Robotic Improvisers: Rule-Based Improvisation and Emergent Behaviour in HRI

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***Abstract*—A key challenge in human-robot interaction (HRI) design is to create and sustain engaging social interactions. This paper argues that improvisational techniques from the performing arts can address this challenge. Contrary to the ways in which improvisation is generally used in social robotics, we propose an understanding of improvisational techniques as based on rules that shape motion choices. We claim that such an approach, represented in what we name the "external" and "emergent" perspectives on improvisation, could benefit the way in which robot movement and behaviour is designed and deployed, increasing playful engagement and responsiveness. As an example of this type of improvisation, we discuss how American dancer and choreographer William Forsythe's *Improvisation Technologies* could be used in an HRI context. We also report on a preliminary experimentation using a Wizard-of-Oz exploratory prototyping system and a participatory design method with professional dancers geared towards the exploration of interactive movement possibilities with a Pepperrobot. Finally, we report on how this workshop offered valuable information about the applicability of these tools, as well as reflections on how it could help increase the level of engagement in the interaction.**

Keywords*—*improvisation, human-robot interaction, theatre, dance, rules, movement

I. INTRODUCTION

A key challenge in human-robot interaction (HRI) design is to create and sustain engaging social interactions. In this regard, the development and assessment of social HRI tends to be focused first and foremost on the communication of messages and intentions (Kwon et al. 2018; Rozendaal et al. 2019), the expression of emotions and personal traits (Breazeal, 2003; Meerbeek et al., 2009; Anzalone et al., 2010; Trovato et al., 2013), and the achievement of concrete tasks (Knight and Simmons, 2014; Dragan, 2015). Although useful for achieving practical outcomes and developing symbolic interactions, these approaches overlook how playful actions and responses that do not rely on communicative content can play an important role in bringing about engagement and sustained interaction, and thus in supporting what Ligthart, Neerincx and Hindriks (2021) observe in a recent study about the quality of the social aspects of HRI, namely that engagement and co-regulation are key in establishing and maintaining interaction as well as keeping users satisfied with said interaction.

Improvisation, as practiced in theatre and dance andmusic, offers examples of how such playful actions and responses can bring about engagement and a sense of co-regulation as a resultof how they engage performers in interactions. Furthermore, so- called *rule-based improvisational methods* offer an algorithm-like basis for behaviour generation (through a formalized set of rules and operations). We claim that such methods lend themselves to the problem of automatically generating complex robot behaviour that is varied and responsive while not primarily based oncommunicative content.

The rules that are part of such improvisational methodsbear resemblance to rules of play, inasmuch as they do notnecessarily deal with the communication of a message but focusinstead on how to be responsive and maintain engagement. Forexample, rules in the game "twister" –such as "right foot to red"– afford movement possibilities, thus creating an engaginginteraction where unexpected movement patterns can emerge fromsimple rules. Similarly, in a dance improvisation context, the rule"avoid an imaginary line in space" does not uniquely determine motion trajectories for (a) dancer(s) but rather offers a plethora of motion possibilities constrained by such a simple rule (the morerules are added the more complex the resulting behaviourbecomes). The value of the actions that arise from such rules doesnot rely on how they can be interpreted based on their symboliccontent, but on how they keep the interaction going. Furthermore,these rules are not about the development of a task or thecommunication of inner states, which are the two main ways inwhich robotics have dealt with non-verbal interaction. Rather, theyoffer elements of surprise and variability that increase engagement without the need of expressing communicative content.

In this paper, we generally aim to show how rule-based improvisational methods can be of use for HRI. Specifically, we claim that what we will refer to as "external" and "emergent" approaches to improvisation, can enrich the way in which robot movement and behaviour is designed and deployed, by increasing playful engagement and responsiveness in social interactions with humans. We believe that this approach to HRI can be beneficial for social interactions among robots and humans in several ways: firstly, it foregrounds playfulness, an essential part of social interaction that is usually unaddressed and that *can enhance engagement*. Secondly, it deals with how the rules of HRI can be *flexible and creative* while not dealing with symbolic and conventional communication. Finally, this approach also exposes a different role of movement in communication: one that does not depend on expressing intention or a particular message but that rather focuses on *responsiveness and on sustaining interaction.*

Concretely, this paper contributes a methodology for translating rule-based dance improvisation concepts in HRI contexts. Firstly, we offer a theoretical framework for the application of such rule-based techniques to HRI by identifying "external" and "emergent" approaches to improvisation. Moreover, we use Forsythe's *Improvisation Technologies* (1999), a well-established rule-based improvisational method, as a case study to illustrate the breadth of possibilities that such a methodology unlocks. Although we focus on Forsythe's tools in this case study, our proposed approach can be used with other rule-based improvisation frameworks and different robotic platforms, including non-humanoid robots. This preliminary experimentation is done with a Wizard-of-Oz exploratory prototyping system and a participatory design method geared towards the exploration of interactive robot movement possibilities with professional dancers controlling and interacting with a Pepper robot.

II. BACKGROUND AND RELATED WORK

A. *Improvisation in Dance*

In theatre and dance, improvisation has usually been described in opposition to choreography (in dance) and the staging of dramatic plays (in text-based theatre). In this opposition, choreography and dramatic theatre fulfil the role of scripted behaviour versus improvisation as unscripted. In contemporary theatre and dance, as well as in the discourses surrounding them, such a binary has been questioned and improvisation has been acknowledged as a way of developing movement materials and modes of behaving that can become part of choreographed or otherwise 'set' performances. Nonetheless, the extemporaneous quality of improvisation keeps on being foregrounded; that is, the fact that it is done "in the moment". Furthermore, elements of surprise and habit-breaking have held a vital position in discourses on improvisation. Often this is associated with the absence of rules and prescriptions controlling behaviour.

However, another type of improvisational practices hasexisted since at least the second half of the 20th century. This type understands improvisation as a rule-based act that responds to aspects of the situation in which improvisation takes place, such as, for example, other performers, space, or architecture, as well as previous movements and actions of the improviser. Improvisation in these practices consists of making choices in the moment and according to sets of rules. These rules do not rely on a mandatory expressive component which has to do with internal states of the improviser. Rather, they offer an external set of possibilities for movement or other behaviour to emerge in response to an input as, for instance, the shape of someone else's movement. In this way, the rules that are part of these improvisation technologies could be described as a set of formalizable constraints on the generation of motion with one's body, and in their interaction with others, describing possibilities for emergent behaviour. That is, from the initial basic rules established in those techniques and by the interaction that these rules afford in one's own body and between dancers, more complex movement actions and patterns can come up, which can allow for surprise and variability in said interaction. In the case of human improvisers, choices are made by humans and are therefore not independent from human capacities for choice making. However, within several approaches to rule-based improvisation—including Forsythe's *Improvisation Technologies*—we can observe a tendency towards automation. That is, embedded within these technologies is the possibility of these choices to be determined (at least partly) by external rather than internal factors such as drives, intentions, or affect.

B. *Improvisation as a Tool for HRI and the Arts*

Approaches to improvisation from theatre and dance have been part of social robotics as a tool in two ways. Firstly, robots are used in improvisational settings to help human performers improve their improvisational skills or augment their performing capabilities. For instance, Lu et al. (2011) used robots to develop improvisational exercises for humans; Ladenheim et al. (2020) created a robotic prosthesis that aims to enhance human performer's expressive means and Matthewson and Mirowski (2017) developed a humanoid robot that thanks to a chatbot created improvised lines towhich the human performers needed to creatively adapt. Robots have also been included in improvisational settings as a way of offering new elements to a theatrical show, such as in Duncan et al.(2010) or Cappo et al. (2017). Finally, robots have been used as mediators of audience feedback in improvised comedy shows (Mikalauskas et al. 2018).

Secondly, improvisational techniques are used to develop behaviour of social robots and HRI which is no longer improvised when performed by the robot (Gemeinboeck & Saunders, 2014, 2016; E. Jochum & Derks, 2019; LaViers et al., 2017; Li et al., 2019; Meerbeek et al., 2009; Sirkin & Ju, 2014). As part of the developing process, actors improvise scenarios either with therobots (Sirkin & Ju, 2014), impersonating the robot (Meerbeek et al. 2009) or controlling it through a Wizard-of-Oz system (Rond et al. 2019). Gemeinboek and Saunders (2016, 2014) used professional dancers that interacted with robot prototypes as a mode of inspiration for robotic movement and behaviour. Finally, Jochum and Derks (2019) experimented with a mobile robot and three dancers, in order to learn about relevant aspects of embodiedHRI, as well as the affordances of the robot.

C. *Improvisational Capabilities for Robots*

In other cases, the aim was to make robots improvise. Bruce et al. (2000) created improvisational characters (marked as heroes and villains, with their respective obstacles and goals) within a narrative; Skeppstedts and Ahltorp (2018) trained chatbots by mimicking the way in which two human improvisers create sharedknowledge in a dialogue, and Magerko et al. (2010) explored through improv games how humans improvise from a cognitive perspective to then implement this in the character development ofvirtual agents. These projects are mostly focused on dialogue, and,in some cases, they are developed on chatbots or virtual agents rather than actual robots. Other projects have aimed at creating dancing robot improvisers. For example, LaViers (2019) made a humanoid robot improvise through a system that determines what she calls "style" in robotics. In order to do that, she selected a number of motion primitives or poses, as well as the rules of the sequencing of those poses and the modulation of their trajectories,and had the robot randomly select between them. This is a similar approach to projects that deal with robot choreography, where algorithms that take into account user preferences are used to selectamong poses and create a choreography (Meng et al., 2014; Peng et al., 2019; Ros et al., 2014). In a different manner but with a similar aim, Wallis et al. (2010) programmed a non- anthropomorphic robot as a dancing partner by using Laban's Movement Analysis System.

III. ROBOTIC IMPROVISERS: THE VALUE OF THEEXTERNAL AND EMERGENT APPROACHES

In what follows, we offer a theoretical and critical outlook on how improvisation is being conceptualised in HRI. Based on the previous analysis of the "related work" section, we propose two critical distinctions that will help clarify how improvisation is being understood and used in HRI contexts. Moreover, we will show the benefits of turning to two of the most overlooked perspectives on improvisation so far: the external and emergent approaches.

A. *Critical Perspectives on Improvisation in HRI*

In order to understand how improvisation is being conceptualised in HRI, we propose two distinctions. On the one hand, a difference between more goal-oriented and more emergent approaches to improvisation and, on the other hand, what we describe as an internal and an external perspective on improvisation.

In goal-oriented approaches to improvisation, improvising is a means to work towards a *predetermined goal* that is established before the exploration begins. This goal is usually related to the expression of intention, the communication of a message or the evocation of a particular response. Improvisation is a means towards achieving this goal and often consists in playing around with (usually human) models of doing these things. Examples are the projects of Sirkin et al. (2014) and Meerbeek et al. (2009), in which improvisers are brought in to enact scenarios imagining how a robot would act.

Projects that use more emergent approaches to improvisation do not work towards a pre-given goal but instead useimprovisation to experiment with possibilities for movement and behavior and then select the most interesting and useful combinations based on what emerged from the improvisation. Thisis the case for example with Gemeinboeck and Saunders (2014) where dancers experiment with movement possibilities of robotic bodies, using a prototype as 'costume'. Only in a second instance, the movements thus invented are investigated for their communicative and expressive potential. In a similar vein, Rond etal. (2019) created improvisational scenes with humans and robots,to later on analyse how these movements were perceived and interpreted by the human improvisers.

Most social robotic projects that make use of improvisation so far use a goal-oriented approach to improvisationin combination with what we call an "internal perspective" on improvisation. That is, an understanding of improvisation as basedon the existence, and later expression, of internal states. To say it differently, this implies an understanding of improvisation as relying on an autonomous sentient individual who is moved by internal states which are then expressed in movement. This can beseen in two types of projects. Firstly, in projects that try to program specific personality characteristics in robots that seemingly direct their decisions in improvised settings (e.g., Bruce et al. 2000 or Magerko et al. 2010). In this view, improvisation is also equated to anticipation and problem-solving. Secondly, other projects understand improvisation from an internal perspective, inasmuch as it is considered that the somatic and embodied knowledge that permits the improvisational act are located in the inner sphere of the human individual. These projects, therefore, require human beings to access such bodily knowledge through improvisational practices and then apply it to the development of robots or use it totele-operate robots in improvisational settings.

External perspectives on improvisation, on the other hand, do not approach improvisation as the expression of inner states but work with *sets of rules* that direct behaviour and movement choices. In very few social robotics projects that work with improvisation this tendency towards a formalisation of rules of the specific improvisation technique can be observed. Examples are Wallis et al. (2010), whose use of Laban Movement Analysis shows an interesting approach to the deployment of Laban as not related to the expression of emotions; LaViers (2018) and Li et al. (2019), Rond et al. (2019), and the project of Jochum & Derks (2019). This external perspective on improvisation has been rarely explored and, when used, has been, except in Wallis et al. (2010), still connected to goal-oriented approaches or human models of motion. In what follows, we propose how *a combination of the external and emergent* approach can prove useful when developing robotic improvisers.

B. The External and Emergent Approaches

The external and emergent approaches combined are the least explored in social robotics at the moment, but we propose, the most interesting to further develop. From those perspectives, improvisation involves improvisers rendering themselves to external rules, e.g., like those of the "twister" game. Movement then emerges as a result of how movers let themselves be guided by these rules rather than being motivated by the intention to achieve a particular goal or to represent the inner state of the performer. These sets of rules lend themselves easily to algorithmic thinking, whereby one can clearly identify what counts as a valid versus non-valid motion, based on the set of constraints that these rules create. Importantly, these "algorithmic structures" are not designed to work towards a particular goal but rather guide real- time decision making in response to, for example, the environment, movements performed so far, or the behaviour of interaction partners. Movement therefore emerges from successions of decisions continuously made in real-time.

The external and emergent approaches present an approach to movement creation that enable robots to improvise without relying on humans, thus offering the possibility of developing a robotic way of improvising. Rule-based improvisational frameworks are able to offer parametrised tools that, when used by robots in interactions with humans and their environment, can produce emergent behaviour. Furthermore, they offer a useful framework for developing *responsive, playful,* and *engaging open-ended social interactions* between humans and robots. Figure 1 shows a high-level summary of how we see the external and emergent approaches translated into a HRI setting.

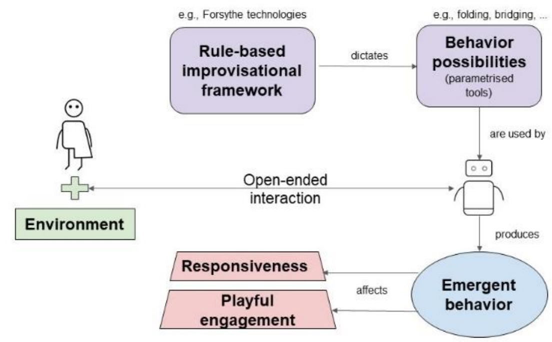

Figure 1. High level overview of a rule-based improvisation approach for robot behaviour generation in an interactive context

IV. CASE STUDY: FORSYTHE'S *IMPROVISATION TECHNOLOGIES*

As an example, we discuss in this section a case study based on the tools developed by American dancer and choreographer William Forsythe. Forsythe offers tools for the creation of motion choices based on highly structured and formalised external rules in improvised settings, which makes him a great case study to exemplify the "external" and "emergent" approaches on an interactive robot. However, it is relevant to foreground how, despite the focus on Forsythe, the approach can be generally applied to other similar rule-based improvisational tools.

A. William Forsythe's Improvisation Technologies: ATool for the Analytical Dance Eye

Forsythe's *Improvisation Technologies* (1999) is a CD-ROM with 60 short video demonstrations that record how Forsythe analyses basic classical dance movements through geometrical shapes and forms (points, planes, volumes or lines) and modifies them by means of folding and unfolding mechanisms of the body. This mathematical thinking, however, does not describe the motion performed by dancers. It presents an analytical tool for exploring what bodies can do when following specific rules of behaviour. This invisible geometry (that is, the different ways in which the parts of the body can geometrically relate to each other but also theway in which the body relates to space and to fellow movers), is rendered visible through computer animations (in Table 1, links canbe found with examples of the animations for each tool). These animations, Forsythe explains, support increased understanding of movement choices available to one's body at any given moment and can also aid in developing new movements.

Forsythe himself has made the comparison with algorithmic thinking in which the positions and poses that define the movement language of ballet are no longer the goal but become starting points for transformations that break away from ballet and take movement in unexpected directions (in Kaiser 1999). The rule-based character of his approach to movement creation is what pulls the human dancers through the "rigors" of their movement habits and towards the emergence of new movement potential. He introduces several tools to support such movement generation and divides them in the following categories: *lines, writing, reorganizing, and additions*. Some of these tools are more focused on motion generation, while others more explicitly address interaction with objects and with the space surrounding the mover.

It is important to mention that our goal in this paper is not to make robots enact Forsythe's tools in order to mimic human improvisation. Forsythe's improvisation technologies were created initially as a pedagogical tool for his dancers to guide them in the discovery of new paths of movements. Because of this reason, this technique tends to deal with an analytical approach to one's own body movement, rather than to explicitly address interaction and engagement. However, we do believe that Forsythe's way of understanding and creating movement can also inform new approaches to HRI that do not focus on symbolic or conventional actions, but rather on the responsiveness and playfulness that keeps an interaction going. In what follows; therefore, we shall explore how Forsythe's tools can be used as a way of creating and sustaining such interactions between humans and robots.

B. Candidate Concepts and Possible Instantiations for HRI

In the following section, we introduce a series of concepts derived from Forsythe's approach to dance improvisation that we believe can be useful in HRI and propose possible scenarios in which these tools could be applied.

Our methodology consisted of the following steps: we began with a theoretical in-depth analysis of Forsythe's 43 tools. The sources of this analysis were Forsythe's own teaching as reflected in the CD-ROM and previous research on his technique (Kaiser, 1999; Spier, 1998, 2011; Salazar, 2015; Ziegler, 2016). Furthermore, one of the authors of this paper followed a week-long workshop with a Forsythe educator in a professional dance development centre in order to embody these concepts. Based on this research, and through additional consultation with experts in this technique, we identified three categories describing how Forsythe's tools could be understood from a robotics perspective. Figure 2 shows a diagram translating these categories into a preliminary high-level architecture. The names of these categories are inspired by robotics terms, and are explained below:

1. ***Motion primitives:*** this category comprises tools that create the movement base for more complex motions. They describe ways of making simple trajectories by means of joining several points or inscribing a shape or letter with any part of the dancer's body. An instance is "point to point line", which consists of constructing a line by joining two points in space or by considering a part of your body as a line. Another instance is "u-ing"; that is, inscribing a U shape around an axis that is located in your body.

2. ***Generative operations:*** this category consists of movement choices that introduce transformations to a previous trajectory, e.g., a motion primitive. As an example of this category, we can turn to "parallel shear", where two or more lines fold themselves in parallel while maintaining a relationship of attraction or repulsion, or to "spatial compression" where the dancer repeats a previously performed movement with only one part of their body while immobilising the rest. This category is therefore always influenced by an external input, be it a previous movement, the behaviour of another improviser or objects in the environment.

3. ***Moving through space:*** the tools in this category are focused on making the dancer interact with their surroundings, as well as creating meaningful connections through the exploration of and responsiveness to space. Therefore, this category is also highly influenced by external input. The movements in this group create navigational patterns rather than limb motion patterns, which carries different social consequences in an interaction. An instance of this type of tools is "transporting lines", where the dancer needs to keep a line in their body static and move it in orientation to the room or to their own body, provoking other parts of their body or their position in space to adapt. Another example is "avoiding volumes": the act of moving around a previously imagined volume in space.

Although some of Forsythe's tools engender operations that cross the lines between these categories and thus do not fit strictly into one category only, we consider this division a useful asset to determine what use each of the tools may have for developing robot behaviour and HRI. Furthermore, it is relevant to mention that the way in which these tools will support and bring about interaction will also depend on whether said rules are known by the human interaction partner, or not.

In terms of motion primitives, the mathematical thinking behind Forsythe's approach to improvisation could offer an interesting alternative for programming and developing robotic motion as a first step towards an interaction. Rather than implementing specific predetermined human-inspired motions from which the robot later on selects, this technique could offer a novel perspective to develop a more varied and creative set of motions that explore the robot's own affordances and possibilities, through algorithmic techniques such as constrained motion planning (model-based), or generative machine learning (data-driven) models. With the right set of constraints, we can see these types of models are underdetermined systems where more than one solution exists, which unlocks richer ways of generating diverse motions that obey externally imposed rules. This could help in building a modular language of robot movements that does not necessarily rely on human models and direct human imitation, and that does not come from predetermined poses, hence making it (at least partially) applicable to any robotic platform, including highly non-humanoid ones (e.g., robot arm).

Generative operations can be of interest to robotics inasmuch as they do not rely on randomising previous poses but on introducing unexpected interactions by modifying a previous motion primitive in surprising and creative ways. We believe that such operations that build on previous movement patterns by the human or by the robot itself could increase direct responsiveness and playful engagement. Furthermore, employing different transformative operations on previous movement patterns could offer a flexible and creative way of engaging with human input without having to deal with the deciphering of messages or the expression of inner states.

Finally, moving through space could be of use to HRI in its focus on spatial interaction. The tools in this category could help robots perceive and react to their surroundings, increasing their responsiveness to their context and making them engage in meaningful connections through navigational patterns.

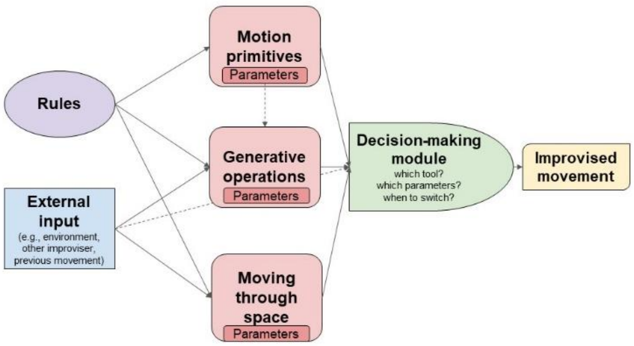

Figure 2. Diagram relating the translated Forsythe concepts into a preliminary high-level architecture for improvised robot movement

V. EXPLORATORY PROTOTYPING

To illustrate the applicability of the previous concepts in HRI, we conducted a workshop where we investigated with a Pepper robot and three professional dancers concrete ways in which Forsythe's *Improvisation Technologies* can inform non-verbal HRI. We conducted this first step as a way of *exploratory prototyping*, following Zamfirescu et al. (2021). Exploratory prototyping is, according to the authors, a type of design exploration that focuses on flexibility, possibility and design insights as perceived by the designers rather than on verifiability and replicability. We agree with Zamfirescu et al. that such techniques can be of use to HRI in exploring ideas and possibilities before taking decisions in the design process: in our case, the design of the programming of the robot and the interaction with the human. Furthermore, such a way of engaging in design exploration will allow us to delve into a more emergent approach of HRI, in which we can investigate the affordances of the robotic platform, as well as the insights of the dancers. Finally, we opted for a *participatory design* in which the dancers were actively involved in the creation of robotic movement and the development of the interaction.

Our main question was the following: how can elements from Forsythe's technologies support engagement and sustained interaction through playful action and response? Our Wizard-of-Oz puppeteering system included two identical Pepper robots where one of them (the "puppet") was kinaesthetically controlled by one or two dancers, while the other robot (the "puppeteered") was replicating the motion of the puppet through wireless communication of the robot's join positions, like the setup of Tennent et al. (2018). The dancers acquired two roles: firstly, they reacted to puppeteered choices of a robot which performed as a dancer, and secondly, they transferred their own improvisational choices through the puppet robot. Although the dancers were controlling the robot through a puppeteering system, it is our intention to ultimately implement such tools through algorithms and have the robot respond without human control.

The participants of the workshop were two of the authors and three professional dancers: two of them directly interacted with the robot, and one of them fulfilled the role of an external observer through an online platform. We were especially interested in obtaining both interaction and observation perspectives during the session, as to multiply the potential interpretations of what took place. The workshop was divided in three phases and coordinated by two of the authors, one of them with expertise in HRI and dance. The session was recorded through a static camera and a wide-angle webcam through which the video conference with one of the dancers was held. In addition to the video material, one of the authors took pictures of the interaction with a phone and notes of the discussions. The information shared about the dancers' ideas and comments are extracted from those notes. Informed consent, including sharing video material of the session, was obtained from our collaborators. The workshop was divided in three phases. This allowed the dancers to explore first the possibilities of the robotic platform, and to later get more in depth with interaction possibilities. Finally, once they became more familiar with this framework, they could explore tools that were more oriented to potential social scenarios beyond dance.

TABLE 1. Forsythe Tools Used During the Workshop

Forsythe Tool	Description	Category in our framework	Possible Algorithm for Automation
Imagining lines (shorturl.at/glowW)	Constructing a line by joining two points in space or by considering a part of your body as a line	Motion primitives	Inverse kinematics (IK), constrained trajectory planning (CTP), and stochastic selection of parameters (joint, point in space, length, duration, etc.)
Folding (shorturl.at/lrN36)	Extending or reducing a line by means of folding your body	Generative operations	Force fields, potential-based methods
Dropping points (shorturl.at/auFI5)	Abruptly moving points in your body towards the floor	Generative operations	
Transporting lines (shorturl.at/fuJ39)	Maintaining a line in your body static and moving it in orientation to the room or to your own body, provoking other parts of your body or your position in space to adapt	Exploring space	IK/CTP + localization (e.g., odometry- or vision-based)
Avoiding volumes (shorturl.at/bkAQS)	Establishing a volume in space and moving around it	Exploring space	Obstacle avoidance algorithms with hallucinated obstacles

A. First Phase: Designing Robot Movement

During this phase, the dancers got acquainted with the robotic platform and the puppeteering system by designing movement based on Forsythe's motion primitives and generative operations; in particular, line work with the tools "imagining lines","bridging" and "folding" (see Figure 3a). The tools were not pre-determined, but due to the simplicity of lines, it turned out to be the most productive choice. In Table 1, the tools used during the workshop are specified. During the session, we only explored the first three columns; the last column is meant to be part of future steps aimed at automating the explored robot behaviours. In the appendix, a full version of this table with the 43 Forsythe tools can be seen.

One of the first realisations was that due to the different embodiment of the robot, many of the movements that would be available to a human being were not feasible on Pepper; therefore, certain generative operations such as "bridging" became difficult. However, as soon as the dancers avoided replicating human movements and started working with the material specificities and limitations of the robot body, other operations became relevant. For example, "transporting lines"; that is, fixing a point in space and moving the rest of the body according to this point. This seemed an easy exercise for the robot to do and created an engaging way of moving in the robot, as perceived by the dancers as well as the external observers.

Moreover, the capability of the robot to move its limbs towards the back proved to be an interesting asset. This showed an alluring variation of Forsythe's "back approach"; that is, his interestin moving towards the back as much as towards the fore (see Figure 3b). In the case of Pepper, its limbs could reach towards the back to a degree unavailable to humans, which created a set of intriguing movements and poses that did not resemble human motion. Finally,the "saturation" experienced by the robot during the puppeteering,when the commands conflicted with the self-stabilising factor, which at the beginning was understood as a limitation, turned out to be an engaging asset in other situations, as it introduced abrupt change and gave an impression of using the "dropping points" toolin unexpected moments.

Figure 3a. Phase 1: The dancers get acquainted with the puppeteering system. On the left is the "puppet" robot, and on the right the "puppeteered" one mirroring the puppet (on the left)

Figure 3b. Phase 1: Pepper uses the back approach (On the right)

B. Second Phase: Interacting Through Improvisation

After this first exploration, we moved into the interaction, with oneor two people manipulating the puppeteering robot, and another person physically interacting with the puppeteered Pepper. We decided to continue exploring line work, due to the simplicity of these tools and the fact that they had already been explored in the first phase. Figure 4 shows how one of the dancers interacts with the robot by kneeling on the floor, establishing contact with both hands on the extremities of the robot and letting herself be moved by it. The second interaction was made by the other dancer who was standing up and engaged in diverse ways with the robot, including imitating, complementing, and contrasting Pepper's movements. Several observations were made after these first two improvisation sessions:

Firstly, the collision avoidance of Pepper, which preventsit from approaching objects surrounding it in order to avoid damage, was initially limiting in the interaction as it would preventthe robot from getting closer to the human. Secondly, during the improvisations the dancers and the observer realised that instead ofmerely mimicking what Pepper was doing, it was more engaging and interesting when the human would take up one of Pepper's movements and amplify it or build on it, for example, by doing anisometry of Pepper's motions. Thirdly, it appeared to be more engaging when two people were puppeteering the robot at the sametime, and especially when one of them took care of moving the head quite often. As a result, we speculated about the possibility of bringing one or two professional puppeteers to the next sessions inorder to control Pepper while the dancers interact with the puppeteered robot.

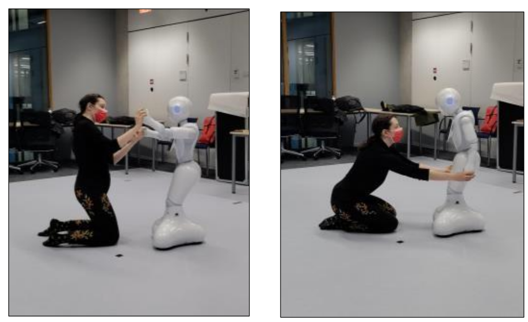

Figure 4. Phase 2: Pepper gives the impression of "dropping points" (left) and makes the dancer follow its lead (right)

Figure 5. Phase 3: Pepper explores the negative space of the dancerusing the "avoiding volumes" tool

C. Third Phase: Imagining Social Scenarios

Finally, we initiated another improvisational session where we tried to explore more socially oriented scenarios. Together we thought of three possible applications to several of Forsythe tools: first, using the tool "transporting lines" as a mode of creating, showing and teaching joint attention, perhaps of use for children with autism or other groups that might experience difficulties in engaging in joint attention (Warren et al. 2015). Second, the tool "avoiding volumes" seemed promising for communicating spatial boundaries through motion in, for example, storytelling or interactive game scenarios with children. Finally, we considered the potential of the tool "universal writing" for creating playful engagement, especially with children, when learning the alphabet.

As a preliminary exploration of such scenarios, we decided to explore only one of those scenarios: that of avoiding volumes, because it would allow us to engage with space (real andimaginary) in a way that we hadn't yet addressed. As with the firstphase, we began with creating shapes only with the robot body, without interaction. At this moment, we realised that smaller shapesworked better, as with bigger shapes, the delimitation of imaginaryvolumes was less clear. We also noted that due to the way in whichthe hands of the robot were made and how they moved while delineating a shape, it was possible to simulate the effect of weight, which turned out to be a very engaging factor in constructing such an imaginary volume.

After that, we began to introduce interaction. Firstly, we tried to have Pepper and the human both interacting at the same time with the same shape. However, the interaction turned much more attractive when the human remained still, forming a shape with their body and Pepper interacted with that shape. The human dancer would then strike a pose and the robot would approach it. The collision avoidance, which at the beginning seemed to be a limiting factor, proved useful in this context, as it would allow us to perceive the ratio that Pepper would have when moving around a human, establishing a sort of imaginary boundary that it could not trespass. Another interesting interaction that arose (see Figure 5) was when Pepper was exploring the "negative space" of the dancer: that is, the spaces that form within the shape of the human body.

After the workshop, we held a discussion with the participants where we addressed our perception of the session as external observers, talked about the impressions of the dancers while participating, and finally speculated together about future steps. With the question in mind "how can Forsythe's Technologies contribute to increased engagement and playful action andresponse in HRI?" the dancers made several observations.

The dancers reported feeling interested, curious and entertained during the interactions with the robot, even after the "surprise effect" of relating to a new technology had vanished. According to their experience, the framework offered them a base from which to explore open-ended interactions, which gave them enough freedom to play with Pepper but also the necessary constraints not to feel lost in the different scenarios. Specifically, the dancers pointed out that some of the most engaging moments with Pepper happened when the robot seemed to take action on its own accord. This happened usually when the robot stopped following the interaction that was taking place and did something different. Such moments took place outside of human control, namely when the puppeteering system interfered with the safety system that allowed the robot to balance and prevented it from performing unsafe motions. Interestingly, this switching behaviour was perceived by the dancers as "stubborn". At other moments a similar effect resulted from how the robot would unexpectedly switch to its "autonomous life" mode, which would make it try to recognize faces and people around it, while dropping the current interaction. Even though this was not meant to happen during the puppeteering of the robot, it turned out to be a compelling feature, as it would show a "conflict" in the robot that would get resolved according to its own distributed control algorithm.

Moreover, we speculated about what else could be changed or added in order to increase engagement and playful interaction. With regards to this, the dancers pointed out two main strategies: the first was that interaction and engagement might be further improved by a stronger sense of connection between human and robot during the interaction. In order to increase this feeling ofconnection, the dancers proposed two ideas to explore in nextsessions. The first one was to select a movement that couldconstitute a "ground zero"; that is, a motion to which both humanand robot could come back to during an improvisation. The second idea involved the proposal for an adaptation and reinterpretation of the generative operation called "parallel shear".

Secondly, with regards to the topic of the robot taking initiative on its own, we hypothesised about the possibility of designing a framework in which this type of behaviour could emerge; namely, a moment where several rules are offered to the robot, some of them conflicting with each other, and the robot must decide which way to go. This is also in close contact with Forsythe's mode of improvising, as he was interested in saturating his dancers with many restrictions in order to see how they would react, what rule would they drop, how and when.

In summary, several aspects became relevant when evaluating the lessons learned from the workshop. Firstly, the importance of working from the embodiment of the robot and without an imitative approach in mind. The most interesting movements and interactions came to the fore when the dancers were working from the robot's affordances rather than from an ideaof how humans would engage with a specific tool. Secondly, the workshop taught us that the limitations of technology can become assets within this improvisational framework. Aspects that at the beginning seemed to be limiting, such as the collisions of differentsystems during the puppeteering, ended up creating surprising andengaging interactions with the dancers. Working with, rather than against, the limitations of the robotic platform offered us a less anthropocentric and more creative way of approaching HRI. Other aspects seemed likewise promising but were not fully explored during the workshop. For example, the idea of overloading the robot with many rules. That is, creating conflicting commands in Pepper's software, and forcing it to drop some of them, thusselecting which path it will take when confronted with many rules at once.

In relation to the goals of our project; that is, the exploration of how external and emergent approaches to improvisation increase playful engagement and responsiveness, the workshop offered several insights. Firstly, rule-based improvisation techniques provided the dancers with a structured base that delimited the possibilities of the interaction, therefore giving shape to the encounter as well as aiding in the emergence of creative and unexpected moments between them and the Pepper robot. Similar results were found in the workshop organized by Rond et al. (2019) where human improvisers played a game called "relativity" with a non-anthropomorphic robot. In the discussion of their project, the authors point out how such a structured improvisation game helped them explore the movement possibilities of the robot, and how the dancers ended up finding the robot as a creative, flexible and surprising partner. However, their project focused on enhancing humans' improvisational abilities and once automatized, the robot's behaviour stopped being improvised, whereas our intention is to create robot improvisers.

Furthermore, having both the humans and the robot rendering themselves to external rules allowed them to connect on a similar ground and gave them the possibility to explore movement beyond the expression of inner states or goal-oriented tasks. Finally, the workshop showed how, even when controlled by humans, the external and emergent rule-based improvisational methods, such as that of Forsythe, allowed the dancers to investigate diverse ways of moving and interacting that were not necessarily human-like and that emerged from the limitations and characteristics of the robotic platform. Interestingly enough, when the human imitation drive was abandoned, the most engaging movements and behaviours emerged.

VI. CONCLUSION

In this article, we argue for the relevance of external and emergent perspectives on improvisation as a way of developing playful open-ended interactions that do not rely on communicative content yet can play an important role in bringing about and sustaining HRI. We argue that rule-based improvisation techniques in dance offer an approach to improvising that is not based on the expression of internal states, that does not necessarily focus on the communicative content of an interaction, and that works with a framework of rules without a goal-oriented purpose.Furthermore, these rules offer an algorithm-like basis for programming robot behaviour that allows for movement to emerge in response to stimuli in ways that are not about expressingemotional states or communicating a message but about playful interaction. The improvisational aspects of this framework do not lie in the algorithms themselves but in how a robot stochasticallyselects the parameters for these algorithms (e.g., joint, point in space, length, duration, etc.). For now, we assume that randomselection of such parameters can create rich enough behaviour, butin the future, we would like to investigate more complex decision-making algorithms to guide the improvisational choices.

Forsythe's *Improvisation Technologies* proved to be an excellent example of this type of rule-based improvisation technique and, the exploratory prototype, as well as the participatory design, provided us with valuable information about the applicability of his tools, the level of engagement that the interactions brought about, as well as the possibilities given the specific robotic platform before implementing algorithms. Further ways in which we plan to develop and complement these initial steps are the following: firstly, we aim at exploring this technique in several robotic platforms, as to discover in which ways the embodiment of the robot influences the interaction and the possibilities within rule-based improvisational techniques. Secondly, it is our intention to automate improvisational decisions through planning, decision-making and control algorithms on the robot that allow for the emergence of playful behaviour in HRI. The exploratory prototyping through the puppeteering system permits us to discover which tools and which interactions are engaging before developing the programming of the robot. However, our goal is to have the robot improvise on the base of these techniques.

Once this is achieved, we plan on also researching different levels of playful engagement in HRI through the use of different generative operations. That is, given an initial trajectory, how does the human respond to the different transformations that the robot can do using Forsythe's generative operations. This, we believe, can prove interesting for HRI in general, not only in artistic contexts. Furthermore, it is our intention to continue exploring the potential of rule-based improvisational techniques beyond Forsythe's technologies. Other possibilities are, for example, Countertechnique by Anouk van Dijk, Viewpoints by Anne Bogart and Tina Landau, and The Underscore by Nancy Stark Smith.

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