From Felt Experience to Robotic Design: Embodied Techniques for Expressive Movement and Shape

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Abstract

This paper builds on the premise that the performing arts constitute a field of knowledge that can inspire new approaches to robot design and behaviour in social robotics, and provides concrete guidance on how designers can integrate embodied performance techniques into their practice. Our work draws specifically on the concept of de-mechanisation from Augusto Boal's Theatre of the Oppressed. De-mechanisation focuses on disrupting participants' habitual bodily patterns through playful, accessible prompts that invite imaginative movement without the need for prior training. We argue that these exercises enable robot designers—who are not typically trained in expressive movement—to explore motion from a first-person, embodied perspective, fostering empathy and sparking inspiration for more imaginative movement design for non-anthropomorphic robots. In addition to a selection of de-mechanisation exercises, we propose a wearable body-extension toolkit designed for body extension and body encasement as part of an embodied ideation approach. We tested this approach in a workshop centred on designing an emotionally expressive two-cuboid robot. Using interpretative phenomenological analysis (IPA), we examined how participants experienced bodily disruption, reconfigured movement perception, and developed expressive, affective, and imaginative understandings through the interplay of form and movement. Based on these findings, we evaluate the effectiveness of the method and articulate how our approach extends existing embodied design methods.

CCS Concepts

• **Human-centered computing → Interaction design process and methods**.

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theatre-based design, embodied prototyping, performance techniques, expressive movement, human-robot interaction, non-anthropomorphic robots, bodystorming, playful design method, soma design, toolkit

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1 Introduction

As robots increasingly move from industrial contexts into everyday social environments, designing robots that people can intuitively understand and comfortably interact with has become a central concern in human–robot interaction (HRI)[8] . While early discussions around the uncanny valley [22] places strong emphasis on visual appearance to avoid negative reactions, growing evidence suggests that movement plays an equally—if not more—critical role in shaping human perception of robots, as humans are highly sensitive to motion cues[14][32]. Recent HRI research therefore advocates bringing the communicative impact of movement into the early stages of design, alongside and in relation to emerging visual form, rather than treating movement as something added after shape has been determined [12]. This expressive movement-centric approach has led to the development of robots with simple or abstract forms whose expressive qualities emerge through carefully crafted movement rather than anatomical realism. Such strategies have proven particularly effective for simple, non-anthropomorphic robots, which are well suited for consumer-facing applications such as robotic furniture, abstract companions, and everyday interactive objects. Despite the value of this approach, implementing it in practice remains challenging. Designing movement that is socially legible and contextually appropriate—and ensuring coherence between movement and physical form—typically requires iterative, rapid prototyping rather than abstract ideation alone. Early-stage movement prototyping requires technically demanding processes such as mechanical design and programming, and therefore poses significant developmental challenges for designers.

A growing body of research in social human–robot interaction points to the potential of performance-based and embodied design methods for integrating embodied knowledge early on into design processes, enabling the carefully crafted integration of specific movement aesthetics and experiential qualities of interaction within technically complex systems[21][48][39][26][43][38][9][37]. However, many such approaches either rely heavily on expert performers or adopt performative formats that are not well suited to non-actors, often introducing performance pressure and social anxiety that constrain, rather than enable, designers' creative exploration. As a result, these methods remain difficult for designers to apply independently, particularly during rapid, early-stage exploration.

Building on this gap, we therefore consider whether there are specific performance techniques which can be easily integrated into frameworks that designers can actively use. In this context, we focus on theatre, as theatrical methods have long been applied beyond professional performance settings, and many theatrical training practices foreground playful exercises as a core mode of exploration[33][40][35]. Play has been widely recognised for its capacity to reduce pressure and social anxiety, while encouraging open-ended exploration and experimentation[7][29].

More specifically, we ask: How might playful, theatre-based embodied methods support designers without performance training in generating imaginative movement and shape for simple, non-anthropomorphic robots?

To explore this question, we draw on Augusto Boal's *Theatre of the Oppressed*, specifically on the exercises developed to support his notion of *de-mechanisation* [2]. These exercises were selected for two key reasons. First, they encourage participants to break away from habitual, everyday movement patterns—an aim central to de-mechanisation—which we argue supports the exploration of more imaginative, non-anthropomorphic robotic movements and forms. Second, their playful and accessible nature—originally designed for both professional and non-professional performers—enables non-performers to engage in movement exploration while reducing performance pressure and supporting creative confidence.

Building on this, we introduce a wearable body-extension toolkit made from cardboard that constrains and reconfigures the human body, encouraging the exploration of non-anthropomorphic robotic forms through first-person movement experience.

We applied our approach in co-creation workshops centred on exploring emotionally expressive movement for a two-cuboid robot through embodied ideation. To understand how participants experienced and interpreted this embodied ideation process, we adopted an Interpretative Phenomenological Analysis (IPA)-informed approach, examining how bodily constraint, movement exploration, and form shaped participants' expressive, affective, and imaginative sense-making.

2 Related Work

2.1 Social Human-Robot Interaction

As robots increasingly move from industrial settings into everyday social spaces, questions of how to design robots that people feel comfortable around and can readily understand have become central to human–robot interaction research[8][5]. A substantial body of prior work has associated robot likeability and social acceptance with the use of human or animal-like features, frequently equating animacy with anthropomorphic appearance and interaction cues such as verbal communication and facial expressions[6][4][11][1][24].

However, more recent research has begun to challenge the assumption that social expressiveness and likeability must be tied to anthropomorphic or zoomorphic forms, arguing that such coupling can raise user expectations and increase the risk of uncanny valley effects when behavioural fidelity does not align with visual realism[41][47][17]. At the same time, in many applications robots are required to adopt functional, task-driven forms that cannot accommodate anthropomorphic features—for example, domestic cleaning robots or robotic furniture—yet still need to express emotions, moods, or a character in order to be socially acceptable and engaging for users[3]. These considerations have motivated growing interest in non-anthropomorphic robots and alternative channels for social expression. Within this line of work, movement has emerged as a particularly important expressive channel, as it allows robots to convey affective and social information while performing their functional tasks, without relying on additional expressive components such as faces or screens. This makes movement-based expressivity especially suitable for domestic robots, where adding dedicated expressive components may increase cost and complexity without directly supporting task performance. Prior studies suggest that humans' high sensitivity to motion cues enables robot movement to be interpreted as expressive even in non-anthropomorphic embodiments, which in turn has been shown to significantly enhance the perceived quality of human–robot interaction[16][28][45]. For example, a study comparing robots iCat and Roomba have demonstrated strong relationships between motion characteristics—particularly acceleration and curvature—and perceived affect, showing that arousal and valence can be systematically encoded in motion parameters[31]. Other work using mechanoid robots without anthropomorphic facial features has shown that variations in velocity and acceleration alone are sufficient for users to reliably perceive different emotional states, with consistent results across multiple affective models[36]. Similarly, research integrating movement analysis frameworks such as Laban Movement Analysis into robotic manipulators has demonstrated that robots can express both emotionally expressive states (e.g., angry, happy, sad, shy) and functionally expressive states (e.g., hesitation) purely through the design of movement trajectories[27].

Existing approaches to robotic movement design often demand a diverse and highly specialized skill set, spanning animation, mechanical design, and control or model-based programming. Animation-based methods frequently abstract away real-world physical interaction dynamics, while control-centric approaches tend to prioritize feasibility, efficiency, and stability, requiring substantial technical expertise. Within such workflows, considerations of social interaction and user experience are commonly introduced after key decisions regarding form, structure, and actuation have already been made. As a result, their influence on movement design is limited due to the range of possible movements being inherently constrained by the morphology and mechanical structure of the robot.

In response to this limitation, Hoffman and Ju proposed an expressive movement-centric HRI design framework that introduces the expressive impact of movement early in the design process in parallel with the development of mechanical structure and visual form[12]. This often leads to robots with simple or abstract forms whose expressive qualities emerge through carefully crafted movement rather than anatomical realism. Such approaches have proven particularly effective for simple, non-anthropomorphic robots which are well suited for consumer-facing applications such as robotic furniture or abstract companions. At the same time, this expressive movement-centric design approach still presents several design challenges, including uncovering expressive movement qualities while accounting for mechanical constraints and achieving coherent alignment between form and motion. These challenges point to the need for participatory design processes and exploratory, rapid-prototyping methods. Recent work by Lalioti and Ionescu[18] proposes a design-centric participatory approach for creating expressive and culturally sensitive robot movement, explicitly prioritizing expressiveness even in the absence of functional goals. While their participatory structure supports early incorporation of user insight, the resulting understandings are largely grounded in abstract ideation, which may constrain the diversity and richness of movement expressions that could emerge through more embodied and experiential exploration.

2.2 Performance-Based Method in Social Human-Robot Interaction

Performance art plays a critical role in social robotics by contributing embodied knowledge, movement literacy, and interactional expertise that enable robots to communicate social meaning, intention, and affect through the body—particularly in the absence of language, anthropomorphism, or abstract cognition. A growing body of work has demonstrated that performance-informed approaches can enhance not only the aesthetic qualities but also the experiential dimensions of social human–robot interaction by foregrounding movement, timing, and relational dynamics[21][37][39][43][10].

One area of research in particular, is focused on exploring embodied improvisation and personality-based design for autonomous robot behavior[21][37][39]. These approaches draw on improvisational theatre skills to generate and evaluate design ideas, using personality as a guiding framework for robot behavior. The design process typically begins with selecting a desired personality through brainstorming, and/or initial interaction in order to understand affordances and potential capabilities of a robotic object. This is followed by a phase in which improvisational theatre actors or dancers improvise interactions with the object based on the chosen personality. Designers document these sessions through sketches, storyboards, or video recordings, and subsequently translate performers' expressions and movement qualities into robotic behaviors. The process often concludes with evaluation activities, such as think-aloud protocols or crowdsourced studies, to gather people's perceptions of the robot's newly generated expressions. These approaches establish a form of co-design that brings designers and performance experts together to generate and evaluate ideas using embodied performance knowledge.

Machine Movement Lab's performance Alloyed Bodies[10] presents an explicitly artistic approach to exploring human–robot relationships by framing performance-making itself as a mode of inquiry and an embodied prototyping tool. The work introduces Relational Body Mapping, a method that allows dancers to embody machine-like artifacts in order to generate movement data for robot design and machine learning. Through artistic exploration and the use of physical props, Alloyed Bodies expands understandings of human–machine relationships and challenges conventional notions of interaction and embodiment. By harnessing dancers' expertise, the project investigates transcorporeal attunement to non-human-like forms and supports more-than-human modes of meaning-making.

Other research has explored how principles of improvisation can inform robot behavior design beyond goal-oriented interaction[43]. Irene and Hendrik investigate the use of rule-based improvisation to support non-goal-oriented interaction in human–robot interaction. They demonstrate how structured improvisational rules, drawing on practices from performance and improvisational arts, can guide a robot's movement choices without relying on explicit goals or emotional states. Their results show that this approach facilitates rich and playful interactions; furthermore, interaction conditions based on improvised timing and action patterns are perceived as more animate, while also sustaining user engagement over longer periods of time.

Together, these studies provide strong evidence that performance arts expertise can meaningfully enhance the aesthetic and social qualities of human–robot interaction. However, they rely heavily on expert performers and therefore cannot be readily carried out by designers alone, limiting their accessibility and practicality for rapid early-stage exploration.

With the development of interaction technologies from screen-based interfaces to full-body, embodied forms of interaction, design methodologies have increasingly emphasized placing the designer's body directly within the design process[20][34][13][23][15][44]. Within HRI, one of the most widely adopted embodied ideation techniques is bodystorming[48][26][38]. Bodystorming is an embodied design technique in which designers explore interaction ideas by physically situating their bodies within the context of the interaction being designed. By combining role-playing, props, and immersion in environments resembling the target context, bodystorming enables empathic and spontaneous prototyping, drawing on designers' tacit bodily knowledge to generate insights into user experience.

Prior work has demonstrated the value of bodystorming across diverse HRI contexts. Amazon reports the use of bodystorming in the early-stage behavior design of two robots: Astro, a home social robot supporting everyday domestic assistance, presence, and proactive interaction, and Proteus, a warehouse mobile robot focused on safe and socially acceptable navigation in shared human–robot workspaces[38]. This work highlights several advantages of bodystorming in industrial HRI design. These include the ability to explore robot behavior without modifying code or hardware; its suitability for early-stage behavior design, interaction exploration, and social norm testing; and the benefits of low-fidelity enactments, in which real robots might otherwise constrain designers' imagination. In addition, bodystorming allows designers to draw on bodily experience to assess whether robot behaviors feel socially appropriate, revealing interactional details—such as distance, timing, rhythm, and interruption—that are difficult to surface through abstract discussion alone. At the same time, the authors note that bodystorming introduces a relatively high psychological and performative barrier for participants, as it requires acting, improvisation, and bodily engagement; not all participants feel comfortable with such activities, a challenge that is particularly pronounced in formal or "serious" work environments such as warehouse settings.

At the level of technical systems, Synthé is a software environment designed to facilitate bodystorming for human–robot interaction[26]. It allows designers to enact multiple demonstrations of the same interaction, with two designers role-playing the human and the robot. These enactments are recorded using cameras and microphones, and are automatically captured and translated into robot behavior prototypes through program synthesis. Synthé aims to support designers in drawing on their intrinsic understanding of human interaction when creating human–robot interactions. The authors also identify a similar key challenge: designers may feel uncomfortable performing or acting, which can result in unnatural enactments and limit the realism of the resulting interaction behaviors.

Embodied methods such as bodystorming have demonstrated significant value in social human-robot interaction design, particularly in early-stage exploratory processes; however, their practical application reveals persistent challenges. While bodystorming adopts the form of performance and improvisational practices, it is typically conducted with designers or participants who lack formal performance training. As a result, participants often experience pressure or social anxiety during enactment which can limit the naturalness, expressiveness, and diversity of interaction behaviors that emerge. A key limitation of many existing approaches is that they draw on performative formats without explicitly transferring the underlying techniques and embodied knowledge of performance training to designers. This gap points to the need to more directly integrate concrete performance training methods and techniques into embodied design approaches that are accessible and supportive for non-performers.

2.3 Translating Performance Practices into Embodied Design Methods for Non-Performers

Recent work has begun to explicitly address the importance of equipping roboticists and designers with concrete skills drawn from performance. Rather than positioning performance expertise solely in the hands of trained artists, these approaches treat embodied training itself as a critical component of robot design practice.

Choreographic and somatic approaches have been applied at the Robotics, Automation, and Dance (RAD) Lab to cultivate embodied thinking in engineers, primarily drawing on the Laban/Bartenieff Movement System[19]. Through practices such as effort motive annotation, spatial pull exploration, and improvised scene composition, engineers are intentionally immersed in somatic learning environments. These exercises develop perceptual and expressive capacities including sensitivity to rhythm, breath, posture, and spatial patterning, which are essential for designing robot behaviors that are socially legible, emotionally expressive, and spatially responsive. Importantly, this work emphasizes that certain forms of movement knowledge cannot be acquired through abstract instruction alone, but require direct, bodily experience. The authors further argue that such subjective and creative approaches constitute a strength rather than a limitation, as they allow designers to explore a broader range of movement mappings without prematurely constraining robotic behavior.

Applied improvisation has been adopted as a training framework for social robotics in educational contexts, integrating improvisational theatre methods alongside technical training in human–robot interaction[46]. In a teaching case conducted by Williams at the Colorado School of Mines, in collaboration with the Denver-based improv troupe Not My Robot, social robotics is reconceptualised as an Applied Improvisation project. The resulting curriculum combines weekly improvisation sessions with technical HRI training and is structured in two phases: first, building embodied sensitivity and perceptual awareness through theatre-based exercises; and second, translating these embodied experiences into concrete strategies for robot interaction design. The curriculum centers on three improvisational skill domains identified as essential for social robots—Hyperperception, Rapid Action, and Quality Communication—and employs exercises such as Zip-Zap-Zop, collaborative storytelling, and physical object roleplay to cultivate attentiveness, interaction timing, spatial coordination, and nonverbal communication. These embodied experiences are explicitly mapped onto robot behavior modeling and design decisions, and even within short-term training, students reported increased confidence, engagement, and perceptual acuity when designing interactive robot behaviors. This demonstrates that structured improvisational training can rapidly equip non-performers with embodied design skills relevant to social robotics.

These studies demonstrate the feasibility and effectiveness of integrating concrete performance training techniques into the education and practice of engineers and designers. They show that, when appropriately structured, performance-based training can enable non-performers to acquire and apply embodied skills that significantly enhance the quality of social robot behavior design.

Motivated by this body of work and by calls to integrate expressive movement into the early stages of movement-centric, non-anthropomorphic HRI design, we turn to Augusto Boal's Theatre of the Oppressed, particularly his notion of de-mechanisation. De-mechanisation describes a process of undoing habitual, socially conditioned bodily mechanisms, through which everyday gestures, postures, and modes of interaction—shaped and constrained by cultural norms—are opened to exploration and transformation. Boal's physical, sensory, emotional, and imaginative exercises dismantle bodily automatisms and invite participants to rediscover the body as an expressive and autonomous instrument. These exercises are particularly suitable for our context for two reasons. First, by encouraging participants to break away from habitual movement patterns, de-mechanisation supports the exploration of more imaginative and non-anthropomorphic robotic forms and movements. Second, their playful and accessible nature—originally developed for both professional and non-professional performers—allows non-performers to explore movement expressivity with reduced performance pressure.

We further extend Boal's de-mechanisation approach by introducing a wearable body-extension toolkit. Informed by the use of body-extension props in Alloyed Bodies[10] which prompts participants to rethink non-anthropomorphic robot movement through their own bodily experience, our toolkit constrains the human body to approximate the possible robotic form and movement capabilities. By functioning as a physical obstruction, it foregrounds subjective, first-person movement experience and fosters relational empathy with the robot, supporting the translation of de-mechanised bodily exploration into early-stage robotic movement design.

3 Methodological Framework

3.1 Authors' Positionality

The first author is a human–robot interaction design student who was exposed to performance-based approaches through creative robotics studies but initially perceived barriers to applying them in practice. This perspective shifted during an internship at LEGO, where they experienced how theatre-based games can be used in co-creation workshops with children to generate embodied insights, reduce pressure, encourage participation, and support creative exploration. At the same time, exposure to modular, hands-on construction systems fostered an appreciation for tangible, playful, and constraint-driven design practices. Together, these experiences shaped the first author's interest in using playful and material constraints to support embodied ideation for non-performers.

The last author is trained in both performance and engineering, bringing experience in embodied movement exploration alongside technical system design. Collectively, the authors' backgrounds span computer engineering, performing arts, animation, creative robotics, and interaction design. These perspectives shape how we approach robot movement as a material for design, how we value embodied and experiential knowledge, and how we translate performance-based practices into accessible tools for designers. Rather than positioning this method as neutral or universal, we acknowledge that it emerges from these intersecting practices and ways of knowing, and we consider reflexivity central to responsible embodied design research.

3.2 Methodology Overview

We propose an embodied ideation approach for exploring expressive movement and form for simple, non-anthropomorphic robots. To realise this aim, we adopt a practice-based design methodology that combines performance-based exploration—drawing on Augusto Boal's de-mechanisation techniques from the Theatre of the Oppressed—with a purpose-built wearable toolkit. These activities encourage participants to break away from habitual movement patterns and explore more imaginative bodily expressions.

To further support this process, we introduce a wearable body-extension toolkit made from cardboard that constrains and reconfigures the human body, encouraging exploration of non-anthropomorphic robotic forms. As a physical obstruction, the toolkit supports somatic, first-person movement experiences and fosters relational, embodied engagement. Our research method centres on phenomenological bodily exploration, positioning movement as a first-person, situated, and reflective design material.

We applied this approach in a case study exploring an emotionally expressive robot form. The study deliberately imposed strong formal constraints, limiting the configuration to a minimal structure composed of two cuboid elements. This setup enabled a focused investigation of expressive movement qualities at a fundamental level and supported participants in attending to how bodily proportion, form, and constraint shape expression.

The study received ethical approval from the University of the Arts London prior to commencement. Informed consent was obtained from all participants for their involvement and for the collection, use, and analysis of materials generated during the workshops.

To examine how participants experienced and made sense of embodied ideation through theatre-based exercises and the wearable toolkit, we adopted an Interpretative Phenomenological Analysis (IPA)-informed approach. Our analysis is grounded in a phenomenological perspective, focusing on participants' lived, first-person bodily experiences. Rather than treating responses as evaluative feedback, we interpret them as accounts of how participants perceived, felt, and made meaning of their embodied interaction with the toolkit and activities.

The Circumplex Model of Affect from Figure 3 was also used during the workshop to structure participants' exploration of emotional expression and to inform the interpretation of movement qualities in relation to arousal and valence, providing a complementary quantitative perspective to the qualitative analysis.

3.3 Wearable Body-extension Toolkit

3.3.1 Iterative Toolkit Development. The wearable body-extension toolkit underwent iterative development. In its initial version, the toolkit included a wider range of geometric shapes, intended to offer participants multiple options for bodily augmentation and to encourage diverse explorations of form and movement.

This configuration was tested in a preliminary study with three participants. During the movement exploration exercises, we observed that when participants attended to multiple connection points simultaneously, their movements became increasingly random and less focused. Expressive movement qualities tended to emerge primarily along a single axis, while the diversity of shapes and configurations made it difficult to identify consistent patterns across explorations.

Based on these observations, and to reduce perceived complexity, we introduced additional constraints in the next iteration of the toolkit. First, we reduced the shape vocabulary to include only cuboid forms of varying sizes. Participants were then instructed to adopt a minimal wearable configuration, limiting themselves to "two movable bodies," meaning that only two body extensions could be used simultaneously. Together, these constraints aimed to support more focused embodied exploration and to make emerging movement patterns easier to observe and compare across participants and across iterations.

3.3.2 Wearable Body-extension Toolkit. The wearable body-extension toolkit (Figure 1) constrains and reconfigures the human body to encourage the exploration of non-anthropomorphic robotic forms. By functioning as a physical obstruction, the toolkit supports subjective, first-person movement experiences and fosters relational empathy through embodied engagement.

Figure 1: Wearable Body-extension Toolkit

While a broader range of geometries could offer richer possibilities, this work focuses on cuboid forms to investigate how altered body proportions, apparent volume, and shifts in centre of mass influence movement and expressive potential. The dimensions were selected to align with Laban Movement Analysis perspectives on Body and Shape [25]. We therefore created the cuboid bodies with the following distinct proportions: 1×1×1, 1×1×2, 1×2×2, and 2×2×2.

To enable these forms to be worn on different parts of the body, the cuboids were fabricated from lightweight cardboard and incorporated a range of attachment mechanisms—including Velcro, elastic bands, handles, and simple slot-based connections. These allowed the cuboids to be securely mounted on the head, arms, and in a full-body torso configuration [42].

A full inventory of the manufactured shapes is shown in Figure 1, with corresponding descriptions provided in Table 1.

3.4 De-mechanisation–Based Embodied Activities

The workshop activities (Table 2) were adapted from Augusto Boal's de-mechanisation exercises from Theatre of the Oppressed [2]. These exercises were selected for two main reasons. First, by encouraging participants to break away from habitual bodily patterns, de-mechanisation supports more imaginative approaches to movement exploration. Second, their playful and accessible nature—originally developed for both professional and non-professional performers—enables non-performers to engage in embodied exploration while reducing performance pressure.

Recognising that designers without performance backgrounds may lack movement literacy for expressing particular qualities, we adopted a strategy that foregrounds a play–explore–discover process.

To encourage broader experimentation, we selected exercises that activate different body parts and explore varied spatial levels and speeds, helping participants engage rarely used bodily capacities and discover expressive qualities through playful exploration. We also combined tasks that emphasised first-person bodily perception with tasks guided by an external focus point. This allowed participants to both sense how their movement experience was altered, and explore movement through externally directed actions rather than self-conscious performance.

Based on these considerations, we selected three exercises that together form a progressive sequence, moving from warm-up and general bodily activation, to more specific and focused movement exploration. These exercises are described in Table 2as originally presented by Augusto Boal. For the purposes of our research, however, we extend Boal's method by enabling embodied movement exploration through wearable body augmentation and structured ethnographic reflection. We introduced the following alterations.

The first exercise, *"Keep the Balloon in the Air"*, was used in our workshop as an icebreaker prior to introducing the wearable body-extension toolkit. Its simplicity, playfulness, and collective nature made it effective in engaging all participants simultaneously, whilst gently easing them into movement-based exploration. To support its function as an icebreaker, participants were arranged in a circle formation, and the balloon was passed across the circle from participant to participant. Participants were asked to remain in the circle and collectively keep the balloon in the air using different parts of their bodies.

The second exercise, *"What Is the Object?"*, originates from Boal's *Dynamising Several Senses* series [2]. In our adaptation, participants were divided into groups of three. Within each group, one participant took on the role of the *Robot*, one the role of the *Assistant*, and the third the role of the *Ethnographer*.

The participant enacting the *Robot* was instructed to select cuboid shapes from the wearable toolkit and attach them to their body. They were then blindfolded.

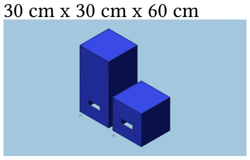
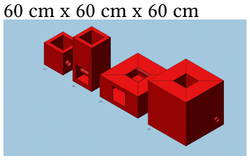
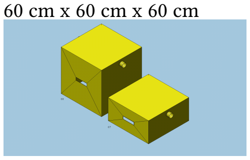
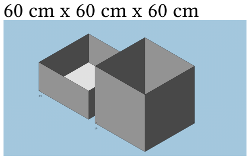
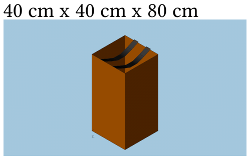
The participant enacting the *Assistant* was responsible for ensuring the safety of the *Robot*. They were further instructed to select an object from the provided set and offer it to the *Robot* for exploration. The items included a jacket, a balloon, a student ID card, a chair, and a pen.

The *Robot* was instructed to use their wearable body extensions to touch, hold, and explore the object.

The *Ethnographer* was given a templated movement reflection card (Figure 2) and encouraged to observe the interaction and annotate their observations.

In Boal's original version, the exercise aims to increase sensory sensitivity in the parts of the body that come into contact with the object. In our adaptation, it is designed to extend this enhanced sensitivity throughout the augmented body, encouraging participants to imagine it as a touch-receptive form. As in the original exercise, accurate object identification was not the goal. Instead, as the first activity following the adoption of the body-extension, it offered a concrete exploratory task that supported first-person

Table 1: Wearable Body-Extension Toolkit Components

No.	Dimensions	Body Part	Additional Features	Average Body Assumptions
1, 2	30 cm x 30 cm x 30 cm, 30 cm x 30 cm x 60 cm 	Head	1. The structure consisted of two crossed cardboard strips with Velcro fastenings at the ends, allowing adjustment and fixation within a range of 30–90 cm to accommodate different head circumferences. 2. A horizontal cardboard strip (10 cm wide) was positioned approximately 26 cm from the opening end of the box to rest against the top of the head. Held in place by friction, it remained stable while allowing slight flexibility. 3. A 12 × 4 cm opening was cut at the center of the structure, approximately 14 cm from one open end, allowing the participant to see through the structure during use.	Adult head anthropometry were considered, including head circumference (520–620 mm), head height (220–250 mm), eye-level-to-vertex distance (120–150 mm), eye opening height (9–12 mm), eye width (24–30 mm), and interpupillary distance (58–70 mm).
3, 4, 5, 6	30 cm x 30 cm x 30 cm, 30 cm x 30 cm x 60 cm, 60 cm x 60 cm x 30 cm, 60 cm x 60 cm x 60 cm 	Arm	1. A 20 × 20 cm opening was cut into the center of one face, allowing participants to insert their arm into the box. 2. A cylindrical handle made from rolled cardboard was positioned approximately 5 cm from the opposite edge to support gripping and stabilise the cuboid during use. 3. As cuboid variants No. 4 and No. 5 are not fully centrally symmetric, additional openings were incorporated on both the top and side surfaces to support multiple orientations.	Adult arm anthropometry were considered, including upper arm circumference (approximately 230–360 mm) and shoulder-to-wrist length (approximately 510–610 mm).
7, 8	60 cm x 60 cm x 30 cm, 60 cm x 60 cm x 60 cm 	Upper Body	1. The bottom face of the structure was left fully open, allowing participants to enter the structure. 2. A cylindrical cardboard handle spanned the cuboid horizontally, positioned approximately 5 cm below the top face, allowing participants to grip the structure with both hands and move it together with their body. 2. A centrally positioned rectangular opening (16 × 4 cm) was cut into the structure to provide visual access to the outside.	Adult upper-body anthropometry was considered, including shoulder circumference (approximately 900–1100 mm) and waist circumference (approximately 650–1000 mm).
9, 10	60 cm x 60 cm x 30 cm, 60 cm x 60 cm x 60 cm 	Lower Body	An empty cuboid with an open top face allowed participants to adopt flexible postures, including standing, squatting, or sitting inside the structure.	Adult lower-body anthropometry was considered, including hip circumference (approximately 900–1100 mm) and thigh circumference (approximately 450–650 mm).
11	40 cm x 40 cm x 80 cm 	Torso	1. Two 5 cm wide Velcro shoulder straps were centrally positioned and spaced 14 cm apart, enabling flexible attachment of the cuboid module at different torso locations and allowing the arms to be positioned either inside or outside the structure. 2. Interlaced cardboard strips were placed in the central region to provide friction-based fixation, improving wearing stability across different torso sizes. 3. While maintaining an overall 1 × 1 × 2 proportion, the base unit was scaled to 40 cm (rather than 30 cm as in the other modules) to better accommodate torso-related body dimensions.	Adult torso anthropometry was considered, including waist circumference (approximately 650–1050 mm), shoulder breadth (approximately 360–480 mm), and hip circumference (approximately 850–1150 mm).

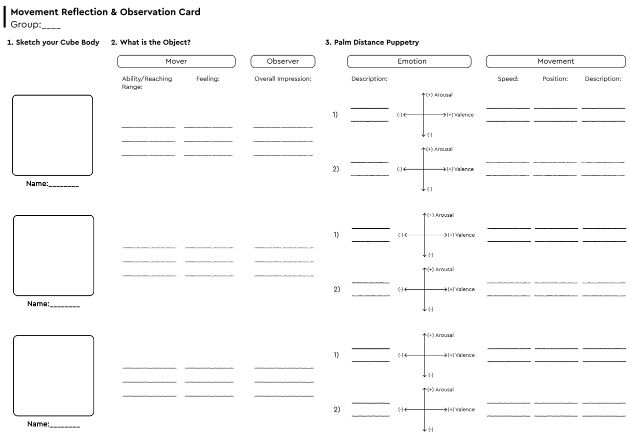


Figure 2: Templated Movement Reflection Card

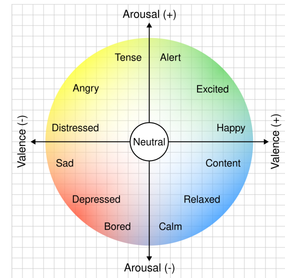


Figure 3: Circumplex Model of Affect

reflection on how the transformed body configuration influenced perception and movement.

The third exercise, *"Palm-Distance Puppetry,"* was adapted from Colombian Hypnosis, which also belongs to the Restructuring Muscular Relations series [2]. In Boal's original exercise, participants are divided into pairs. Within each pair, one participant takes on the role of the *Leader* and the other the *Follower*. The *Leader* is instructed to hold their palm parallel to the *Follower*'s face at a fixed distance and use it as a stimulus for movement. The main rule of the exercise is that the *Follower* must keep moving so that their face remains parallel to the *Leader*'s hand and at the same distance from it.

In our version, as in the previous exercise, participants were divided into groups of three. Within each group, one participant took on the role of the *Robot/Follower*, one the role of the *Leader*, and the third the role of the *Ethnographer*. As before, the *Robot* was instructed to use the wearable body-extension toolkit during the exercise.

The *Robot/Follower* and *Leader* followed rules similar to those in the original exercise, with one key modification: we did not restrict the interaction to the face. Instead, the *Leader* was allowed to guide any augmented body part of the *Robot/Follower*. Boal's original version introduces an external reference point to initiate movement and activate bodily responses that are rarely used in everyday motion. Rather than emphasising muscular activation alone, we focused on exploring uncommon movement patterns through the augmented body across varied speeds, directions, and spatial positions. The *Robot/Follower* was encouraged to integrate the entire body augmentation into their kinetic sensitivity.

As in the previous exercise, the *Ethnographer* was given a templated movement reflection card (Figure 2) and encouraged to observe and annotate the interaction, while also acting as the group's active reflexive lens throughout the activity.

The wearable toolkit constituted a key component of our adaptation and an extension of Boal's original physical theatre method. By functioning as a physical obstruction, it constrained the body to approximate a robotic form, enabling first-person, embodied engagement with the experience of inhabiting a non-humanoid robotic form. These embodied explorations were intentionally designed to generate movement qualities and relational insights that would later inform robotic prototyping in Phase 2.

In parallel, the reflection card(Figure 2) operated as an ethnographic instrument supporting real-time documentation during ideation. It guided participants to sketch the augmented body configuration, reflect on bodily sensations while moving, and capture how altered form and movement were perceived by others.

The embodied movement material and observations generated through these activities formed the core empirical basis for understanding how participants experienced constrained bodily transformation, expressive movement exploration, and playful embodied ideation.

3.5 Open Materials

To support transparency, reuse, and adaptation of the method, we provide an open-source repository containing the workshop structure, activity prompts, and toolkit files used in this study (see https://github.com/jwhitmoo/demechanisation-embodied-design-in-HRI). The repository will be maintained as an evolving resource, with additional materials and documentation added over time.

3.6 Case Study

We applied our approach in co-creation workshops centred on exploring emotionally expressive movement for a two-cuboid robot through embodied ideation.

The study deliberately imposed strong formal constraints, limiting participants to selecting and combining two modules from the wearable body-extension toolkit to create a minimal altered body form. This configuration supported the exploration of expressive movement qualities at a fundamental level, directing participants' attention to how bodily proportion, altered form, and movement constraints influenced expression.

Emotion, as defined in the Circumplex Model of Affect (Figure 3), was used as a concrete case for exploring expressive movement, as it provides a clear and well-established context in HRI for examining how movement qualities communicate affect. It also offered a focused workshop task through which expressive movement could be enacted, observed, and discussed within the constrained two-cuboid setup. To support this, in addition to the de-mechanisation-based embodied activities and wearable body-extension toolkit we introduced an "Emotion Enactment and Guessing" activity, which

Table 2: Original de-mechanisation exercises as described in Boal's Theatre of the Oppressed [2]

No.	Activity	Description	Goal
1	*Keep Balloon in the Air*	Participants are instructed to keep one or more balloons in the air using any part of their bodies rather than relying solely on their hands. They are encouraged to imagine both the balloon and their own bodies as light, inflated, and continuously moving through space.	The exercise is designed to promote relaxation, increase bodily awareness, and stimulate fluid, whole-body engagement beyond habitual movement patterns.
2	*What is the Object*	Participants are instructed to wear blindfolds and explore objects using body parts other than their hands in order to infer their material and spatial qualities.	Visual recognition is deliberately removed to heighten tactile sensitivity across the body and encourage perception through embodied contact.
3	*Palm-Distance Puppetry*	Participants are instructed to work in pairs, alternating between leader and follower roles. The leader positions their palm at a fixed distance from the follower's face and moves it slowly through space, while the follower must continuously adjust their entire body to maintain the same distance and parallel alignment.	The exercise intentionally drives the follower into unfamiliar and exaggerated positions, activating rarely used muscular and spatial movement patterns and expanding bodily responsiveness.

allowed us to examine participants' engagement with embodied performance and whether the workshop helped generate expressive movement ideas and embodied insights that could inform future robot design. The Circumplex Model of Affect further served as a shared reference for structuring participants' exploration of emotional expression.

We collected multiple forms of qualitative data, including video recordings, reflection cards, and semi-structured group discussions. These were consolidated into a unified data corpus and analysed using an IPA-informed approach to examine how designers experienced embodied ideation through the de-mechanisation-based activities and wearable body-extension toolkit, and how these experiences informed the generation of expressive movement concepts for robot design.

3.6.1 Participants. Two co-creation workshops were conducted with a total of ten participants (5 female, 5 male), aged between 18 and 28. All participants were students or early-career practitioners in engineering and/or design, and none had professional training or formal experience in performance or theatre. This was intentional, as the study aimed to examine how non-performers engage with embodied ideation methods adapted from physical theatre. Four participants took part in the first workshop and six in the second.

Owing to this difference in participant numbers, the first workshop was structured primarily around individual participation rather than fixed groups, while the second workshop was organised into two groups of three. In the first workshop, although participants were not divided into fixed groups, they still supported one another during the collaborative activities (Steps 4–6; Figure 4) by flexibly taking on the roles of Assistant, Leader, and Ethnographer as needed.

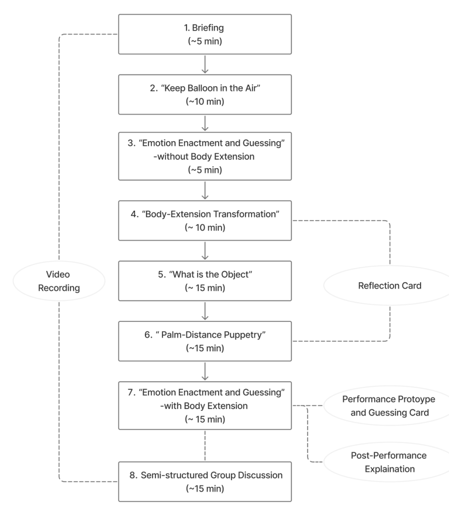


Figure 4: Methodological Workflow Diagram

Participation was voluntary, and informed consent was obtained from all participants prior to the workshops.

3.6.2 Procedure. The workshops were conducted in an indoor open space of approximately 3 × 6 metres, with a smooth and unobstructed floor that provided sufficient room for full-body movement activities. The first author assumed the role of Facilitator, and each session lasted approximately 90 minutes. Although indicative durations were planned for each exercise (as detailed below and in the diagram presented in Figure X), timing remained flexible to sustain a comfortable and creative atmosphere; activities were shortened or extended depending on participants' engagement and physical comfort. Throughout the workshop, the Facilitator encouraged participants to articulate and discuss their bodily sensations and perceptions. The sessions followed a progressively structured sequence of activities, outlined below and illustrated in Figure 4).

The procedure was designed to progressively transition participants from familiar bodily movement to augmented, exploratory, and expressive forms of embodied ideation.

Step 1) Briefing (5 mins): The *Facilitator* introduced the workshop's aim—to explore expressive movement for a two-cuboid robot through embodied ideation—and outlined the session structure. Participants were also introduced to the Circumplex Model of Affect [30] (Figure 3), which was later used to inform completion of the reflection card (Figure 2).

Step 2) "Keep Balloon in the Air" Activity (10 mins) — Warm-up: Participants stood in a circle and collectively kept a balloon in the air using different parts of their bodies. This served as an icebreaker and encouraged broader bodily activation and readiness for non-habitual movement exploration. The activity is illustrated in Figure 5(a).

Step 3) "Emotion Enactment and Guessing" (5 mins) — Without Body Extension: Participants were invited to enact an emotion nonverbally through bodily movement without using wearable augmentation. This task functioned as a control condition, conducted prior to the introduction of the wearable body-extension toolkit to establish a baseline for participants' expressive movement, engagement, and comfort levels. For practical reasons and to maintain a comfortable workshop atmosphere, the activity was positioned after the initial warm-up exercise ("Keep the Balloon in the Air") and before the Body-Extension Transformation (see Figure 4). This sequencing enabled comparison between participants' expressive strategies before and after engaging with the embodied activities and wearable augmentation.

Step 4) "Body-Extension Transformation" (5 mins): Participants explored and selected modules from the Wearable Body-Extension Toolkit (Figure 1, Table 1) and attached them to two chosen body parts.

Step 5) "What Is the Object?" Activity (15 mins): Participants closed their eyes and explored a set of objects using their wearable body extensions. They then sketched their augmented body configuration and documented both first-person bodily sensations and third-person impressions on the reflection card (Figure 2). The activity is illustrated in Figure 5(b).

Step 6) "Palm-Distance Puppetry" Activity (15 mins): One participant assumed the role of *Leader* and guided the movement of a *Follower* through the position of their palm. The *Follower*, wearing body extensions, maintained a fixed distance between the *Leader*'s palm and a designated augmented body part. The participant taking the role of the *Ethnographers* recorded observed movement qualities, perceived emotions, and expressive features on the reflection card (Figure 2). The activity is illustrated in Figure 5(c).

Step 7) "Emotion Enactment and Guessing" (15 mins) — With Body Extension: Participants were given five minutes to reflect on prior activities and rehearse expressive movement using their augmented bodies. Each participant then enacted one to three emotions while others guessed and articulated the movement cues informing their interpretations. The activity is illustrated in Figure 5(d).

Step 8) Semi-structured Discussion (15 mins): The workshop concluded with a semi-structured group discussion in which participants reflected on perceived relationships between movement and emotion; comfort and familiarity with performance before and after the workshop; engagement with specific activities; experiences of using the wearable toolkit; and suggestions for improvement or further exploration.

4 Data Analysis and Interpretation

4.1 Data Collection

Multiple forms of qualitative data were collected to capture participants' embodied experiences, movement ideas, reflections, and overall engagement throughout the workshops. Ethical approval for the study was obtained from the University of the Arts London prior to its commencement. Informed consent was obtained from all participants for their involvement in the study and for the collection, use, and analysis of materials generated during the workshops.

To ensure privacy and confidentiality, all ten participants were anonymised and are referred to throughout the paper as Participants A–J. All collected materials were consolidated into a unified data corpus and analysed using an Interpretative Phenomenological Analysis (IPA)-informed approach.

The following data sources informed the analysis:

Video recordings (Steps 1–7): Video recordings collected throughout the workshops (as shown in Figure 4) captured participants' verbal expressions, embodied movement behaviours, and interactions. These recordings were transcribed using Otter.ai and subsequently manually reviewed and corrected by the facilitator to ensure accuracy, forming a key component of the qualitative data corpus.

Reflection cards (Steps 4–6): Reflection cards were used to document participants' chosen body-extension configurations, their perceived movement abilities, and their subjective experiences and interpretations during the activities. The cards included both written descriptions and participant-generated sketches, as shown in Figure 6.

In the first workshop, each of the four participants was given an individual reflection card; although participants did not work in fixed groups, they took turns observing one another and contributing observer notes to each other's cards. In the second workshop, participants worked in two groups of three, with one reflection card provided to each group. In this context, the observer contributing to the reflection card was the participant taking on the role of the Ethnographer, ensuring structured third-person documentation of movement and expression.

Performance and guessing cards (Step 7): The performance cards documented both the emotion intended by the performer and the emotion perceived by other participants, enabling examination

(a) "Keep Balloon in the Air" Activity (10 mins) — Warm-up

(b) "What Is the Object?" Activity (15 mins)

(c) "Palm-Distance Puppetry" Activity (15 mins)

(d) "Emotion Enactment and Guessing" Activity(15 mins) — With Body Extension

Figure 5: Storyboard of the Embodied Workshop Exercises.

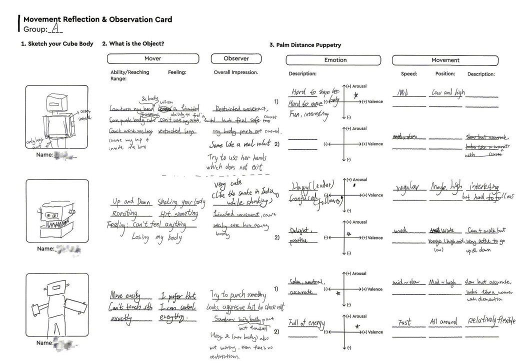


Figure 6: Example of a Filled-in Reflection Card

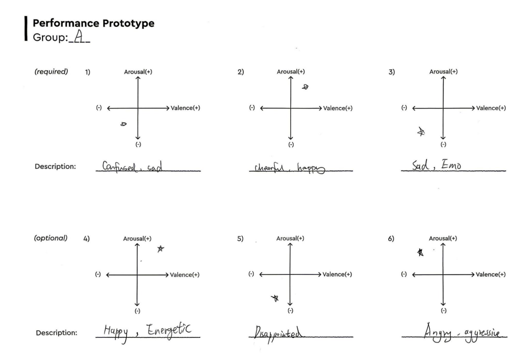


Figure 7: Example of a Filled-in Performance Prototype Card

of how movement cues were interpreted. Performers used a Performance Prototype Card to record the emotion they intended to express (Figure 7), while audience members used a Performance Guessing Card to note the emotion they perceived (Figure 8). Both performance cards were explicitly structured in reference to the Circumplex Model of Affect (Figure 3), providing a shared framework to guide participants in selecting and articulating emotions.

In the first workshop, each participant was given an individual Performance Prototype Card. In the second workshop, participants worked in groups of three and shared one Performance Prototype Card within each group. In both workshops, all participants completed individual Performance Guessing Cards.

Post-performance discussions (Step 7):

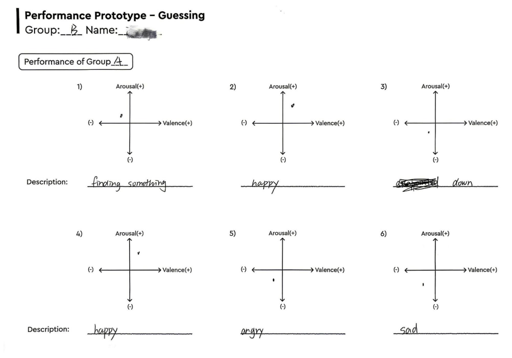


Figure 8: Example of a Filled-in Performance Prototype Guessing Card

Figure 9: Video Snapshot of the Post-performance Discussion

After each performance, participants engaged in a short post-performance discussion reflecting on both the emotions expressed and those perceived. These discussions aimed to capture how participants interpreted movement and attributed meaning to the performance. The facilitator paused after each performance and invited participants to engage in a brief, facilitated group discussion, arranged in a spatial setup designed to support comfort and open expression, as illustrated in Figure 9. Each discussion lasted approximately 1–2 minutes. All discussions were video recorded, transcribed, and manually reviewed for accuracy.

Semi-structured focus group discussion (Step 8):

At the end of each workshop, a semi-structured group discussion was conducted to gain deeper insight into participants' experiences. Participants reflected on the perceived relationship between movement and emotion, their comfort and familiarity with performance before and after the workshop, their engagement with specific activities, their experiences using the wearable toolkit, and suggestions for improvement or further exploration. Figure 10 shows the facilitator in conversation with participants during one of the final discussions. Each discussion lasted approximately 15 minutes. All discussions were video recorded, transcribed, and manually reviewed for accuracy.

Figure 10: Video Snapshot of the Semi-structured Focus Group discussion

4.2 IPA Analysis Framework

This multi-modal corpus enabled a triangulated analysis of participants' embodied experiences, integrating self-reported reflections (first-person accounts), observed movement behaviour (documented by participants in the Ethnographer role), and group discussions (captured by the facilitator through video recordings and their transcriptions). The corpus was analysed iteratively using an Interpretative Phenomenological Analysis (IPA)-informed approach, focusing on identifying meaning units, clustering them into experiential themes, and interpreting how participants made sense of their embodied interaction with the toolkit.

We identified meaning units—significant statements that captured participants' experiences of their bodies, movement, and interactions with the toolkit. These units remained closely grounded in participants' language (e.g., "losing part of my body," "safer in the box," "becoming another person") and were annotated with both descriptive and interpretative notes.

Meaning units were then iteratively clustered into experiential themes, grouping recurrent patterns of bodily perception, affect, and meaning-making across participants. This clustering process was informed by phenomenological analysis techniques, focusing on identifying shared structures of experience rather than the frequency of responses. Through this process, a set of interrelated themes emerged:

Theme 1 – Disruption of bodily shape, senses, and habitual movements
Theme 2 – Reconfiguration of bodily perception and movement
Theme 3 – Expressive and affective movement experience
Theme 4 – Imaginative associations and meaning-making

These themes were supported by recurring experiential clusters, including *bodily constraint*, *reconfiguration*, *movement organisation and dynamics*, *altered sensory perception*, *affective and expressive experience*, and *imagination*, which functioned as mid-level analytical categories linking data-close meaning units to higher-level thematic interpretation.

Finally, themes were interpreted in relation to the study's research question, the design intentions behind the wearable body-extension toolkit, and the theoretical grounding in Augusto Boal's concept of de-mechanisation. This interpretative step examined how embodied disruption, constraint, and play contributed to participants' ability to generate imaginative ideas and draw on first-person experiences to inform creative shape and movement design for non-anthropomorphic robots.

Taken together, this analysis reflects a double hermeneutic process, in which participants made sense of their embodied experience and the researchers engaged in a second-order interpretation of these sense-making processes. An example of the mapping from raw data to meaning units and clustered themes is presented in Tables 3, 4, 5.

5 Findings and Discussion

This research investigates how playful, theatre-based embodied methods—specifically Boal's de-mechanisation-inspired exercises and a wearable body-extension toolkit—supports designers without performance training in generating imaginative movement and shape for simple, non-anthropomorphic robots.

Our findings suggest that this approach extends existing performance-based methods in HRI (such as working with trained performers or bodystorming, as discussed in Section 2) by enabling a structured process of embodied ideation. This process is reflected in four interrelated experiential themes: disruption of bodily shape, senses, and habitual movements (Theme 1); reconfiguration of bodily perception and movement (Theme 2); expressive and affective movement experience (Theme 3); and imaginative associations and meaning-making (Theme 4). Together, these findings suggest that embodied disruption and constraint can be structured as a generative process for supporting non-human design ideation in early-stage HRI.

By leveraging playfulness and embodied constraint—both inherent in performative practices such as Boal's and augmented by the wearable toolkit—this approach reduces self-consciousness and supports more open-ended creative exploration. At the same time, bodily disruption and reconfiguration enable the imagination of non-human robotic forms and movement logics to emerge. The findings further suggest that embodied exploration through bodily reconfiguration can function as an accessible participatory method for addressing the challenge of exploring robotic shape and movement in the early stages of social HRI design.

Our findings also reveal a more unexpected affective dimension: throughout the workshop experience, the wearable body-extension toolkit was experienced not only as restrictive, but also as protective, containing, and at times empowering. This indicates that bodily reconfiguration reshapes how participants relate to performance. This ambivalent yet productive affective state—in which constraint coexists with comfort and support—warrants further investigation.

The following subsections discuss these findings through three interconnected aspects: non-human imagination through bodily disruption and reconfiguration; expressive meaning through shape–movement interplay; and the role of playfulness and constraint as protective empowerment in supporting embodied exploration.

5.1 Enabling Non-Human Imagination through Disruption and Reconfiguration

In extending existing bodystorming work in robot design beyond humanoid movement explorations[26], our findings suggest that bodily disruption (Theme 1) and reconfiguration (Theme 2) can support designers in imagining non-human robotic forms and movement logics (Themes 3 and 4).

These findings resonate with Boal's concept of de-mechanisation[2], in which disrupting habitual bodily patterns helps undo socially and culturally conditioned bodily automatisms, allowing the body to be re-experienced as an expressive and exploratory medium and opening up more imaginative possibilities. Our results demonstrate how this concept can be applied in a design context, enabling robot designers to generate imaginative movement and form for simple, non-anthropomorphic robots.

In our study, this de-mechanising process was also augmented through the wearable body-extension toolkit, which materially reconfigured participants' bodily shape, movement possibilities, and sensory access, making habitual bodily patterns explicit and opening them to reconfiguration in relation to robotic form. We argue that this expands and complements Boal's framework by structuring reconfigurations of the body and guiding them towards robotic shapes, while also paving the way for future toolkit design.

Across participants, a shared experiential trajectory began with an initial disruption of bodily shape, senses, and habitual movements (Theme 1). In the beginning, participants reported discomfort and restriction, describing their bodies as "minimally uncomfortable" (Theme 1) or noting that "I am feeling a bit stuck." (Theme 1). Alongside these physical constraints, participants experienced significant sensory shifts, including reduced touch, restricted vision, and a sense of "losing my body"(Theme 1). This disruption made bodily constraints explicit, shifting movement from something habitual and implicit to something conscious and effortful. Rather than moving habitually, participants became aware of their bodies as constrained systems, marking the beginning of a transition toward increased awareness and altered embodiment.

Following this initial disruption, participants began to experience a reconfiguration of bodily perception and movement (Theme 2). Movement became more segmented and structured, as reflected in statements such as "can turn my head and body… can't move my legs" (Theme 2). This reconfiguration was often accompanied by continued discomfort, suggesting that the experiences described in Themes 1 and 2 represent a transitional phase that participants move through in order to access the more expressive and imaginative experiences associated with Themes 3 and 4. Over time, imaginative thinking began to emerge. Participants started to describe movement in analytical, robotic terms—such as "X or Y axis, Z axis"—indicating a shift toward a more system-like understanding of their bodies (Theme 2).

This transition builds toward expressive and affective movement experience (Theme 3) and imaginative associations and meaning-making (Theme 4). As participants adapted to their reconfigured bodies, movement began to generate imaginative and non-human interpretations. Observers described actions as "same like a real robot," "plant-like, sensitive, flexible," or "like a snake… shaking" (Theme 4), while also noting mismatches such as "trying to use

Table 3: Example mapping from raw data to meaning units and clustered themes for first-person accounts (textual form)

Raw Meaning Units (Data-close)	Meaning Units	Clusters	Final Theme	Data Stream
"Minimal uncomfortable"	Experiencing initial bodily discomfort and unfamiliarity	bodily constraints + affective and expressive experience	Theme 1	Reflection card
"I am feeling a bit stuck"	Experiencing spatially restricted	bodily constraints	Theme 1	Video recording transcriptions
"can't feel anything, losing my body"	Experiencing loss of bodily sensation and altered embodiment	bodily constraints + altered perception	Theme 1	Reflection card
"Restricted view"	Experiencing restricted visual perception	bodily constraints + altered perception	Theme 1	Reflection card
"More difficult to use arm; Limited in a 2D area"	Experiencing difficulty moving under constraint	bodily constraints + reconfiguration	Theme 2	Reflection card
"can turn my head and body…can't move my legs"	Becoming aware of differentiated movement affordances	bodily constraints + reconfiguration + movement organisation and dynamics	Theme 2	Reflection card
"X or Y axis, Z axis, Hand or Head"	Becoming aware of structured and segmented movement	reconfiguration	Theme 2	Reflection card
"Expand contract"	Exploring transformation through constrained movement	reconfiguration + movement organisation and dynamics	Theme 2	Reflection card
"I feel more safe in the box."	Experiencing safety within enclosure	reconfiguration + affective and expressive experience	Theme 3	Semi-structured Group Discussion (Video recording transcriptions)
"Happy was like swaying. Excited was like everywhere, spinning"	Differentiating emotions through distinct movement qualities	movement organisation and dynamics + affective and expressive experience	Theme 3	Post-Performance Discussion (Video recording transcriptions)
"bulky but cozy"	Experiencing tension between comfort and restriction	reconfiguration + affective and expressive experience	Theme 3	Reflection card
"This is the how I destroy B, like minecraft, pickaxe"	Projecting a powerful and destructive role through game-based imagery	reconfiguration + imagination	Theme 4	Video recording transcriptions

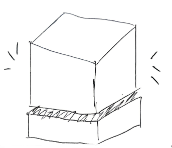
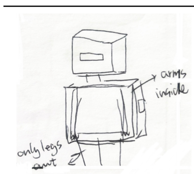
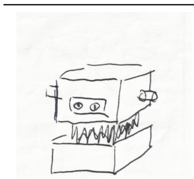
hands which do not exist" (Theme 4). These interpretations indicate a shift away from human-centred expressivity toward non-human, system-like, or organism-inspired movement logics.

Importantly, this progression from Theme 1 to Theme 4 reflects a staged transformation of embodied experience. As illustrated in Figure 4, the sequencing and timing of the activities play a critical role in modulating this transition, gradually guiding participants through phases of disruption, reconfiguration, and expressive exploration. The introduction of the wearable body-extension toolkit (Figure 1, Table 1) at a key point in the process further intensifies this transformation by materially reshaping bodily perception and movement capabilities. Together, these findings suggest that non-human imagination emerges through a staged process of embodied disruption and reconfiguration, rather than through unconstrained ideation.

5.2 Creating Movement and Shape Designs for Simple, Non-Anthropomorphic Robots through First-person Embodied Exploration

In addressing the challenge in expressive movement-centric HRI design of exploring form and motion together at an early stage[12], our findings suggest that embodied exploration from a first-person

Table 4: Example mapping from raw data to meaning units and clustered themes for first-person accounts (drawing + text form

Drawing	Raw Meaning Units (Data-close)	Meaning Units	Clusters	Final Theme
	"Enclosed cube body"	Experiencing body as enclosed and bounded	bodily constraints + reconfiguration	Theme 2
	"Extended arm structure"	Exploring directional movement affordances	reconfiguration	Theme 2
	"Abstract/non-human form"	Imaginative projection of body	imagination	Theme 4
	"Wearing a turtle shell"	Feeling enclosed and protected	imagination + affective and expressive experience	Theme 4
	"Can't feel anything"	Loss of bodily sensation	bodily constraints	Theme 1
	"Snake-like"	Non-human movement interpretation	imagination	Theme 4

perspective through bodily disruption (Theme 1) and reconfiguration (Theme 2) can provide a rapid participatory way for designers to directly sense and investigate relations between shape, movement, and expressive qualities.

This builds on the embodied basis of bodystorming[34][13][23][15][44], which places the designer's body directly within the design process and draws on tacit bodily knowledge to support empathic

Table 5: Example of mapping from raw data to meaning units and clustered themes for third-person accounts (observer: participant in the Ethnographer role

Raw Meaning Units (Data-close)	Meaning Units	Clusters	Final Theme	Data Stream
"try to use her hands which does not exist"	Noticing mismatch between intention and altered embodiment	bodily constraints + reconfiguration	Theme 2	Reflection card
"Bulky but strong, Limited, But can simple movement"	Experiencing constrained yet simplified and expressive movement	movement organisation and dynamics + affective and expressive experience	Theme 3	Reflection card
"the faster you will be moving about your body parts you will be more energetic"	Associating faster movement with greater energy and emotional intensity	affective and expressive experience	Theme 3	Semi-structured Group Discussion (Video recording transcriptions)
"energetic flower"	Interpreting movement through lively organic imagery	imagination	Theme 4	Post-Performance Discussion (Video recording transcriptions)
"Armor Warrior"	Associating form with a strong and protective warrior-like character	imagination	Theme 4	Post-Performance Discussion (Video recording transcriptions)
"king, with the long crown"	Associating form with a king figurer	imagination	Theme 4	Video recording transcriptions

and spontaneous prototyping. In our study, this embodied exploration was shaped through the combination of the wearable body-extension toolkit and de-mechanisation activities. While the wearable toolkit made the relation between shape and movement directly felt through bodily constraint, the de-mechanisation activities encouraged participants to move beyond habitual patterns and explore a broader range of movement possibilities.

Participants consistently highlighted how movement structured through the given activities (Steps 5–7 in Figure 4) made otherwise abstract forms expressive and legible. Initially, the cuboid wearable toolkit was often perceived as abstract and undifferentiated, described as "just cubes… doesn't make sense" (Themes 1 and 2). However, once movement was introduced (Step 6 in Figure 4), these forms came to be described as "quite vivid" (Theme 3). In the later Palm-Distance Puppetry activity (Step 6 in Figure 4), which involved more movement-based exploration, participants further interpreted relational dynamics such as "confrontation" or "obey" (Themes 3 and 4).

At the same time, participants' shared reflections also suggested that bodily constraint became not only a limitation, but also a generative condition for movement exploration and expressive interpretation. They described their altered bodies through metaphors such as "wearing a turtle shell" (Theme 4) or "bulky but strong" (Theme 3), reflecting an emerging awareness of how shape and structure shaped movement possibilities. Observers similarly described the resulting movements as "slow, big, united" (Theme 3), suggesting that form-based constraint simplified and amplified movement, making it more legible and intentional.

Participants showed noticeable differences in their movement experiences (Theme 3). These differences appeared to arise from the specific bodily configurations they embodied, which shaped how particular expressive qualities were perceived and interpreted. For example, vertically stacked cuboid bodies were often perceived as "harmless" or "cute" (Theme 3), while configurations involving extended arms were interpreted as "strong" or "aggressive" (Theme 3). More subtle differences in size and weight also influenced interpretation, with larger forms described as "big" and "slow" (Theme 3), and smaller forms as more "flexible" or "sensitive" (Theme 3). These accounts suggest that direct bodily experience enabled participants to identify relations between form, movement, and expressive and affective interpretation (Theme 3).

As participants progressed through the activities, they developed increasing sensitivity to how movement and form could generate imaginative associations and support meaning-making (Theme 4). In the later Emotion Enactment and Guessing activity (Step 7 in Figure 4), this sensitivity was reflected in their ability to notice more nuanced distinctions in emotional expression. Participants described performances using expressions such as "died for a long time, because she is not moving," "yeah, it's sad, don't want to move," "happy, jumpy," and "sad, disappointed, because his head is down."(Theme 4).

5.3 Supporting Embodied Exploration for Non-Performers

In addressing the performance pressure often associated with existing embodied design methods, our findings suggest that the wearable toolkit and de-mechanisation-inspired exercises (Steps 2 and 4–7 in Figure 4) can reduce self-consciousness (Theme 3) and enable more open-ended imaginative associations (Theme 4), thereby supporting designers who are not trained in performance.

Although the wearable toolkit physically constrained movement, participants frequently experienced this reconfigured body (Theme 2) not only as restrictive (Theme 1), but also as protective and containing (Theme 3). They described feeling "restricted movement but feel safe," "safer in the box," or "bulky but cozy" (Theme 3), while others referred to a sense of "stronger security" (Theme 3). This suggests an ambivalent yet productive affective state, in which constraint coexists with comfort and support.

In some cases, this sense of containment was experienced as empowering. Participants described feeling "stronger," like "armor," or "more in control" (Theme 3), while others reported having "become another person… more free to move" (Theme 3). These accounts indicate that bodily reconfiguration not only altered movement capacity, but also transformed how participants related to performance—reducing self-consciousness and enabling more confident and imaginative expression.

The playful nature of Boal's de-mechanisation exercises appeared to support engagement across participants, particularly through the use of an external point of focus. For example, in the Palm-Distance Puppetry activity (Activity 6 in Figure 4), one participant who did not initially engage later chose to participate because the interaction looked "fun" (Theme 3), and noted that "tracing the hand is interesting" (Theme 3). This suggests that introducing an external point of focus and a simple guiding rule gave the activity a more playful quality, which in turn encouraged participants to engage more willingly and experiment with non-habitual movement.

Gradually, this combination of restriction (Theme 1) and playful, affective movement experience (Theme 3) also helped participants open up their imagination (Theme 4) beyond simply following instructions. Participants began to improvise within the exercises, for example by suggesting "clapping sound" (Theme 4) as a guiding cue when vision was limited, or by using the whole body to "jump" (Theme 4) in order to guide the Robot/Follower. These accounts suggest that restriction and playfulness not only encouraged participation, but also opened space for imaginative associations (Theme 4).

5.4 From De-mechanisation to Design: A Conceptual Framework for Embodied Ideation

This paper provides a framework that combines Boal's de-mechanisation exercises with a wearable body-extension toolkit to support the integration of embodied performance techniques into design practice. While grounded in a practical workshop format, we conceptualise this framework as a structured process of embodied ideation, through which designers can engage movement and form from a first-person perspective. As shown in Figure 4, the framework brings together three de-mechanisation-inspired activities (Steps 2, 5, and 6) and a material toolkit, organised in sequence to scaffold participants' experience of bodily transformation and movement exploration.

In this way, the framework extends Boal's concept of de-mechanisation beyond theatrical training into a design-oriented strategy for decentering habitual, human-centred movement patterns. Rather than only disrupting bodily automatisms for expressive awareness, it structures this disruption toward the exploration of robotic form and movement. The wearable toolkit plays a key role in this translation, materially constraining and reconfiguring the body so that movement is experienced in relation to non-anthropomorphic shapes. Together, the exercises and toolkit form an integrated system that enables designers—particularly those without performance training—to explore motion as an embodied, situated, and generative design material.

Across our study, this process can be understood as unfolding through four interrelated stages, corresponding to the identified themes:

- Stage 1 – Disrupt (Theme 1): habitual bodily patterns, sensory expectations, and movement assumptions are interrupted through constraint and sensory alteration.
- Stage 2 – Reconfigure (Theme 2): participants reorganise movement in relation to new bodily constraints, developing awareness of segmented, system-like movement possibilities.
- Stage 3 – Express (Theme 3): movement becomes an exploratory medium for generating affective and expressive qualities within constraint.
- Stage 4 – Project (Theme 4): participants attribute meaning, imagination, and non-human interpretations to movement and form, enabling the emergence of novel design concepts.

These stages describe not only a sequence of activities, but a conceptual progression through which embodied experience becomes design-relevant. Movement shifts from being habitual and implicit to being consciously explored, structured, and ultimately perceived and interpreted as expressive and meaningful. Within this progression, constraint and disruption function not as limitations, but as generative and epistemic conditions that support designers in moving beyond anthropocentric assumptions and toward alternative, non-human movement logics. In this sense, non-human imagination emerges not from unconstrained creativity, but from structured bodily disruption and reconfiguration.

The framework can be understood as building on bodystorming by providing a more structured and guided approach to embodied exploration, while remaining accessible and engaging for non-performers. In contrast to open-ended role-play, it introduces specific techniques derived from de-mechanisation, alongside materialised bodily constraint through the wearable toolkit. Our findings suggest that this combination not only structures movement possibilities, but also shapes the affective conditions of participation—reducing self-consciousness and enabling more open-ended imaginative engagement through a sense of protective empowerment and support.

Taken together, this framework contributes to design research in three ways. First, it reframes de-mechanisation as a design strategy for descentering habitual movement in the exploration of non-anthropomorphic systems. Second, it demonstrates how embodied constraint can function as both a generative and affective condition for ideation, rather than merely a limitation. Third, it articulates a transferable process model of embodied ideation, through which disruption, reconfiguration, and first-person experience can be translated into expressive and meaningful design concepts.

While our experimental results demonstrate how the framework and toolkit guided participants' experiences in this study, we see this work as part of a broader design process. Future work will focus on extending this approach with additional modules—such as a modular robotic prototyping toolkit—to support the translation of embodied insights into implemented systems. More broadly, this framework contributes to ongoing discussions in DIS on how design knowledge can emerge through first-person, situated, and experiential practices, and invites further exploration of embodied and performance-based approaches across different design contexts.

6 Future Work

6.1 Extending Embodied Insight to Robotic Prototype

Through our study, we observed that embodied ideation enabled designers to generate imaginative ideas about non-human expressive form and movement. This prompted us to consider how the method might be extended further: from supporting embodied exploration to also facilitating the translation of embodied insights into robotic prototypes in a similarly playful and accessible way.

We therefore see strong potential for developing this approach into a two-phase participatory design method in future work, moving from phenomenological bodily exploration to modular robotic prototyping. As an initial step in this direction, we propose a motorised, modular robotic prototyping toolkit (Figure 11), inspired by LEGO bricks, to support the materialisation of embodied ideas through hands-on robotic making.

6.1.1 Introducing Modular Robotic Prototyping Toolkit. The proposed toolkit is composed of minimal units that function as modular building blocks for robot design, enabling rapid assembly and reconfiguration. By relying on direct physical connections and tangible control interfaces, it allows both robotic structure and movement parameters to be adjusted without programming. This design supports the exploration of expressive movement and form through hands-on experimentation. By lowering technical barriers and encouraging low-pressure trial-and-error, the toolkit aligns with the playful approach of the preceding embodied ideation phase and aims to support the materialisation of embodied insights into tangible robotic movement prototypes.

Consistent with the wearable body-extension toolkit used in our embodied ideation phase, the modular robotic prototyping toolkit includes four cuboid bodies with distinct proportions: $1\times1\times1$, $1\times1\times2$, $1\times2\times2$, and $2\times2\times2$. Building on this shared formal vocabulary, motor actuation was introduced to enable dynamic movement.

Movement is primarily controlled through motor–joint modules physically connected to the cuboid bodies. All cuboid bodies and joint components were fabricated from 2mm laser-cut wooden panels and assembled using interlocking slot-based structures, enabling precise alignment, structural stability, and rapid reconfiguration. Two motor–joint modules were created to correspond to the two edge lengths used across the cuboid bodies. To support modular reconfiguration, both the cuboid bodies and motor joints were designed with two types of openings: motor-mount opening for attaching the motor body and horn-mount opening for connecting the output horn. All dimensional measurements of the motor joints and mounting openings were derived from the physical dimensions of the SG90 servo motor and its corresponding horn, ensuring mechanical compatibility and reliable assembly. This positive–negative hole system enables the motor modules and cuboid bodies to be combined in multiple orientations.

For movement control, we built a simple Arduino-based controller using potentiometers, enabling real-time servo adjustment without rewriting code.

A full inventory of the manufactured shapes is shown in Figure 11, with corresponding descriptions provided in Table 2.

6.1.2 Studying the Translation from Embodied Insight to Robotic Prototype. A key direction for future work is to examine how participants interpret and translate their embodied insights when actively engaging in robotic prototyping. This includes investigating how they make sense of their bodily experiences and reflections during the translation process, as well as the practical and interpretive challenges they encounter when using the modular robotic prototyping toolkit. Such challenges may in turn introduce productive constraints or generate new design insights.

Future work should include a more systematic evaluation of expressive translation across modalities. In particular, this could involve studying how observers interpret the expressive qualities of the robotic prototypes and comparing these interpretations with the meanings associated with the original embodied performances. Such evaluation would help assess the extent to which expressive intentions, affective qualities, or movement characteristics are preserved, or reinterpreted in the transition from bodily enactment to robotic form.

6.2 Situating the Method Across Interaction Contexts and Robot Types

As robot expression is often highly context-dependent, we need to further explore how our method performs across a range of situated interaction contexts, as well as with different robot types, such as anthropomorphic and abstract robots, in order to better understand its generalizability and improve the ecological validity of our findings.

6.3 Examining the Method Across Participants With and Without Performance Training

Future study should expand the participant pool, particularly by comparing participants with and without performance training, to better understand how our method supports embodied design thinking and whether it is particularly beneficial for non-performers.

7 Limitations

Our activities and toolkit design present limitations in terms of inclusivity. The current tasks assume that participants can engage in

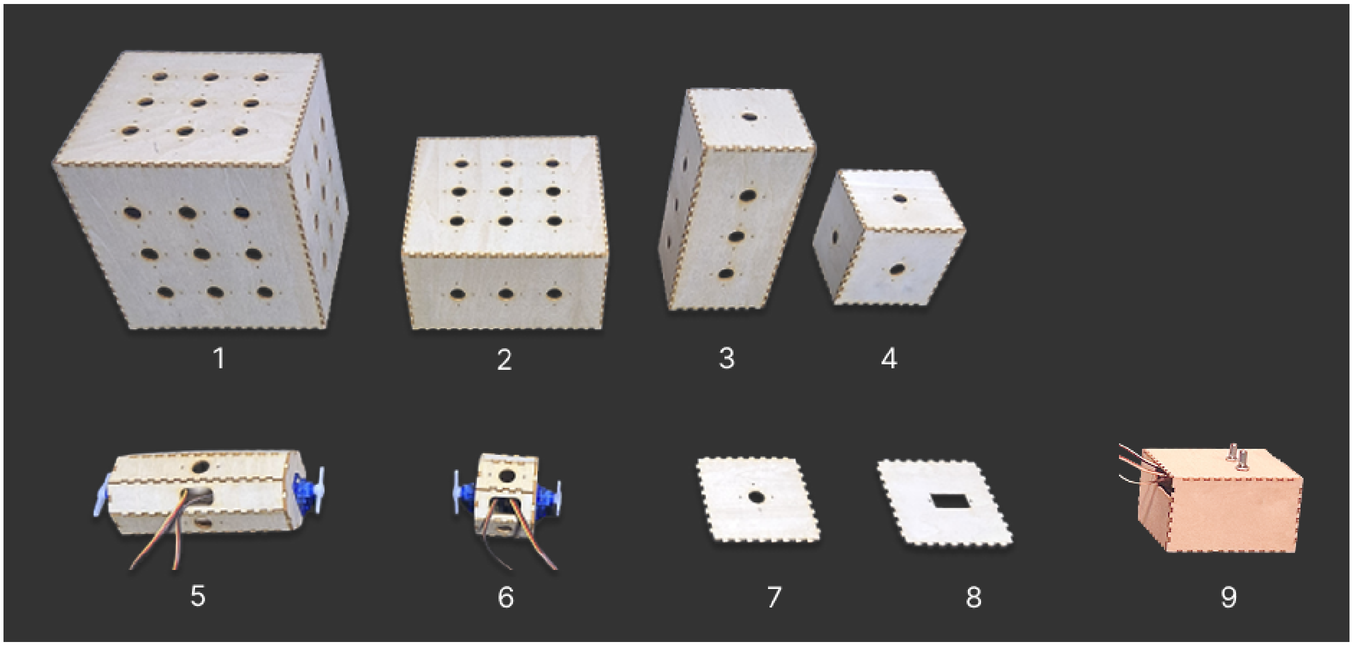


Figure 11: Modular Robotic Prototyping Toolkit

self-directed full-body movement, wear and manipulate the body-extension modules, and comfortably take part in physically demanding embodied activities. As such, the approach in its present form is not fully accessible and does not yet accommodate a diverse range of bodily abilities.

8 Conclusion

This study developed an embodied design approach for exploring expressive movement and shape in simple, non-anthropomorphic robots. Drawing on Augusto Boal's concept of *de-mechanisation* from *Theatre of the Oppressed*, our approach combined performance-based practices with a wearable body-extension toolkit to support phenomenological bodily exploration of movement and shape. By introducing wearable forms that position the human body as an active instrument for exploring movement and morphology, the approach provides an accessible participatory and exploratory strategy for expressive movement-centric human–robot interaction. By translating specific theatrical techniques—particularly playful, outward-oriented exercises and the use of props—this work expands performance-based methods in HRI by enabling designers to access and articulate embodied knowledge.

As robots increasingly enter everyday and social environments, embodied and co-creative design methods that foreground somatic experience and the aesthetic dimensions of interaction can play an important role in supporting designers from diverse backgrounds in shaping expressive, relatable, and socially meaningful human–robot interactions.

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Table 6: Modular Robotic Prototyping Toolkit Components

No.	Dimensions	Module	Description
1	140 mm × 140 mm × 140 mm	Cuboid Body 1	Nine motor-/horn-mount openings evenly distributed on each face.
2	140 mm × 140 mm × 70 mm	Cuboid Body 2	Nine motor-/horn-mount openings evenly distributed on each 140 × 140 mm face; three motor-/horn-mount openings evenly distributed on each 140 × 70 mm face.
3	70 mm × 70 mm × 140 mm	Cuboid Body 3	Three motor-/horn-mount openings evenly distributed on each 140mm × 70mm face; one motor-/horn-mount opening located at the center on each 70mm × 70mm face.
4	70 mm × 70 mm × 70 mm	Cuboid Body 4	One motor-/horn-mount opening located at the center of each face.
5	Side length: 20.7 mm; height: 108 mm	Motor Joint 1	The module takes the form of a regular octagonal prism (side length: 20.7 mm; height: 108 mm). Its height was defined to correspond to the 140 mm edge length of the cuboid body, allowing the module—once two motors are installed—to align with and connect to the inner ends of the cuboid. Motor-mount openings are incorporated on both the top and bottom faces. Four of the eight side faces, arranged in an alternating pattern, are equipped with horn-mount openings, while one additional side face includes a larger rounded-rectangle opening (approximately 10 × 20 mm) for routing servo motor cables.
6	Side length: 20.7 mm; height: 38 mm	Motor Joint 2	The module is designed as a regular octagonal prism (side length: 20.7 mm; height: 38 mm), with dimensions aligned to the 70 mm cuboid body to enable direct internal connection when two motors are installed. Motor mounts are located on the top and bottom faces, while alternating side faces include horn-mount openings. An additional side opening (approximately 10 × 20 mm) allows for servo cable routing.
7	Central : Ø10 mm; surrounding : Ø1 mm,	Horn-mount Opening	The horn-mount opening consists of a central circular opening (Ø10 mm) that supports screw-based fixation between the horn and the servo motor, surrounded by four Ø1 mm circular openings symmetrically positioned at a radial distance of 11 mm to accommodate self-tapping screws for connecting the horn to another module.
8	Rectangular : 23.5 mm × 12 mm; circular: Ø1.4 mm	Motor-mount Opening	The motor-mount opening consists of a rectangular opening (23.5 × 12 mm), positioned such that one short edge and two long edges are tangent to a centrally located circular clearance opening. The rectangular opening is horizontally aligned with the horn's rotation axis. Two Ø1.4 mm circular openings are symmetrically placed on either side along the centerline of the rectangular opening, offset by 2.25 mm from its long edges, to support screw-based motor fixation.
9	100 mm × 80 mm × 60 mm	Motor Controller	The controller enclosure houses an Arduino-based control board that uses potentiometers to capture user input and generate motor outputs. Two potentiometers are mapped to paired motors, enabling independent control of each motor pair.

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