spatial organisation [15, 4]. Repeated research has demonstrated they are common and observed in all children [26]. Play patterns help make sense of a very young child's repeated action, which may sometimes seem aimless to an adult; for example, turning round and round demonstrates the child's preoccupation with circular motion – the rotation schema. Linking objects together is concerned with connection, den making is associated with wanting to be enclosed, inside, outside etc. [15].

| Patterns of Play | Illustrative Examples |
|------------------|---|
| Transporting | Picking & moving up things and self |
| Rotation | Exploring circular things lines, turning self |
| Transformation | Exploring things that change |
| Connection | Joining, separating, scatter or tie things up |
| Enclosure | Covering self or other items, making dens |
| Trajectory | Vertical, horizontal, diagonal movement |
| Orientation | Looking at things from different angles |
| Positioning | Placing objects or self in particular places |

Table 1. Common Patterns of Play / Schemas

Schemas are used in many early years' settings in the United Kingdom. We propose that they can be used for a new purpose in design to help make sense of children's actions and help inspire, generate and analyse design features. In the next section we demonstrate the use of play patterns as a design framework.

Application of Play Patterns in the Design Process

Play patterns can be employed as a framework either to initiate new designs or to adapt an existing concept or product. We utilised them in the design process during both the ideation and the prototyping phases .. Both methods facilitate active change and adaptation of ideas and designs to afford one or more play patterns. Our design method was inspired by the Design Thinking model [14] and Gordon's 'Synectic Think Cycle' which interconnects thinking approaches to problem solving the three 'Rs' referring, reflecting and reconstructing [34]. Our application of this new play pattern framework involves the following processes:

1. **Selection:** Select a play pattern based on a design requirement or make a random choice.

2. **Ideation:** Begin a process of divergent thinking to generate creative ideas for a new or an existing prototype bearing in mind the schema affordances. Then explore the solutions and the kind of interactions they facilitate. For example, how well does it work with the narrative and concept? How can it promote agency, sensory interaction in children?
3. **Construction:** Sketch and prototype your ideas or add or adjust an existing prototype.
4. **Combining:** Then consider the other schemas from table 1 and repeat the process and think about how they combine with your original idea.

When using the play pattern framework, it is important to bear in mind how it supports and is compatible with other criteria in a design brief. For the interactive performance we considered the affordances of touch, tangible objects, space, materials, narrative, the performer's role and technologies as an other design materials that can activate sounds, lights, vibrations and smells, all of which we discuss further in the prototypes presented below.

1) Suspended Discs

The suspended discs vary in size and are detachable, flat, lightweight, flexible structures that can be hung (Figure 1).

Selection: Rotation

Ideation: We began the design process by exploring leaf shaped and circular objects and we looked at the round and round scribbles of a two year old's mark making [21]. Seed pods and mobiles can afford rotation.

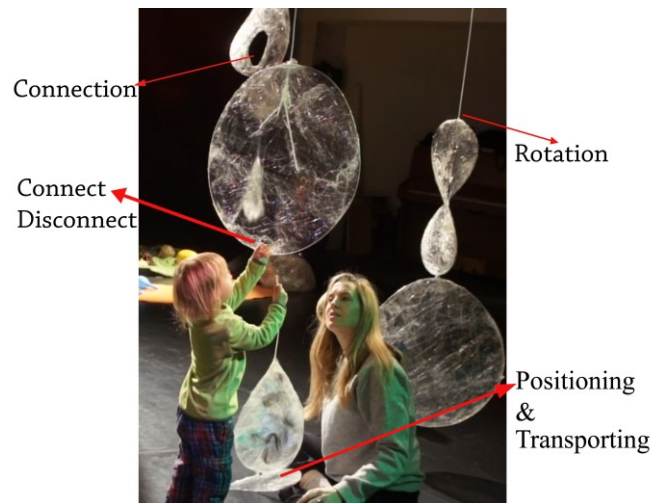


Figure 1. A suspended disc being connected by a participant. Multiple schemas applied to a simple round shape.

Construction: The circular fame was made from lightweight carbon and glass fibre rods and wrapped in several layers of clear shrink-wrapplastic and tape. The material is translucent and creates an aesthetic effect under theatrical lights. The disk was suspended from one point to afford kinetic movement similar to a mobile.



Figure 2. Prototypes: 2 Tactile Mats, 3 Musical Fruits& Vegetable, 4 Felt Creatures, 5 Malleable objects: gel beads and gloves

Combination: Further exploration of the *Connection and Positioning* play patterns was afforded by magnets around the circle, which enabled connect, detach and reposition. Some discs had small holes cut out on the surface areas to afford connections through playful interaction and peekaboo games. Others had tactile material added to the surface such as feathers, fabric and small strips of plastic to afford more tangible interactions.

2) Stepping stones

The stepping stones are force sensing tactile mats that trigger sounds when jumped or stepped on (Figure 2-2).

Selection: Trajectory

Ideation: We started the design process with an initial idea to create an experience that the participant can activate. We considered using sound as it is usually operated backstage and is not in an audience's grasp. Then, we chose the *Trajectory schema* to explore ideas around children's movement, such as the affordance of full bodied interaction i.e. jumping and running. This led to visual research that explored ideas of stepping stones in rivers, forest floor textures, and dance mats, which in turn led to technology explorations of floor and force sensors.

Construction: We made twelve circular stepping stones from black felted mats and inserted a simple force sensor made from foil and copper wire. They attached to the 'Touch Board' a microcontroller sound board. When stepped on, it triggered different sound effects. For haptic and exploratory play the surfaces had different tactile materials such as hard buttons, heat sensitive materials for making hand prints, soft pom-poms, cold metal washers, rough fabrics, etc. The design of the mats afforded both 'whole body' interactions and more intimate exploration through touching, pressing and stroking.

3) Musical Fruits and Vegetables

A large tray of fruits and vegetable that activate sounds when touched (Figure 2-3).

Selection: Connection

Ideation: Influenced by projects that used microcontrollers and sensors with real objects, we decided to use real fruits and vegetables as they are familiar to children and are not expected to make sounds. TEY found using familiar objects and stories connected to very young children's everyday reality can increase engagement [10].

Construction: Ten common fruits and vegetables were converted into tactile capacitive sensing interfaces that enabled pre-recorded sounds, that can be heard when out in the woods and in urban areas (birds, child's voice, trains, etc.), to play when touched. The fruits were in a large tray covered with a sheet of artificial grass. Wires were attached to the fruits and connected directly to the 'Touch board.'

4) Puppets: Felt Creatures

A series of small felted creatures using wearable technologies to animate various characteristics (Figure 2-4).

Selection: Transformation

Ideation: Inspired by the shape of trumpet and tulip, we crafted small white felted cone shaped objects with stems, using wet felted craft techniques. We considered *Transformation schema* and experimented with LEDs to explore ideas around animation and then led to transforming the felted shapes into hand puppets to help promote storytelling and pretend play.

Construction and Combination: We used soft circuits/ wearable technology [11] designed to be flexible and lightweight to be grasped by tiny hands. A tilt sensor activated the LED eyes. Puppets were all mobile and also embodied the *transportation schema*. Inspired by this we then developed other ideas around *transformation* lights and felt, such as a larger caterpillar shaped puppet with an accelerometer connected to an 'Arduino Lily Pad' to activate the frequency and brightness of the lights. A sound-activated creature in a cardboard suitcase box was inspired

by the *enclosure* schema and made from felt and Little Bits modules – sound sensors, vibration module, and LEDs.

5) Malleable and sensory objects

The malleable and sensory objects provided opportunities to explore and manipulate material qualities.

Selection: Transformation, Transportation & Connection

Ideation: We were interested in observing young children's use of sensory material that can transform, stretch, mould and be easily deformed.

Construction: A series of malleable objects were provided, such as conductive Playdoh, wet gel like water beads, ice cubes with embedded objects, inflated blue surgical gloves with LEDs (Figure 2-5), finger LEDs, stretchy fabric.

The Performance Space

The performance studio we used had a piano, black drapes, theatre lights and no rigged seating. We divided it into four distinct areas for each of the prototypes. We interconnected the areas hanging the suspended disc along the centre. The participants stood or sat on the floor mats provided.

THE PERFORMANCE STUDY

Study Participant and Procedure

The performance study took place over two and half-days. There were eight performances, 45 minutes in length with a maximum of five children in each. A total of 40 participants took part of which nineteen were children: 7- 1 year olds, 7- 2 year olds, 2- 3 year olds, 3- 4 year olds. They were recruited through the theatre's audience and social media network. The installation performance was free. The first four performances had one performer while the last four had two. They initiated improvised play and facilitated group and child-led interactions. On arrival at the theatre, the participants were briefed by a researcher then completed a consent form for data collection and a short survey about their child's play activities. Then the audience was led down a well-lit narrow corridor to the performance space entrance and a researcher explained that they could freely interact with the props supported by the performers. The performer introduced herself and invited them to explore the space. To increase the children's anticipation, she encouraged them to peek through the glass pane door before entering the performance space. After 45 minutes the house lights were switched on and the participants left.

Data Collection and Analysis

Video recordings of the performances, field notes and a short pre-show survey (children's current play activities) were used for data gathering. A fixed camera recorded a wide angled view from the front of the room and a second roving camera captured close up selective interactions. If a child seemed uncomfortable when filmed close up we moved away. From the video recordings we made an index of events each indicated the number of participants involved, their position in the performance space, the object(s) that they were playing with, schemas that were recognised and a summary of what happened. From this

data we identified some episodes for detailed observation using Flanagan's critical incident technique 1) to report the facts of the behaviour and 2) to report the significant behaviours of the observed activity [27]. A multimodal transcription [13, 15] of the recordings with a description of what happened was produced together with an account of the 'non-verbal signifiers' and embodied interactions (gaze, gesture, body position, and sound) which are particularly important when observing pre-verbal participants.

RESULTS

The open, playful, relaxed nature of the performance installation encouraged the child participants to freely explore the space and engage with the objects and performers. An interesting finding was that only three out of the nineteen children stayed very close to their parents and did not communicate directly with the performer. Nonetheless, they watched and then imitated the activities, suggesting they were very much active [28].

| Prototypes | Schema in design process | Children's interaction | Schemas in the performance |
|--|---|--|--|
| Suspended Disc | Transporting Connection Positioning Rotation | Carried, touched, worn as hats, used as wings. Jumped and walked on. Used as a mirror, lake, train, for hiding and seek, hitting, head-butting, pulled, dragged. Attach, detach. | Transporting, Connection, Positioning, Rotation, Enclosure, Enveloping, Trajectory |
| Stepping Stones | Trajectory | Step, walk, jump, touch, pick. Sat on, turned | Trajectory; Connection, Rotation |
| Musical Fruits & Veggies | Connection | Touch, pick up, examine, move, smell, taste, stepped on, worn | Connection, Positioning, Transport |
| Puppets | Connecting Transporting | Carried, smell, touched, threw, friend, prop, used to peek a boo game, put in a line | Connecting, Transporting, Positioning. |
| Malleable/Sensory Objects Gel water beads & Playdoh gloves, LEDs | Transporting Connection Transformation | Squeeze, thrown, step on, touch, drawing Stretch, pulled and dragged. Den making, swing Squeeze, carried, thrown, hide and seek | Transporting, Connection, Transformation, Enveloping, Enclosure, Positioning |

Table 2. Schemas designed for vs. observed in the prototypes

In most of the sessions, there were sounds of laughter heard around the musical fruits & vegetables. There was a disregard for boundaries when the children tried to taste the fruits, move and pick them and even sat in the large tray.

Overall there were more play patterns observed than we designed for as seen in Table 2. The greatest number was associated with the suspended disc and it was also the most popular. The design permitted more varied types of

interactions and play patterns. For instance, a child wore one around her neck and pretended to be inside a train while the actor used it as a hat. Some children were more occupied with a particular play pattern and exercised their agency by repeatedly coming back to play with that object. We now present three episodes that give a more detailed account of how the play patterns are revealed.

Episode 1: Construction & Connecting

This episode was initiated by a young male participant who came to the performance pretending to be a dog, he moved around on all fours and barked for attention. He spent his first ten minutes crawling around the perimeter of the room alone.

The young boy and the performer are on the floor connecting discs, he crawls forward towards the tactile mats, the performer then moves away, he stops, then turns his head and looks behind him, he moves a bit more and then turns his head and looks behind him. He then crawls, behind the performer and glances at her a few times, before he utters "woof" and moves towards the middle of the room. He stops, on all fours, he looks forward and notices something, he lifts his body upright and scuffles on his knees to a column of discs, he reaches for the large disc at the bottom, with one hand he holds the disc and pulls it away from the column of discs. He turns around holding the disc with both hands and shuffles on his knees to the performer. The young boy reaches the performer, looks directly at her, he is holding a large disc in his right hand, he tries to hand it to her, but there are other children with her, he drops the disc on the floor in front of the performer. She asks him something (not audible), both her hands are open with her palm facing upwards resting on her knee as if she asks a question-what shall we do with it?



3. Positioning and connecting the disc

The boy crawls back to the centre of the room where they last played and looks directly at her, the performer pushes the large disc towards him and he reaches for it with one hand and positions it at the bottom of the line of the discs. (Figure 3) The performer then gets up and moves toward him to resume their former play. (Day 1, session 1.)

Schemas: Transporting, Connecting and Positioning

This extract reveals a young participant's sustained interest and determination to play with a particular object as well as

demonstrates how a combination of schemas can work together – first *disconnecting* a disc, *transporting* it, then *positioning* it and *connecting*. Crawling away was part of his role play, he wanted the performer to follow him. The performer did not seem to recognise this and walked away. To get her attention he loudly uttered 'woof!' and when that didn't work he *transported* the disc to her. He gained a sense of confidence and *connected* with the performer. He was interested in playing with the discs, although she disconnected from their original play, he took the bold initiative to get her attention. They continued to play the game of connecting for ten minutes in different areas of the room. Interestingly, in the last four minutes, he started running upright, but still fully engaged with the combination of schemas. His schema play could be seen to propel him out of his role play to constructive play.

Episode 2: Knock, Knock – Schemas and sound

Episode two took place on day three. There were two performers and a mixed group of five child participants with their grownups. The interaction is between the male performer and an 18 month old participant. The young child is very confident and plays away from his father. The extract begins just after he played a few keys on the piano.

The child moves towards the fruits and vegetables. He bends over and slaps a swede with his right hand, it triggers a train whistle. He crouches on his knees and slaps the celeriac twice and the sound of a hard hat echoes, he slaps the swede and it triggers the train whistle, then he moves to the melon and the sound of a baby's voice says 'Mama, mama ah ha'. The male performer is standing near him and then lounges to the floor opposite the boy (getting down to his level). The boy looks at the performer who points to an avocado and the performer looks directly at the child and touches the avocado with one finger and it triggers the sound of a knocker. The performer lifts his hand away, then slowly touches it three times with his finger, the boy looks on, then the performer hits it with his knuckles and says: 'hello anyone at home?' 'hello anyone at home?' As he moves his hand away the boy slaps the melon with his palm and the sound 'mama mama, ah woo' is heard. The performer repeats the action and says, 'hello anyone at home?' Then the boy imitates the performer and touches the melon with one finger that activates the sound again. The performer then touches another fruit and the child stands up, moves a few steps, then points at the avocado and he says something inaudible. The performer says 'Melon?', and then the boy touches the melon, four times and pushes it towards the performer, he turns around, and sees his father then looks down at the tray, reaches in and picks up a pompom then turns around and walks away singing 'Mama.... Mama.... Mama''... (Day 3, session 5).

Schemas: Transformation and Connecting

Vygotsky found that using a physical object helps very young children to pretend play [33]. But what the object represents in reality does not seem to matter for symbolic

play to occur. In this episode, the sound transforms the avocado into a door knocker and the melon into a baby. It demonstrates a simple example of how the *transformation* schema with sound can play a role in imaginative and symbolic play. The child's encounter with the performer further enriched his experience by *connecting* the sound to an imaginative narrative as the sound took precedent over the material object. Secondly, the moments of interaction between the child and the performer demonstrate the very young child's awareness of the performer's question and turn taking. When the performer touched another object, the boy's response was to stand up and point to the avocado (knocker) it seems as if he want to continue with the previous activity. The performer misreads the child's action, the child perceives this and moves on. The young child's turn taking and imitation of subtle gestures and sounds can be indicative of an intelligibility of action.

Episode 3: Tuning In – Schema and dramatic play

Fantasy and sociodramatic play are common with children at this age. Our pre-show survey found that 17 out of 19 children engaged in role play such as being, a hairdresser, shopkeeper, doctor, etc. In the performance the felted hand puppets became the catalyst for sociodramatic and symbolic play (Figure 4). The following extract was the longest pretend play (14 minutes) episode during the study.



Figure 4. The LED light transforms the inanimate felt object into a 'live' hand puppet.

Child: 'That does not work, if you stand it up.'
Performer: 'Oh, right,' 'Flop flop' (she flicks her finger and the standing puppet fall onto the green mat)
Child: (stares at it holding it in both hands, he presses it and slightly moves it, so the tilt switch is triggered.)
Child: 'Ahh! I switch it on. I switch it on and off' and proceeds to put his left hand into the hand puppet. The performer leans over to look at the puppet's eyes turning on and off. The boy names all the puppets 'Peter' and as the play continues he takes one of the puppets to the shop. He acts with the puppet and the performer is the shopkeeper. She refers to the puppets by their name 'Peter'. The boy interchanges himself with the puppet by saying 'I want' instead of 'Peter wants' and as the play continues it shifts and he talks directly to the shopkeeper rather than through the puppet. The performer responds using his real name. The boy orders a packet of salt and vinegar

crisps for himself and his mum and dad. Once he gets the pretend crisp packet, he runs over to his mum, first he takes the crisp packet and the second time he explains, how he used a credit card. Then he and his puppet join the shopkeeper at the back of the shop (Figure 5) and he makes the puppet jump up and down on the wool saying 'dong-ing, dong-ing' with a smile.



Figure 5. 'Dong-ing, dong-ing' making the puppet jumping up and down on the carded wool in the basket

Schemas: Transformation and Trajectory

The tilt switch affords the puppet a *transformative* state, awake or asleep. In this extract, the child had a strong motivation for exploratory play, which led him to try and figure out how the tilt switch works. We also observed his curiosity to discover how things worked with the other prototypes. His enjoyment and engagement in play was noticeable by his laughter, especially when bouncing the puppet up and down (*trajectory*). Seeing the child as an active participant can shift the adult's role from leading to being a partner or a facilitator. This shift of roles also occurs when the child's real and imaginative world *transform* as the child takes over the role of the puppet.

DISCUSSION

No previous study has used play patterns as a design framework for digitally enhanced TEY. We reflect on our use of the play pattern framework, multisensory, tangible technologies and the role of adults in TEY.

Play pattern framework

Each play pattern represents a naturally occurring behaviour in children that affords the designer a specific way of thinking about and extending ideas for interaction design. The results presented in this study are encouraging: the play patterns applied to the design were evident in the children's interactions and additional patterns were also observed (Table 2), even if not every child experienced all patterns presented. We see the opportunities offered by multiple, overlapping play patterns (designed and experienced) as the key reason for the suspended discs being the most popular item. Our results demonstrate how a combination of patterns that support a logical sequence of actions works well together. The ambiguous form of the suspended discs may be a complimentary reason for their popularity. Ambiguity in design can free an object and open it up to the participants' imagination, permitting a wider

variety of interpretation and interaction [16]. The play pattern framework presents a new approach to design for TEY beyond its original purpose to analyse (rather than design for) the play of children. There are other performance frameworks [7, 21] that have been proposed for both design and analysis of HCI experiences. A crucial limitation of this framework is that it does not address important areas such as multisensory interactions (e.g. sound and lights enabled through tangible technologies) and the role of the performer is also outside its object-focused remit, both of which we will address below.

Multi-sensory Tangible Technology

Arguably, the boundaries between very young children and technology have never been more porous and for the current generation of toddlers, swiping a screen is as normal as shaking a rattle. Beyond this screen-focused interaction the combination of interactive sound, lights and tangible props creates novelty in an object and adds to its performativity as demonstrated in the work presented here. It can create fun, playful, tactile and embodied interactions that fill the entire theatre stage. For this we have combined familiar objects and themes, which young children respond to [10], with the 'unexpected' playful interaction afforded by multisensory, tangible technologies with the aim of creating 'richer and more varied experiences' [29]. We found that embedded electronic components can be seen as another material that can afford more agency to young participants as they were for example, able to activate sounds and make choices. Typically the choices of sound and lights are not in an audience's control. Episode 2 has provided examples of how interactive sound can play a role in introducing narrative and how vocal repetition of digital sounds resulted in children having a deeper relationship and connection with a particular sound. We also note that relatively cheap and brittle technologies such as conductive threads, embedded LEDs, and washable microcontrollers were suitable for props and provided a robust short-term solution. However, whether they will stand the rigors of a typical touring TEY production will need to be explored in the future. As multi-sensory tangible technologies become even more widespread, accessible and reliable, there will be a need for HCI designers and theatre practitioners to work collaboratively to understand better how to design and make these spaces more conducive for interactions for this age group. To achieve this teams of designers should draw on an expanded set of play patterns that captures multi-sensory interactions with tangible technologies.

The Adult and Child

The children in all three episodes responded to the devised and impromptu invitations from the performers to play. In turn, they were sensitive to the children, supported their interests by imitating their actions, following their stories, being part of their imaginative play and gained their trust as a result. In episode 3 for example, the performer left moments of silence to give the child time to think and to take the initiative, make choices and lead the 'play' while

she remained engaged in storytelling throughout. By being alert and following his lead, she was valuing what he had to say. However, at times the performers missed some of the children's cues; devising in a live situation is very challenging for actors, especially with such an unpredictable and authentic audience. Beyond leaving enough space for play, another strategy that performers employed was that of engineering surprise. Previous studies with two year olds found that if the functions of a physical object are introduced to a child as if it is found by accident or in a playful manner, then they tend to be more exploratory than if the functions were introduced formally [30]. In addition to the performer, parents play a central role in scaffolding. An adult's reaction to a child's behaviour is important because, from a very young age, children are responsive to the values and judgment of adults, especially those familiar to them [15]. Connecting to a parent or carer by touching base and sharing an experience, as we found in episode 2, was important to many of the participating children. In episode 1, for example, it was only after the child was introduced to the female performer while sitting on his mother's lap, that he played with her, so the role of the parent should not be underestimated and space must be given for the minority of children who do not want to play with a performer. An invitation from a performer that is refused by a child should be honored. A child who only engages with a parent should not be considered as a passive observer or be seen as missing out. Whether designing an interactive performance or object, our findings provide evidence that when interacting with very young children the role of the adult needs further consideration. An implication of this is that HCI researchers should consider using a performer or theatrical methods when testing interactive toys and objects with very young children (those under 36 months of age). This is because children at this stage are expected to tend to play with adults who provide the appropriate framing and support.

CONCLUSION

Research on how very young children act in interactive performance spaces is limited. In this paper we presented how schemas can be used as a framework to design an interactive performance installation that incorporates children's natural play patterns. Studying how young children experienced this installation enabled us to reflect on the opportunities offered by tangible technology and the role of adults in TEY.

ACKNOWLEDGMENTS

This work was supported by the Horizon Centre for Doctoral Training at the University of Nottingham (RCUK Grant No. EP/G037574/1) and by the RCUK's Horizon Digital Economy Research Institute (RCUK Grant No. EP/G065802/1). The Authors would additionally like to thank the performers Sophie Johnsonhill and Sean Myatt and the staff at the Lakeside Arts Centre.

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