RESEARCH-ARTICLE

# Lanterns: Configuring a Digital Resource to Inspire Preschool Children's Free Play Outdoors

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# Lanterns

## Configuring a Digital Resource to Inspire Preschool Children's Free Play Outdoors

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## ABSTRACT

Previous HCI research has highlighted opportunities for digital technologies to support outdoor play amongst children. However, the tendency has been to focus on older children and forms of play that are structured and rule-based. We report on a Research-through-Design (RtD) inquiry, grounded in an Embodied Interactional approach, that investigated configurations of off-the-shelf Internet of Things (IoT) tool-kits to inspire new forms of free play outdoors for preschool children. We designed the Lanterns, a tangible interactive resource that is made using household materials and guided by a template, and which explores new possibilities to inspire social play and embodied interaction outdoors. Based on observations of the Lanterns being used by preschool children and Early Years Practitioners outdoors, we identify qualities of free play promoted by the Lanterns outdoors, such as enchantment, improvisation, anticipation and choice. We discuss our findings by defining three sensitising concepts to support future design research in this space: Choosing the Way; Improvising through Movement; Anticipating a Response.

## CCS CONCEPTS

• **CSS CONCEPTS**; • **Human-centered computing** → Human computer interaction (HCI);

## KEYWORDS

interaction design, tangibles, iot, tool-kits, preschool, children, free play, outdoor play, pervasive play

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## 1 INTRODUCTION

There is evidence that children are playing outside less frequently than previous generations [43], despite free play outdoors both at home and at school being essential to their health, well-being and development [6]. Free play amongst preschool children (aged 3 to 5 years old) is important for their learning and development as it enables them to start understanding the world by interacting with their environment. For Maria Montessori, whose educational approach has been adopted throughout the world, preschool children are "*pragmatic explorers of the world around them*" ([34], p.149]) and should be provided with suitable materials to support them in this exploration. However, preschool children are reported to be especially restricted in their opportunities to play in the outdoors, often due to increasing demands on working parents; and children therefore spend more time in childcare [21]. Researchers have, in turn, suggested that childcare settings provide vitally important opportunities for children to experience free play outdoors [21] and, as such, childcare environments for preschool children should provide outdoor spaces and associated resources that enable free exploration through a "*multi-sensory, movement-based, holistic and stimulating experience*" ([56], p.7).

Whilst interactive screen entertainment continues to captivate children and draw them into virtual environments, there are increasing opportunities for encouraging children outside by designing compelling interactions with tangible computing devices [2–4, 15, 24, 25, 36]. A rich design space is opening up for interactive technologies that pique children's interests in outdoor play settings, and thus can have proven social and physical benefits for children [6, 22]. Extant Human Computer Interaction (HCI) research has highlighted the opportunities presented by digital, networked technology to support outdoor play for children [4, 15, 24, 44], but as yet little is known about designing interactions specifically for preschool children. Given innovations in embedded hardware and the Internet of Things (IoT), researchers have looked at the design of tangibles for children's outdoor play and these include both games [44, 45] and open-ended interactions [24, 25, 50, 52]. The majority of these projects focus on children over the age of 5 years, who are more likely to engage in rule-based play and games than preschool children. Furthermore, when considering design to support outdoor play, studies investigating open-ended interactions still take place within a gymnasium, or even a lab, rather than in the 'real' outdoors [2]. And yet, children have been found to behave differently when

indoors compared to outdoors, with evidence suggesting that they are less inhibited outdoors because they are not constrained by etiquette often associated with the classroom, or home, and can therefore be noisier, messier, more assertive, and independent when interacting outside with other children [30, 32].

In our work on a funded, UK-based, Research-through-Design (RtD) [20, 27, 47, 55] project, we have been exploring the Interaction Design opportunities for supporting children's outdoor free play via programmable IoT devices that are now widely available for children. Engaging with extant work, we recognise the importance of studying prototypes in real world outdoor environments, by considering, for example, how outdoor play incorporates its topographical features (such as trees, walls, and open spaces). In this paper, we introduce *Lanterns*, designed by our research team with the aim to create open-ended, tangible interactions that promote play in different outdoor environments for preschool children. Key interactive features involve light, proximity and movement. Also key is the Lanterns being configured using off-the-shelf and accessible materials: they utilise the BBC Micro:bit, which is an IoT tool-kit available in the UK marketplace for preschool children; and they can be constructed with everyday household materials that are easily sourced and worked with by parents, nursery and childcare staff with children in the future.

Herein, we report on the design of the Lanterns and a recent field evaluation of their use at a Montessori Nursery in the North of England. We report on our observational field study of the novel design within this real-world nursery setting with preschool children who were supervised by experienced Early Years Practitioners (EYPs). The nursery has access to an enclosed garden and a nearby woodland that forms part of a Montessori curriculum guided by valuing free play outdoors. We configured the Lanterns in specific ways for each of these settings, to explore the children's embodied interaction [14] and free play [40] with IoT tool-kit resources. Through an analysis of video and fieldnotes taken during our field study of the Lanterns being used in both environments, we consider how the interactive features configured for the Lanterns influenced engagement between children and with the outdoor environment within supported free play.

Through reporting on the findings from our observational fieldwork, we extend existing work at the intersection of play and Interaction Design for children (e.g. [2–4, 15, 58]) by contributing three new Sensitising Concepts [5, 7, 54, 59] for the design of interactive tangibles to support preschool children's outdoor play: Choosing the way; Improvising in movement; Anticipating a response. By introducing these sensitising concepts, we aim to guide future design work in this space, whilst acknowledging the importance of free play being child-led and open to interpretation.

## 2 BACKGROUND

### 2.1 Free Play

Play is known to be a messy concept to define, with Moyles [35] suggesting we should consider play a multifaceted set of activities consisting of various behaviours, motivations, skills and opportunities. Play is understood to be core to a young child's development of a social self [33] and has a key role in developing preschool children's social, physical, cognitive and emotional abilities [6, 21, 22]. Through play, preschool children master the world around them [40], and in turn develop competencies that lead to enhanced confidence and resilience [16]. Play is therefore an essential part of healthy brain development in preschool children [42]. Free play is an approach to play that is *chosen and directed by children*, who decide when to stop and do something else, and contrasts with play that is structured by adults, where there is emphasis on a particular outcome, or goal [40]. Indeed the distinction of game-play from free play is recognised as a developmental step in children as they grow older [33]. Games have structure, fixed rules, and are motivated by challenges and competition. On the other hand, free play is chaotic, spontaneous and improvised; meaning is constructed, and play is motivated by sensation [51]. Attending nursery is an important opportunity for children to socialise, as a setting where free play enables them to learn how to interact with others by sharing, resolving conflict and self-advocating [18]; in such play environments, they are more likely to be motivated to create and explore and, in turn, develop dispositions that support the development of an independent self, such as creativity, curiosity and resilience [11]. Evidence suggests that free play outdoors increases physical activity levels in young children [57], and encouraging outdoor play has been considered a means of dealing with the obesity epidemic [10]. Over and above the health and developmental importance of free play, Cook and Hess [12] remind us of the importance of the lived experience of children by deriving their opinions on outdoor play. These include: having fun; being able to meet and play with other children; being provided with environments and opportunities for play; and doing what they want to do, and not because others see this as important [12]. When adults direct the interests of children, this is less likely to be sustained, and so a stimulating environment and related resources, rather than predefined activities, are more likely to motivate children outdoors [31]. Herein, we hope to raise the visibility of *Preschoolers' Free Play*, as a fascinating, relevant, and arguably under-explored research context for the HCI field.

### 2.2 Supporting Open-Ended Play

Several studies in HCI and related Interaction Design for Children (IDC) literature have explored the design of digitally augmented artefacts for open-ended play [15, 23–25, 29, 48, 50, 58]. There is commonly a focus on digitally enhancing outdoor play and therefore augmenting existing kinds of play resources that are commonly used outdoors [23, 39, 44, 50]. Research has also looked directly at enabling game and rule creation by coding a bespoke device for outdoor play [44]. Subsequently, researchers have been concerned about directly comparing analogue play, and whether digital augmentation supports or hinders social interaction, physical activity, and the creation of rules and games by children [23, 24]. In this study, we did not set out to compare analogue and digital play, but, rather, to propose that both kinds of resources can provide distinct opportunities for free play by children outdoors, and to build a case for further exploring these resources in empirical research. Even when novel open-ended designs are introduced into free play, the tendency is to observe and principally consider rule-based play in subsequent evaluations [15, 36]. Research investigating open-ended designs in free play outdoors looks principally at older children, aged seven and up [2, 4, 15, 23–25, 36, 39, 44, 48, 50, 51, 58], where

we may expect to see children playing games, discussing and negotiating relatively complex rules [37], as a component of their play with open-ended designs. By exception, Pathway [41] was designed for children aged 3-5 years, and the authors report increased physical activity through running, skipping, and jumping on the prototype. There remains a dearth of research on designing open-ended interactions for preschool children's free play outdoors.

Parten [37] provides a continuum of socialisation skills that is useful for understanding how preschool children play with open-ended designs. For preschool children we may expect to observe: *Onlooker play (about 2½ to 3½ years)* – a child is watching others play, but not playing themselves; *Parallel play* – a child plays beside others mimicking their play but there will be little interaction with others; *Associative play (about 3-4½ years)* – a child will begin to coordinate play and share goals with others but play activities will change regularly and may be uncoordinated; *Cooperative play (begins about 4-5½)* – at which point children will begin to coordinate group play with shared goals. Cooperative play is the most complex form of social participation because it requires negotiation and agreement between children, and at this point children will begin to understand social roles. From around six years old, children are likely to move towards games with rules [8]. As a continuum, young children will move between stages, showing variations of their current stage and earlier stages while playing [8].

Though there has been work investigating open-ended devices for play, few studies have focused specifically on the outdoors. The tendency in HCI has been to focus on play as engagement with a designed artifact in isolation, and neglecting to consider the social and situated nature of outdoor play [3]. Back *et al.* [2] suggest that the influence of the environment is commonly seen as secondary to play itself, and this is evident in evaluations that take place in large indoor settings, like a gym [28, 53], or lab [49]. By deploying open-ended playground equipment in a school yard that consists of woodland, Back *et al.* [2] show how children create new opportunities for free play by incorporating aspects of the environment. In a related study, Back *et al.* [4] observed open-ended playground equipment in an urban setting and highlights the role of physical aspects of the space, as well as social practices that influenced play. Wood *et al.* [58] investigate children's free play outdoors in an urban community setting and found this to be enmeshed with complex processes of placemaking, as well as having the potential to build resilience through associated social skills, like confidence and leadership. There is a need to understand the role of open-ended prototypes for free play in environments in which children will engage with them. Designs will be influenced by a range of external factors, for example, in a nursery setting free play will be supervised by EYPs and so will be dependent on their approach, and the freedom given to children outdoors. Children will also behave differently, because they are not constrained by etiquette often associated with the indoors and can therefore be noisier, messier, more assertive, and independent when interacting outside with other children [30, 32].

The previous lack of research exploring the use of open-ended designs in preschool children's free play prompted our investigation of how preschool children may appropriate resources that utilise IoT tool-kits and are designed for outdoor play. We were motivated by a desire to understand how preschool children adapt to, and integrate, embodied interactions [14] as digital resources into their outdoor play. In our research, we asked, can open-ended digital resources be used with preschool children and what role could they have to inspire outdoor free play? Guided by a phenomenological approach [14], our observations and resulting analysis focused principally on the children's physical and social interaction with the Lanterns, within the outdoor environment.

## 3 OUR INQUIRY

The study reported on in this paper is a part of a longitudinal Research-through-Design (RtD) [20, 47, 55] programme of work (ongoing for three years at the time of this study) exploring how IoT can be configured in creative ways to offer children in a wider age range (i.e. zero to nine years old) new opportunities to free play together outdoors. RtD describes our pursuit of HCI design research by combining qualitative (ethnographic) methods with design practice – i.e. 'design-as-inquiry' [ibid.]. We adopted an RtD 'in the wild' approach [27] to recognise the importance of observing play in naturalistic settings to inform design. As with others adopting RtD 'in the wild' [27], we responded through design to our understanding of children's behaviour in a particular environment, which was of social significance and had theoretical potential [17], in this case, to explore and evaluate interactive design features used in outdoor free play. We drew on experience derived from our previous RtD with a focus on free play in older children aged seven to eleven years [15, 58]. Our design process involved mutually informative activities of observation 'in the wild' (i.e. at the nursery) of the attending children at play, combined with ideation, sketching, iterative design prototyping in the studio, and regular meetings with staff at Rowans Nursery (see section 3.1). We subsequently observed the use of the designed Lanterns by the preschool children - as the intended users - at play in the nursery setting. We configured the Lantern's functional features in two different ways for this in-the-wild observation, to further identify and consider the value of particular interactive features in outdoor free play (see sections 3.2 through 3.4). From this work, we developed *"procedural, pragmatic and conceptual insights"* ([20], p.937) in the form of sensitising concepts [5, 7, 54, 59] .

Our larger programme of work has been motivated by the possibility of inspiring a renewed interest in outdoor play, through online resources for children, parents and facilitators, that draw on the increased popularity and prevalence of IoT tool-kits for children. Overarching questions informing our larger project include: What kinds of DIY resources might we provide children, parents and facilitators with? What core functionalities and interaction qualities are of value when playing outdoors? Our methodological approach is empirical, qualitative, and generative in terms of being practice-led, and has been concerned with the study of children's *embodied interactions* with the Lanterns, informed by established phenomenological perspectives that make sense of tangible computing and sociality [14]. In our work, we are concerned with "*the creation, manipulation, and sharing of meaning through engaged interaction with artifacts*" ([ibid]., p.126), focusing on children's social engagement *through* tangible resources in the environment.

In the broader RtD programme of work we chose to work with the BBC Micro:bit, a programmable IoT tool-kit for children that was developed as a product to get them actively involved in programming by designing and building their own things [60]. We also chose this platform for the current study because it was a readily available and affordable product that was already familiar to many UK children through being commonly introduced at primary school and some nurseries [61]. The BBC Micro:bit has also become widely available in other countries through the work of the Micro:bit Education Foundation (microbit.org). The Micro:bit does not connect to the internet, however, it does provide child-friendly, easily understood and programmed networking abilities through a 2.4GHz radio module and Bluetooth; therefore it is appropriate for safely exploring the IoT design space with children. With an ethical imperative to protect children's safety, privacy and security, the Micro:bit foundation has restricted functionality to "*safe educational (closed) environments*" ([26], p.751). Given our desire to share resources more widely with children, parents and community groups, we have opted to maintain this convention and use local networks. Our rationale is that our designs '*talk to each other*' and speak to the IoT paradigm, but in a manner that protects children, and is potentially understood and programmed by them.

## 3.1 Rowans Nursery

In our previous research [15, 58], we had conducted a longitudinal design ethnography with a local community centre whose staff were looking to encourage free play outdoors amongst children who attend their after-school club. We learnt from our fieldwork how the children played with each other in their local neighbourhood; this informed the design of a series of open-ended prototypes that we subsequently evaluated with the same children at the centre. The children enjoyed playing with the prototypes, and responded to their open-endedness by experimenting, planning and subsequently developing their own meaning through rules and stories that connected with their functionality.

The children's enthusiasm for our prototypes motivated us to extend our inquiry to study younger children under the age of five by engaging with a new setting. By discussing the project with a number of collaborators, we were introduced to Rowans Nursery (pseudonymised), a nursery local to the research team's universities. Rowans Nursery accommodated preschool children (aged between 3 and 5 years) and advertised themselves as having a strong interest in outdoor play and nature. This ethos was evidenced by the nursery's access to a large garden, woodland and the availability of nature-based activities, both indoors and out. They were also underpinned by a Montessori educational philosophy, and so placed an emphasis on guided play. The manager of Rowans Nursery (pseudo-anonymised as Liz) was keen to work with us because she was already looking at ways that technology could feature within their curriculum. Liz talked about the need for modern day Montessori activities and described how this had been challenging to realise. She described failed attempts by the nursery staff to set up a wildlife camera to support children's interest in nature. She also described a small toy bee with wheels that could be programmed to move in particular directions simply by pressing arrows on top of the toy. Liz was sceptical at first about playing with technology outdoors, principally because she had imagined the use of tablets. She came around to the idea when we showed videos of physical-digital prototypes from our previous and ongoing work, and explained that children still engage in important aspects of associated with free play outdoors like social interaction with other children and physical activity [15, 58].

Liz gave us an initial tour of Rowans and talked about their ethos and strategic approach. Their indoor space was organised according to different educational themes, with learning materials being carefully arranged on trays that can be freely chosen and removed by children. In line with Montessori, many of the play materials at Rowans had a focus on practical learning and real-world activities. For instance, one tray consisted of wooden blocks, nails and a hammer, another involved pouring liquid from a jug to individual containers of differing volumes. Nature was a central theme within Rowans with books and materials on show relating to the natural world. A majority of artefacts on show were chosen because they were made of natural materials, including: wood, brass, wicker, cotton and glass. Montessori believed that imagination stemmed from children, and not toys, and that interacting with real, everyday materials and things, enriched children's ability to imagine and create, whilst at the same time providing a valuable understanding of the real word [34].

Rowans encouraged free play outdoors, enabled by the large nursery garden, which had been designed around the developmental needs of preschool children. The garden provided open space for the children to be physically active and to develop strength and coordination, with varied landscaping that included uneven, undulated and textured surfaces, walls to jump over and bushes to climb through. There was an area for the children to dig and to engage in construction play with loose materials, such as tyres and different shapes and sizes of wooden planks and plastic pipes. Like materials found indoors, these loose materials can be found in the real world. The intention is to provide children with authentic material experiences, that enable them to explore their different properties, in order to acquire life skills through play. Similarly, there was also a kitchen area, with utensils, that was to support imaginative play, with a focus on real life experiences.

The researchers were shown a woodland behind the nursery that was a five-minute walk to reach. Liz described how the children were regularly taken to the woodland and given the freedom to explore and play in the woods. On occasions staff would also hold craft activities in the woods with outdoor materials, or play games with the children. Playing freely in the woods offered new sensory experiences for the children, enabled them to demonstrate independence, and would hopefully cultivate an interest in nature from a young age. An important policy for Rowans was to take the children to play in the woods in every season and in (almost) any weather.

Rowans' Early Years Practitioners (EYPs) knew each attending child well and had a tacit sense of their needs and the importance of supporting them to learn and develop outdoors through free play with other children. In line with Montessori education [34], the children were encouraged to direct their own play and learning with available resources. Children were introduced to activities, but left to freely choose what was interesting to them. For example, the

doors into the garden are opened twice each day for forty minutes so the children could choose to play indoors, or out, under the supervision of EYPs. Liz explained that some of the children chose to play outdoors more than others, and while many of the older children played cooperatively, the youngest children would tend to play alone, but watch the older children. We did observe the children playing 'What's the Time Mr Wolf' however this was supported by EYPs, the children did not play structured games with rules outdoors independently.

## 3.2 Lantern Development

Based on our discussions with Liz, and on visiting both Rowans and the nearby woodland, our design response centred on developing concepts for configuring tangible IoT resources that would be fitting with the woodland and garden environments in terms of aesthetic form. We decided early on to work with light because our engagements with children would take place in Autumn and Winter, when it gets darker earlier in the UK. We were inspired by the way that light contributes to enchantment for children during festivities prevalent at this time of year in the UK, such as Halloween, Christmas, and Guy Fawkes night. We explored a range of possible forms but quickly settled on a Lantern based design for a range of reasons. Following early discussions with Liz we wanted to reflect concerns inherent in the kinds of resources available to children at Rowans. Liz, like us, was keen for the configuration of our resources to inspire outdoor free play but to have some basis in the real-world in relation to both the woodland and the garden. This would mean EYPs could easily introduce our resources to children in a simple and relatable manner. Lighting up a darkened woodland, for example, made sense as a scenario when introducing the Lanterns to the children, and Lanterns are already common in gardens in the UK and so would not seem out of place.

Our work was also guided by the wider context of our project exploring how programmable IoT might facilitate outdoor play, which involved creating Do-it-Yourself (DIY) resources that families and children could download and make themselves using the Micro:bit. The form factor of the Lantern could be appropriately sized so as to be easily held and played with by preschool children, but also had the capacity to contain a BBC Micro:bit and a Kitronik Halo add-on (a ring consisting of 24 addressable RGB LED, to enable interactions with light). The Halo add-on for the BBC Micro:bit, was widely available in the UK, easy to assemble, and at the time of our work was being used in primary education around computing and IT. While we do not examine this design intention in the fieldwork reported later in this paper, we wanted to ensure our DIY Lanterns could be constructed using affordable off-the-shelf materials, or even recycled or waste materials, and this informed our final design.

We considered the Lantern further by creating a range of prototypes that were discussed within the project team. These early prototypes related to different aspects of the design. Several prototypes explored the construction of the Lantern, ensuring this could be easily made at home while being robust enough to be used outdoors (Figure 1). We also made and iterated a number of experience prototypes that allowed us to discuss, refine and experiment with different interactions within the team [9]. Alongside our own prototyping, we tested an early Lantern with older children from the community centre by having them construct and program their own Lanterns. This was an opportunity to see how these children responded to a variety of open-ended interactions with the Lanterns and to uncover any technical challenges we had not yet considered.

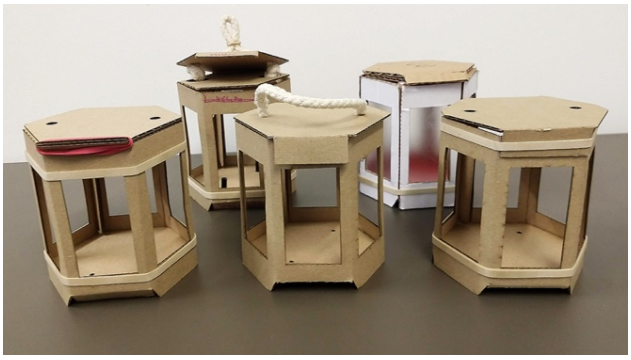

**Figure 1: A series of Lantern prototypes exploring their construction**

In response to the nursery setting, we wanted the preschool children to engage in active free play, by engaging with each other, exploring and making full use of the various environmental features of both the woodland and garden. We did not for example, want the children to become fixated and to linger in specific locations. While experience prototyping as a team, we began experimenting with interactions that involved light moving between Lanterns when they are in close proximity. Intrinsically this encouraged interaction with each other, and we found children at the community centre responded similarly. Correspondingly, and in response to previous design work with children [15], we experimented with different behaviours and related metaphors with light that would be familiar, and appropriate to preschool children, such as, shaking, catching and chasing, which informed our final configurations of the Lanterns which are discussed in more detail in Section 3.4. We felt the movement of light between Lanterns was captivating, and tangible enough to be easily appropriated by preschool children, who could explore their functionality simply by placing the Lanterns close to each other. Sticks are a feature of the outdoors, and children already enjoy playing with sticks. We felt that adding the Lantern to the end of a stick using string added to the appeal of the interaction, since children could extend the Lanterns reach, and it wobbled curiously on the end of the stick. Relatedly, we anticipated that by placing further Lanterns in and around the garden or woodland, which also responded to proximity, the children could be prompted to move around the outdoors, and for example, into, over and under more difficult to reach areas, thus prompting them to explore. The use of light moving between Lanterns when in proximity, could be easily programmed without needing additional components, thus ensuring the design is easily constructed. Using the built-in radio, it is possible to determine the proximity of Lanterns, and to create a simple network with unique identifiers in order to move light to specific Lanterns.

**Figure 2: Lantern Design. (a) Detail (b) Cardboard Construction ©Thomas Dylan**

**Figure 3: Lantern Outdoors at Rowans (a) In-situ Lantern (b) Lanterns in a wicker basket ©Thomas Dylan**

## 3.3 Lantern Design

The final Lantern (Figure 2, a) is made out of cardboard that is cut out, folded and held together using stationery (Figure 2, b). Windows are then added, which softens the light, and although other materials can be used, we chose to cut the windows from milk cartons. Once the main body is constructed, string is fed through holes in the top of the Lantern and then tied. The string can be used as a handle, or attached to a stick using an elastic band. We made the Lanterns showerproof by painting them with off-the-shelf Shellac (PVA glue can also be used). The lid of the Lantern is also larger than the main body, meaning rain will not run inside. The Micro:bit, Halo and batteries are attached using paper fasteners and can be easily accessed by opening the top or bottom of the Lantern.

We wanted to reflect Rowans' concern for natural aesthetics and materials, wherever possible, so that the Lantern did not appear out of place in either the woodland or the garden. In turn, we left the cardboard unfinished so it appeared natural in tone, used cotton string and hung the Lantern from a stick made of willow (though any wooden stick would suffice). We also considered natural qualities of light by using an orange hue that is reminiscent of flame for the default colour of light in both interactions.

In addition to the Lantern itself, a simple structure using sticks (in this case willow) and string can be used to hang the Lanterns outdoors (within this paper we call these in-situ Lanterns), (Figure 3, a). Throughout our fieldwork, we also stored and carried the Lanterns in a natural wicker basket (Figure 3, b) that was in keeping with the importance of the presentation of materials within the Montessori philosophy.

## 3.4 Lantern Configurations

When configuring interactive behaviours for the Lanterns, we were informed by Dourish's now mature conceptual framework of Embodied Interaction [14]. As such, we considered how the tangible nature of the computational artefacts that we designed would interact with the configurability of the space, as well as the children and EYPs in the space, as a relationship of physical and social constraints. Important to note is that we were not designing games, but instead looking to create open-ended functional features that could scaffold children's exploratory free play in ways that are active and social. We designed two configurations of the Lanterns to support our explorations in each outdoor environment (the woodland and the garden). Both build on metaphors that were discussed and coined with the manager of Rowans nursery. Metaphor has been shown as an important means through which children understand the world around them, and can be mapped to gestures and physical interactions that are critical to children's development [1, 38].

*3.4.1 Lighting the Way.* In discussion with Liz, we decided to configure the Lantern design for the woods so that it would mimic a flame. Although the children would be free to improvise with our Lanterns, Liz felt it was important to have a theme around the metaphor of the flame, through which the Lantern could be introduced to the children. In this case, the theme became "Lighting

the Way". We believed this notion would be simple enough to understand, and enchanting enough to inspire the children's free play. If you shake the Lantern, or move too quickly when the light is turned-on, then it will gently turn-off. If a Lantern that is turned-on, and is placed near a Lantern that is turned-off, then this second Lantern will gently turn-on again. In this open-ended interaction there was no specified end goal, and the interaction was direct and consistent. We also speculated that this interaction might encourage the children to share and work together in play by finding ways to keep each other's Lanterns turned-on. The theme Lighting the Way led us to include six in-situ Lanterns that functioned in the same way as other Lanterns. As mentioned, we believed that in-situ Lanterns would offer varied opportunities for improvisation in free play by extending the children's interactions into the environment. Since all the Lanterns can turn-off we also included a Micro:bit 'Match' so that EYPs could 'relight' the Lanterns for the children should they need to: 'When you shake the match close to Lanterns, they will turn-on'.

*3.4.2 Passing the Green.* In the second interaction we wanted to introduce a degree of unpredictability into the Lantern's behaviours. We played with the idea of there being an entity (a ghost, or fairy perhaps) trapped in the Lantern and that children may improvise by catching the entity from other children, by protecting it, or by trying to get rid of it. Since there would only be a single entity, and this would be the main feature of the presented story, we believed it would encourage social play. When showing Liz an early example of this interaction she described it as *"Passing the Green"*; she felt this would be a suitable label for introducing the interaction to the children without structuring their play.

Passing the Green involves all the Lanterns being a default orange colour, except for one Lantern that is green. When a Lantern is close to (within approximately 20cm distance) the Lantern that is green, the green colour will move back and forth between the Lanterns every two seconds as long as they remain close to each other. When multiple Lanterns are close to each other the green colour continues to move randomly between all the Lanterns every two seconds. If a Lantern that is green in colour is moved away from other Lanterns that are orange in colour within two seconds then that Lantern will remain green so long as other Lanterns do not get close. When the green colour moves between the Lanterns it does so by gently fading out, then fading in on another Lantern, as if passing between them.

While testing Passing the Green, the ongoing back and forth movement of the green colour between Lanterns was much more dynamic than a singular passing of the green light. This movement introduced a degree of unpredictability that meant all the children would likely have the green colour at some point, even if by accident.

# 4 EVALUATIVE FIELD WORK

We observed the children and EYPs using the Lanterns and Lighting the Way in the woods (approximately two times 40-minute observations) and the Lanterns and Passing the Green in the garden (approximately two times 40-minute observations). The sessions were 40 minutes long to fit-in with break time. For all sessions we had two EYPs supporting the preschool children who were between three to five years old. While the same nursery group was present, there were fluctuations in numbers due to attendance, and choice around playing outside. Further detail about how the EYPs introduced both themes is found in our observations section.

## 4.1 The Woodland

The woodland location was a sloped clearing that was scattered with trees and shrubs. Children moved within an area approximately 18m by 18m (256 square meters.). On the day of our study it was raining, and because the ground was covered with leaves it was slippery. The same ten children were present in the woodland for both 40-minute observations, and were supervised by Liz, and an EYP, Jesse. There were enough Lanterns for one per child. These Lanterns were kept in a basket and we had pre-placed some sticks around the basket for the children to collect. Though we had thought children could find their own sticks, during an initial visit there were surprisingly few in the clearing. We placed seven in-situ Lanterns throughout the woodland. To make finding and venturing to in-situ Lanterns more challenging, we placed several under bushes, behind trees, and on steeper sections of slope. The woodland was a five-minute walk for the children. Simple ground rules were explained by EYPs: "*You can go anywhere in the woods as long as when I shout 1-2-3, where are you? You stop and make sure I can see you.*"

## 4.2 The Garden

Other than an introduction to the Passing the Green by EYPs, the children were using the garden as they normally would; they were free to come and go while in the garden and so we had a maximum of twelve and a minimum of seven children. The children were supervised by two EYPs, Jesse and Rose. There were six Lanterns available to the children when playing with the Passing the Green. We never provided a Lantern each because we did not want the children to feel they had to play with the Passing the Green. There were other resources available at Rowans, and the children could be either inside or out. The garden is approximately 16 metres by 10 metres (160 Sq. M.), and so there was a good amount of space for the children to play together.

## 4.3 Video and Observation

Much of the children's play with the Lanterns was likely to be non-verbal, and involve gestures and fast-paced movement around both the garden and woodland. As such, we opted to take brief field-notes, and video recordings and photographs using hand-held cameras. Two researchers were present during research engagements. Directly after each visit, both researchers developed and extended their fieldnotes, and shared reflections, commenting on video-clips together. The nursery manager was not concerned about our use of video-clips because these were regularly used to capture and share learning experiences with parents or guardians. At the end of our research engagements, we conducted a follow-up interview with both EYPs. Questions derived from field-notes and observations and related to individual children and their interaction with the Lanterns and each other, as well as the rationale behind EYPs occasional guidance.

We qualitatively analysed the video, in an iterative process of coding and editing clips of footage based on identifying common behavioural themes, mapping to the affordances of the two configurations, Lighting the Way, and Passing the Green, and addressing our research questions. The first author coded segments of footage by describing and interpreting observed behaviours, identifying initial themes; and then the research team collectively reviewed and analysed the selected edits, and reflected together to consolidate the themes, holding fieldnotes, interview transcripts, and other related observational data to hand. All of the data was anonymised, and herein all research participants at both sites are pseudonymised. Given the visual nature of our observations and analysis, we include in our report herein (Section 5) video stills as figures (with children's faces deliberate masqueraded as per our ethics protocol), which are directly associated with specific vignettes. We encourage the reader to consider these figures in conjunction with the observational account that supported our analysis.

## 4.4 Ethical Considerations

The nursery manager was involved at all stages of our process of obtaining informed consent from parents for their children to participate in the study. Information sheets and consent forms were posted to parents, along with a letter explaining the nursery manager's involvement in the project and what would take place on the day. In the morning, prior to study commencement, the nursery manager introduced researchers to the children and explained that we would be using a camera to learn about how they play. EYPs were introduced to the project in person and invited to participate. They were given information sheets and consent forms. The children were always supervised by EYPs and the prototypes themselves were used as part of normal activities meaning there was minimal disruption to the children's time at nursery.

# 5 OBSERVATIONS

## 5.1 Observing Lighting the Way

*5.1.1 Freedom to find and Explore the Lanterns.* Though the children would be given the freedom to play with the Lanterns on their own, Liz (manager) was keen to introduce them in a manner that would contribute to the children's woodland experience. When the children arrived, they were asked what they could see. Answers included, the stream, trees, and finally one of the children spotted a Lantern and said "*I can see this*". Liz asked, "*and what do you think that is children?*" One of the children replied, "*a light*". Meanwhile, Sophie and Martha were already over the other side of the woodland area and announced: "*look what we have found!*" The children were then asked if they could find any more Lanterns. This continued for some time until all the Lanterns were found and the children had some familiarity with where they were located. The children were then asked if they would like their own Lantern, and if so to find a stick, and get a Lantern from the basket. One of the researchers then helped the children add the Lantern to the end of a stick; all the children took a Lantern. EYPs then began guiding the children so they could learn how the Lanterns functioned. For instance, when Maddie was given her Lantern, Liz said "*Are you going to light it Maddie?".* Jesse (EYP) pointed to one of the situated Lanterns and said, "*Look, you can use that one over there?*" Maddie ran down the hill, put her Lantern close beside the in-situ Lantern so it turned-on, held her Lantern up and announced "*Look!*" to the rest of the group. Maddie ran back up the hill, back toward the other children, only for her Lantern to turn-off. Banging the Lantern to the floor, Maddie said, "*not again!*" And ran back down the hill. For some children it was not immediately apparent whether the Lantern turning-off was a feature, or a problem with the Lantern. For example, when Edwards' Lantern and an in-situ Lantern turned-off because he banged them together, he looked concerned and ran back up the hill to Jesse (EYP).

*5.1.2 Children were Guided in Play.* Sometimes guidance would be given when it was apparent children were not sure how to play with their Lantern. David was not playing with the other children and seemed unsure about what he could, or should be doing, and so sought Jesse. In turn, David was shown how to use the match, by Jesse, and encouraged to "*help*" by finding and lighting Lanterns so the other children could play. David looked for further reassurance from Jesse and in turn, she said kindly, "*I'm just watching you; I'm not doing it for you*". Jesse stayed with David initially to provide some reassurance, before leaving him alone to explore, find and relight Lanterns for himself (Figure 4). David made his way around the woods and lit four Lanterns before he was called upon to help a small group of children by Liz: "*David, come and light these ones, help Anna*". David made his way over to the other children and began lighting their Lanterns. Jesse commented on how happy David was with his new role and subsequent engagement with the other children. We observed that some children were better able to improvise while playing with the Lanterns, others required additional guidance which was given with a focus on encouraging independence.

In a related instance, Edward looked lost and apparently unsure what to do next and so Jesse encouraged *him* to help the other children. Jesse asks, "*Edward, can you light your one with that Lantern?*". On lighting his Lantern, Jesse replied, O*h wow, good Job*". Hope then shook her Lantern deliberately and announced playfully to the rest of the group, '*Oh no, what am I going to do?!*" Jesse responded, "*Is Joseph going to help you light yours?*". At the same time, Tim's Lantern turned off and Jesse commented, "*Oh no! Look Tim's has gone out now too*". Meanwhile Fox noticed that the children's lights were turned-off, and with a serious look on his face, turned to place his Lantern next to Hope's Lantern, quickly followed by Tim's.

*5.1.3 Children Chose how to Play.* Edward continued to be unsure about how to play with the other children and was screaming and holding his Lantern in front of Jesse, as a prompt for her to use the match. Once lit, Edward would shake the Lantern, and scream again. Jesse tried to encourage Edward to go and play with the other children, but after a short while resigned to giving him the match. Martha, Laura and Hope had been watching and began screaming for Edward to light their Lantern with the match. This repeated numerous times, with the children shaking their Lanterns, watching the light turn-off, and screaming until Edward used the match (Figure 5). The match allowed the children to easily relight their Lanterns and so there was no incentive for them to find the pre-placed Lanterns. This meant the children moved around very little. Nevertheless, the children were visibly enjoying their interaction with each other and their play with the Lantern was something

**Figure 4: David helping other children by lighting Lanterns that have extinguished ©Thomas Dylan**


**Figure 5: Children repeatedly lighting, screaming and extinguishing their Lantern ©Thomas Dylan**


**Figure 6: Martha and Sophie moving between the Lanterns ©Thomas Dylan**

they chose. The children were perhaps enjoying their play so much, precisely because they felt the Lanterns were not intended to be used in this way. The children visibly enjoyed screaming, something they were free to do outdoors, but not in the classroom.

Sophie and Martha never sought any support from EYPs, were quick to experiment with the Lanterns, and wanted to demonstrate their independence. Liz commented on how keen Sophie and Martha had been to challenge themselves, by lighting their Lanterns, with in-situ Lanterns that were much farther away than other children would venture. Martha said to Sophie, "*Come on, let's go this way*", while using her Lantern to point to an in-situ Lantern

**Figure 7: Passing the Green in the garden ©Thomas Dylan**

that was nestled under a bush. Martha agreed by saying, "*Look!*". Once there the children bent their knees, and reached out so their Lanterns were close enough to the in-situ Lantern for it to turn-on. Sophie then raised her Lantern up, shook it on the end of the stick, and watched intently as the light turned off. Both children did this repeatedly until, on the sixth time, Sophie knocked the preplaced Lantern and caused all the Lanterns to turn-off. As shown in Figure 6, both Sophie and Martha stopped for a moment, as if processing what had just happened. Sophie then spun around with her Lantern, pointed to something in the distance, and said to Martha, "*There, look, it is the same!*" (still turned-on). Martha responded by saying, "*We need to go down.*" Sophie and Martha enthusiastically ran down the hill, steadying themselves so as not to slip, towards a preplaced Lantern that was positioned beside a tree, and their play continued in this way.

Martha and Sophie had a shared purpose and valued the freedom they had to explore and choose between the in-situ Lanterns. There was likely a sense of achievement in demonstrating their independence and challenging themselves in the woods. As with most of the children, Sophie and Martha's play was directed by their *enchantment* with the way that the Lantern moved when shaken, the light gently turning-off, and their *anticipation* of being able to repeat this by finding a means of turning the Lantern on again.

## 5.2 Observing Passing the Green

*5.2.1 Children were Guided.* The Lanterns were left in the garden for the children to find (Figure 7), with Jesse providing initial guidance by prompting the children to "*pass the green light*". Jesse would say, "*Oh Jenny! Look you have the green light now*" and "*Maddie pass the green light to Anna, that's it, oh wow!*". The children followed

**Figure 8: Maddie provoking the children to come after her ©Thomas Dylan**

Jesse's lead, watched as the green light moved to other children, and meandered around a small area near were Jesse and Rose (EYP) were standing. Generally, for about the first 10 minutes the children appear to be following guidance, and were supervised in their play.

*5.2.2 Play was at Times Provoked.* During early explorations, many of the children were curious, but appeared unsure about what they could, or should be doing. Play lacked spontaneity and interaction with the Lanterns appeared on occasions, coincidental. The following vignette describes Maddie's improvisations and failed attempts at using indicative and playful gesturing to provoke the other children to play with her.

A group of four children, including Maddie, had pointed their Lanterns inwards and were banging them against each other, watching as the green moved between Lanterns. The group began to drift apart and just as it did so, Maddie noticed Sophie had 'the green' and lunged forward reaching her Lantern out, clearly intending to make her own Lantern green. Sophie appeared somewhat disinterested, walked away and left her Lantern on top of a wall. Maddie walked away, looking at her Lantern, which was now green. She held her Lantern carefully, away from the other children, as if she had caught something precious. Maddie then got a little too close to David, but he never noticed, or cared as his Lantern turned green. Sophie then returned and a small group formed again. As before, the children banged their Lanterns together, only this time Maddie exclaimed "*Got you!*" as they did so. Again, the group drifted apart and reformed, but this time, Maddie stepped outside the group in a more obvious manner as if trying to provoke the other children to come after her. Maddie can be seen provoking the group with the green light in Figure 8. The other children stood banging their orange Lanterns together whilst Maddie held her Lantern, which was green, out in front of the other children and teased them: "*ha! ha!*" Maddie slowly walked away and the group followed, and again Maddie taunted them by jumping backwards several times, away from the group, with the green light. Jesse said: "*Oh! Maddie has stolen it*".

There was little verbal communication between the children during this interaction. Maddie instead used *improvised* movements to communicate intent. Her playful gestures and teasing, showed she understood how she wanted to play with the green, but this required the other children to share that understanding.

*5.2.3 Children's Guided Play Transitioned To Free Play.* Once the children took ownership of their play with Passing the Green, they became significantly more active in their movement in the garden. The transition between play that was introduced by EYPs, and free play, took place when Ben, who had been watching Maddie, was given a Lantern. Jesse said, "*you need to pass the green light*". The green was passed to Ben, however he had other ideas, and ran away holding his Lantern out in front while playfully making noises (Figure 9, a). The other four children began chasing Ben while playfully shouting: "*Give it back*", "*He has the green one*" and "*he stole it*". The other children caught up with Ben and get close enough for Maddie to have the green, all the while the other children are chasing and shouting: "*Give it back*", "*Go get her*", *Come back with that*". As shown in Figure 9 (b), every so often, the children would catch up with each other, stop and watch intently as the green light moved between their Lanterns. It wasn't until one of the children decided to run away with the green, that the chasing would begin again. The children were excited by the functionality of Passing the Green and knew how they could play with it; collectively the green light became known as 'the green one', and was commonly seen as an entity to be caught by the children. The children made full use of the garden when playing with Passing the Green. They would meander around the tarmac, jump over walls, stand in the construction materials and hide in the bushes. The children became more engaged and this was expressed through excitement, shouting, and movement, which was encouraged by the prevalence of the green light, but expressed freely through choice.

*5.2.4 Movement of Light Created Excitement And Anticipation.* The following vignette is typical of our subsequent observations, though as noted in the proceeding section, play was spontaneous and children would often stop, choose to do something else, and re-join shortly after. The Lanterns were passed between children, or left lying and picked up, and so different children played at different times. That being said, there was a core set of children, including Maddie, Ben and Charlie, who instigated much of the group play we observed.

Ben and Charlie chased Maddie. Ben shouted, "*I want the green one*". Maddie was running with her Lantern out in front of her, it was wobbling quickly on the end of the stick. She was approaching the end of the garden, but decided to climb up the wall and into the bushes. Sam protested, "*out of the Batcave*". As Maddie entered the bushes, with Ben close behind, Charlie decided to run the other way, to catch Maddie as she tried to come back out of the bushes and over the wall on the other side. Maddie spotted Charlie as she made her way toward the wall, and is smiling as Charlie swung his Lantern out towards her. Maddie turned around quickly, only to have Ben behind her, she was trapped and the children stopped running because 'the green' was now moving between the Lanterns, and no one could easily get away.

Other children with Lanterns spotted 'the green' and made their way over, seven children (some with, and others without a Lantern) formed a group around 'the green', some holding their Lanterns high in the air as 'the green' moved around (Figure 10, a). Children with Lanterns were watching, anticipating 'the green', and as soon as Ben noticed his Lantern was green, he held it out, quickly taking a few steps forward and going "*Ah! Oh! Ahhh!*" as he tried to get

**Figure 9: (a) Ben running away with Passing the Green (b) Children grouping together around the green light ©Thomas Dylan**

**Figure 10: (a), (b), (c) The children group together and anticipate the movement of the green light ©Thomas Dylan**

away (Figure 10, b). As soon as he did the Lantern moved again, and Charlie, who was now beside him, got 'the green' instead (Figure 10, c).

Although there were no explicit rules, and play varied, overall, the children developed a shared understanding of trying to "*catch the green one*". The children's play was spontaneous and rarely competitive. Though Charlie caught the green in the above vignette, Ben was smiling and appeared to revel in *anticipation* and suspense, as vocalised and expressed in his movement with the Lantern. The green moving between Lanterns, when nearby other Lanterns, was a direct function that was understood by the children and informed their free play. However, the green moved unpredictably, and this introduced *anticipation* and suspense, which was *enchanting* for the children.

As play progressed with the Passing the Green, we observed the children becoming more sophisticated in their play and control of the Lantern. Ben and Edward were particularly elaborate in their movement with the Lantern. In Figure 11 (a), for example, we see Ben holding the Lantern out stretched, and in Figure 11 (b), spinning around to avoid Maddie. The physical form of the Lantern complimented Passing the Green, and the observed free play, because this introduced novel kinds of movements, dexterities and motor-skills that were enchanting and rewarding for the children. The way the Lantern wobbled and shook on the end of the stick, as the children ran, and spun around, contributed further to their delight in playing with the Lantern.

*5.2.5 There were Other Ad Hoc Playful Interactions Outdoors.* The children were free to choose in the garden and so while we have presented vignettes relating to core aspects of the children's play, children came and went, and were playing in other ways. Children, for example, were playing on space hoppers, rolling pipes down the hill, and pretending to be Batman. Others were meandering around, climbing on walls, sometimes seeming unoccupied. Children ran alongside those playing with the Lanterns, or simply watched. David and Maddie were observed fishing over a temporary wall and putting their Lanterns in a puddle. Jesse asked them not to in case they broke the Lantern. Our observations were full of variety, children exploring the world around them, and children enjoying their own explorations.

## 6 DISCUSSION

We have reported on our RtD study investigating the configuration of digital resources for preschool children's free play outdoors. We have shown the ways in which open-ended resources can support social and physical aspects of outdoor play, and through our observations, we can identify interactional qualities of free play promoted by the Lanterns. These include expressions of: enchantment, improvisation, anticipation and choice – resonant with the literature on free play [8, 37, 40]. We now turn to consolidate our study findings and present transferable insights that may support and guide interaction designers. While in our work we sought to promote free and open-ended forms of play, there is no doubting that the constraints designers place on functionality, even in open-ended designs, is going to inform children's free play in different ways. However, the ultimate goal is children choose within those constraints. In this way, experiential qualities *"reside in the interaction, neither being properties of the user or the artefact"* [46]. There is no way to know for sure that an experiential quality will be rendered when used, but to some extent, we can for example posit that the dynamics evident in Passing the Green are transferable to other children outdoors. In this case, designing for outdoor play is about creating conditions in which the qualities we are seeking can manifest, but ultimately

**Figure 11: Children becoming more sophisticated when handling the Lantern ©Thomas Dylan**

the nature of free play is unpredictable and open-ended resources should be interpreted by children themselves.

In this spirit, we consolidate our transferable insights via the presentation of three Sensitising Concepts [5, 7, 54, 59]; these build on an long-standing understanding of Embodied Interaction in the HCI field [14], to offer new thinking in relation to the context of children's free, outdoor play and to the latest developments in IoT and tangible technologies. The value of sensitising concepts is in their ability to inspire and guide interaction designers without constraining the design process, and providing a "*general sense of reference and guidance in approaching empirical instances*" [13]. As interpretive devices, they can be used to further investigate and contest assumptions about a situated and social phenomenon [5]. Building on our initial design development and subsequent observations of children's outdoor interactions, we propose the following sensitising concepts: Choosing the way; Improvising in movement; and Anticipating a response.

## 6.1 Choosing the Way

Create conditions for children to able to be 'choose their way' in free play outdoors. Interactions that are open-ended invite children to improvise in their play together. When outdoors, this also relates to movement through a place, providing enough freedom for children to explore, be curious, and to make their own decisions on how they want to use the outdoors. This may be a woodland, garden, public park, or other outdoor setting for recreation.

A key feature of the Lantern design was that the interactive device was configured in a metaphorical form that was relatable to the children: as a Lantern on a stick, with a light inside that symbolised a flame. A stick is a classic open-ended plaything for the outdoors, for poking around and exploring in wider, deeper spaces. In our RtD study, the stick physically projected a Lantern into a bigger and more expansive space than possible in indoor confines. We suggest that these two material forms afforded a playful probing, encapsulated in a pointing gesture, with the light interaction prompting directional movement in a place, and creating just enough enchantment to prompt ad hoc decision making, about where to walk, when to shake, and what to touch. Pointing is recognised as a fundamentally embodied activity of central significance to HCI design ([14], p147), as is the users' direct control of the Lanterns, to act and explore through. We may highlight these features, coupled with Choice and Enchantment, as qualities of free play observed in the Lanterns' use, to understand what worked well to engage the children. As a sensitising concept, 'Choosing the Way' characterises this support to children through design, to decide what they wish to explore.

Our analysis also illuminated how the children initially took some time to understand and direct their own play with the Lanterns, scaffolded by the EYPs. We observed the contrast in engagement between guided exploratory play and free play. That is to say that when the conditions were right, we found the children to be more engaged in their improvisation with the Lanterns. Choice itself was spontaneous, children explored what they found exciting about the Lanterns by experimenting with the light effects, and they also explored social interaction by provoking, and getting a response from each other. Many children came together around shared goals or interests, expressed through gestures and movement, but these were provisional. We observed the importance of independence, and children being creative by setting their own challenges while outdoors. Martha and Sophie explored and ventured further into the woods more than other children, with the Lanterns becoming part of their rationale for doing so. Like Back [2], we emphasise choice as a relationship between the open-ended design, and how its use in free play is expressed in relation to what is afforded by the outdoors. Such a notion extends not only to place and the physical environment, but also to behaviours we might consider inappropriate indoors, like screaming, shouting, or jumping up and down. Although choice can be challenging – and we observed some children requiring support, it also presents opportunity to be creative and to problem solve [21], hopefully leading to greater independence and self-advocacy [18]. Gaver describes ludic design as, "*an engagement that has no fixed path or end, but instead involves a wide-ranging conversation with the circumstances and situations that give it rise*" ([19], p.167). This describes well the free play we observed; however, we draw attention to the important role of Choice as a quality of free play that we observed in preschool children and that expressed a sense of independence through self-directed exploration.

## 6.2 Improvising Through Movement

Consider improvisation in an embodied sense, in practice and in communities of practice, in space and over time, and highlighting the significance of movement for (i) making sense of digital functions and for (ii) improvising in free play to explore digital play resources outdoors.

This concept was informed by the observed significance of movement in the free play interactions with the Lanterns outdoors. The effect of shaking the Lanterns, or moving them abruptly, and bringing them into proximity to each other, was clear to read and understand by the children. We highlight how this feature is about affording direct control to the children, along with a clear mapping between, or 'coupling' of, intentional action and the lighting effects supported by metaphor [14]. As such, the children could meaningfully engage through purposeful *yet still exploratory* movements. With Lighting the Way, making the light 'go out' or trying to keep a Lantern lit, or lighting with a 'match', were engaging features to play with meaningfully; and this included controlling one's body and movement in order to control the Lantern. With Passing the Green, more ambiguity was experienced in the interaction between children and the Lanterns and the lighting effects. But there was still a clear pattern of 'the green one' being 'passed', albeit with some unpredictability, when Lanterns were in close proximity to each other. We see in our video data how this created an engaging embodied interactional context for the children to improvise and move in free, expressive ways, and in social ways, responding to each other, teasing and taunting each other. In these instances, with the children bringing their Lanterns together, the effect of the green light 'dancing about' amongst Lanterns was an interactive feature that *remained interpretable* by the children – their movement caused the green light to be animated – it had a sense of lively 'anima', and this, in turn was connotative of a magical spirit, something they could relate to from children's stories. Significantly, this feature prompted the children's *improvisation through their movement*, and *stimulated a shared focus* on a curious object that they could explore.

Physical activity is central to children's outdoor play [10], and the Lanterns clearly contributed to how the children chose to move and use their bodies *through the Lanterns*. Our observations showed the children expressing excitement in their movement with the Lanterns and, like other researchers, we suggest this can bring about positive emotions [29] like excitement and enchantment. A majority of open-ended designs by others researchers design for outdoor play lead to children subsequently observing rules or forming 'competitive challenges' [23]. As previously argued, this relates to an overarching focus on older children (7-12 years old). Our observations showed preschool children being spontaneous in their appropriation of the Lanterns, with movement being more central to their improvisations, than rules and their negotiation. Although some rules existed, these were *provisional*, and were not expressed in terms of desire to be in competition, more to nurture social togetherness. In turn, we suggest that existing guidelines (e.g. [50, 51]) for open-ended designs for children in free play are contingent on a more careful consideration of age and developmental stages, as outlined for example by Parten [37]. Therefore, this sensitising concept draws attention to the *importance of improvisation through movement in preschool children.*

## 6.3 Anticipating a Response

Afford purposeful yet exploratory interaction with artefacts, people, and environment, through the design of device behaviours that respond with visible effect to device interaction. This 'coupling' supports children's playful anticipation of a response, and prompts meaningful social play around the responses and their interpretation.

Underpinning many of the children's playful interactions with the Lanterns was *anticipation of a response*, which was inherent in both their intrigue and enchantment with the interactive features and in social play. Indeed, we identified Anticipation as another key feature of the children's free play. Lighting the Way offered a consistent response – or coupling [14] – and this was supported by the themes and metaphors that were designed to support the engagement. Sometimes, anticipation emerged from a sense of what could be expected from the Lanterns, around which many of the children created their own play structures. Overwhelmingly, the Lantern 'extinguishing' became a feature in play, where rather than trying to keep the Lantern 'lit' the children anticipated the opportunity to 'extinguish' this for themselves by shaking. Repetition and anticipation also went hand in hand for many of the children. Martha and Sophie were driven to explore not because they wanted to 'light' their Lantern per se, but because they anticipated being able to shake the Lantern and watch it 'extinguish'. Martha, Laura, Hope and Edward, appeared to anticipate not only the interaction, but also screaming, and knowing that the other children were going to scream along with them.

Passing the Green appeared to disrupt this repetition and consistency by introducing ambiguity into the movement of 'the green one' between the Lanterns. This suited the dynamic play we observed, with improvisation in movement being amplified by the spontaneity of the 'green one' as it moved between the Lanterns. The children naturally wanted to catch the 'green one' because there was only one. Anticipation therefore emerged from this experience of ambiguity, where children trying to catch the 'green one' were not certain whether it would appear in front of them; and even if it did, they might not be quick enough to get away from other children. Important to foreground here is the element of surprise that came with the ambiguity, and we observed how this this created fun, excitement and enchantment as part of anticipating – but not being sure of – a response. This experience was further enhanced by what we describe as 'improvisation through movement.'

The importance of a design being *relatable*, by building on metaphors and by affording a coupling where meaningful action (albeit still exploratory) is practiced through the device, was found to be important to preschool children (building on [19]). However, we suggest herein that designers can endeavour to achieve a productive balance between *direct control* and *ambiguity*, because this can support a playful experience of *anticipation* with social dimensions. Too much ambiguity, and it is difficult to know what is going to happen – it's hard to 'choose a way'. But with a degree of ambiguity in an interaction, there is the potential to introduce anticipation as an exciting feature that inspires exploration and improvisation in embodied interaction. This sensitising concept is more specific than the broader concept of affordance. In the context of children's free play outdoors, it refers to how the device feedback supports a child's feeling of anticipation as a ludic and social phenomenon, providing enough of a prompt for meaningful action through direct control, while also introducing 'just enough' ambiguity to support spontaneity and exploration as features of free play.

### 6.4 Limitations and Further Work

Though this work has taken place naturalistically within the nursery setting, our study of the Lanterns in use has derived from a set of four specific sessions. In further studies we plan to study our resources over a longer period of time in additional nursery and community settings to understand their long-term appropriation and use by children outdoors. Though we present sensitising concepts that we believe to be of value to others pursuing design for outdoor free-play, we acknowledge these could be developed further by adopting them iteratively in further design work within our team. Additional studies that more formally explore the differences between analogue and digital play by preschool children is also important when understanding opportunities and consequences, where digital resources for outdoor play to become more ubiquitous in children's lives.

## 7 CONCLUSION

This RtD inquiry has investigated the design of open-ended resources for preschool children's free play outdoors through the design and evaluation of light-based interactions with Lanterns. The Lanterns themselves were designed so as to be relatable to the children and not out of place outdoors. We configured two interactions for the Lanterns with a focus on social and physical interaction. Through our observations, we consider expressions of: enchantment, improvisation, anticipation and choice. In order to provide pragmatic guidelines for future design research in the space we contribute three sensitising concepts: Choosing the Way, Improvising through Movement, and Anticipating a Response. 'Choosing the Way' stresses the importance of supporting children in deciding how they want to play outdoors and by considering the wider influence of the outdoor environment on children's free play. This also highlights choice when interacting with the outdoors, in exploring the woods with the Lanterns. 'Improvising through Movement' relates to the ways in which children expressed themselves in free play through physical interaction with the Lantern, and exploring the outdoor environment. Finally, Anticipating a Response emphasises the value of creating direct couplings between intentional (albeit exploratory) action and visible effects, that also create anticipation and promote social play between children.

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