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Improv with Robots: Creativity, Inspiration, Co-Performance

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***Abstract*— Improvisational actors are adept at creative exploration within a set of boundaries. These boundaries come from each scene having "games" that establish the rules-of-play. In this paper, we introduce a game that allows an expressive motion robot to collaboratively develop a narrative with an improviser. When testing this game on eight improv performers, our team explored two research questions: (1) Can a simple robot be a creative partner to a human improviser, and (2) Can improvisers expand our understanding of robot expressive motion? After conducting 16 scenes and 40 motion demonstrations, we found that performers viewed our robot as a supportive teammate who positively inspired the scene's direction. The improvisers also provided insightful perspectives on robot motion, which led us to create a movement categorization scheme based on their various interpretations. We discuss our lessons learned, show the benefits of merging social robotics with improvisational theater, and hope this will encourage further exploration of this cross-disciplinary intersection.**

Fig. 1: ImprovBot in a human-robot improv scene with the wizard and research lead off stage.

I. Introduction

Many of our daily interactions are unscripted and require impromptu responses. Every social interaction is improvised in the dynamic theater of life, and every conversation is built in the moment. While social robots can be programmed to navigate predictable interactions, they are seldom used for improvisation. It is such improvised interactions that robots must navigate if they are to become social players. Thus, it is worthwhile to learn what it takes for robots to operate in improvisational environments.

Human-robot scenes in improvisational theater offer an opportunity to explore how technology can support and inspire human creativity. In this paper, we develop and test an improv game that facilitates such exploration by allowing a human and a minimal social robot to perform together. We call the game *Relativity* because it is designed to show the robot's interest or disinterest *relative* to an improvised object in the scene, marked by an X on the floor.

In order to test the efficacy of this game, we had eight trained improvisers each create two independent narrative scenes with our robot. We then demonstrated various robot motions and recorded what interpretations the participants had regarding the movement's meaning. Throughout the tests, the robot's motions were the only indication of the robot's actions and emotions. Given this emphasis, our exploratory study asks the following research questions:

1) **Can a simple robot be a creative partner to a human improv performer?** Our goal is to have the robot seen, not as a stage prop, but as a fellow improviser.
2) **Can improvisers expand our understanding of robot expressive motion?** Because improvisers are trained to think outside-the-box, they can be helpful in exploring the possible interpretations to a given robot motion.

To provide background for this study, our paper begins with a discussion about related work and improvisational theater (Sections II-III). We introduce our game, *Relativity*, and present our robot, ImprovBot (Section IV). We explain how the game fits into our experiment where trained improvisers first create narrative scenes and then apply labels to individual robot motions (Section V). We discuss how participants were able to collaborate with ImprovBot in scene development and how they found the robot to be supportive and creative (Section VI). We also explain how some robot motions resulted in a diverse range of interpretations while others had low variance, thus leading to new perspectives on robot expressive motion (Section VII). We discuss test results, describe how participants were thrilled to work with ImprovBot, and discuss our goal to incorporate *Relativity* into live performances (Section VIII). We conclude by encouraging others to continue into this cross-disciplinary exploration (Section IX).

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II. Related Work

Our research is inspired by previous work that combines live improvisation with minimal robot expression. For example, Mathewson et al. [1], [2], [3] developed chatbots for improvisational theater by training neural networks with dialogue from over 102,000 movies. After hearing the human improviser's line, his algorithms provide a contextually appropriate line into the scene. Another example is Skeppstedt et al. [4], who compared improvisation scenes with computer-generated dialogue. Finally, Simone [5] is a professional improviser who created Bot Party, a human-robot improvisation show where six teleoperated robots interact in various ways with human improvisers.

However, these all have a heavy reliance on dialogue and do not take advantage of expressive motion as an alternative form of communication. Our novelty is that we target how motion can make a robot more effective at improvisation. We already know that expressive motion impacts how people interpret robot intention, emotion, and tasking [6], [7], [8]. While the design of robot motion typically focuses on pragmatic function [9], robot movements can also contribute to a common ground for human-robot collaboration [10]. Thus, our intent is use expressive movement to foster such collaboration in improvisational narrative development.

The use of expressive motion in improvisational robots is slowly gaining traction. For example, other researchers have integrated both dialogue and movement in order to improve unscripted robot communications. Greer et al.[11] had an improvising robot that used motion and a "gibberish" language to develop off-stage human-robot interactions. Bruce et al.[12] explored the audience's response to an improvised conversation between two mobile robots. However, our research differs, not only because we focus solely on robot motion, but because we study how the robot can be a creative inspiration for the human during the interaction.

III. Traditional Improv Scenes

A typical improv scene begins with two improvisers who get a **suggestion** from the audience. This suggestion is an unanticipated word that acts as the seed for an improvisational scene [13]. From this seed, the improvisers provide impromptu dialogue and mime the use of objects in their environment [14]. The improvisers work together to create an entertaining story until the off-stage host ends the scene by calling "Scene."

Many scenes incorporate an **improv game**, which is a set of rules the improvisers must abide by [13]. This makes every scene more unique and entertaining. Game examples include *New Choice* where the improvisers must replace their previous line with a new line every time the off-stage host dings a bell, or *Genre* where the improvisers periodically jump between genres during their scene.

Improvisers develop the scene by providing **offers**, which are pieces of information that establish what is going on [15]. Offers clarify the world being created on stage, provide inspiration for what could happen next, and are essential in progressing a scene. Improvisers can provide offers through dialogue ("Pass me that hammer, Ed"), the way words are said (tone of voice), motions (throwing an imaginary ball), and body language (looking sad). Insertion of new information through offers helps to progress the scene because the improviser is essentially saying, "Let's go in this direction."

This highlights the importance of teamwork. If both improvisers take the scene in different directions with their offers, the scene becomes disjointed and confusing. However, if both improvisers are attentive to the offers of their partner, they can take the scene in a unified direction. This makes the scene more entertaining, funny, and successful.

IV. Scenes with ImprovBot

Inspired by the improv principles described above, we present an improv game where the robot's motions act as offers. We then present our improv robot which was designed in conjunction with our game.

A. The Game: Relativity

The improv game is depicted in figure 2. We call it *Relativity* because on the floor is a small X (Fig. 3a) that provides a point relative for motion. The improviser first provides an opening line that addresses an imaginary object

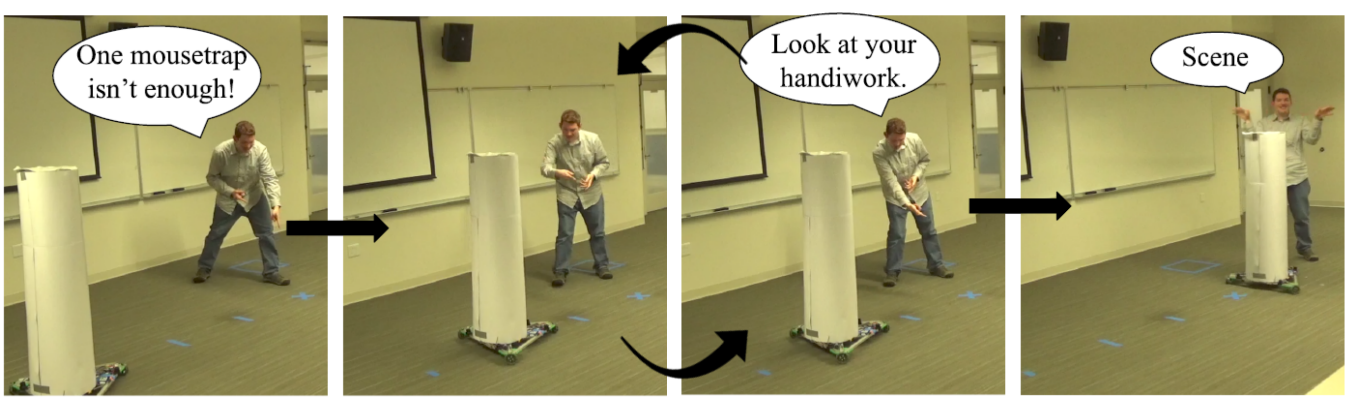

Fig. 2: Each individual scene has an opening line, multiple cycles of robot movement with a human reply, and then ends when the improviser calls "Scene."

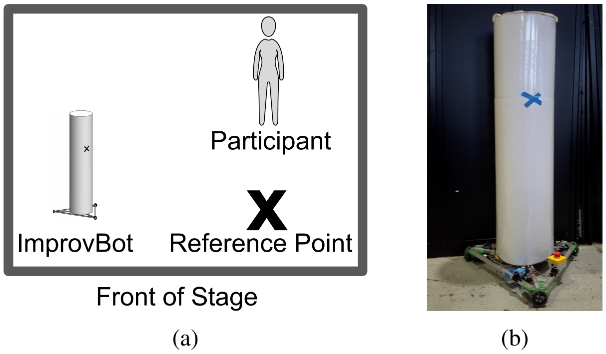

Fig. 3: (a) Relative starting positions of ImprovBot, participant, and reference point. (b) ImprovBot has omni-directional wheels, a cylinder body, and max speed of 1.5 m/s.

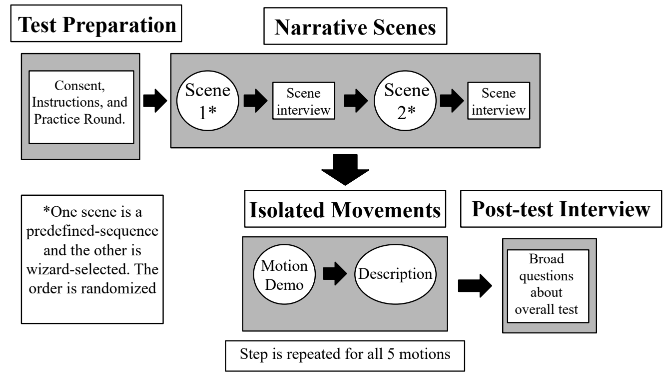

Fig. 4: Study Procedure: Each participant is prepped with consent forms, instructions, and a practice round. We collect our first data set through two narrative scenes, each followed by an interview. We collect our second data set from motion demonstrations and descriptions. We end with a post-test interview.

on the X. Next is a cycle which consists of a single robot motion and an improviser response. Multiple cycles ensue until the improviser feels the scene has become stagnant, at which point they end by calling "Scene." The X provides a reference point for robot motion, thus allowing the robot to show interest and disinterest towards an object. Participants appreciated the X because it provided a point of interaction between the human and robot. One participant said, "The X gives another thing for the robot to react to." They explained that when creating a story, having those moves in relation to something was helpful. While the robot can also move in relation to the improviser, this is challenging because the improviser is frequently moving.

B. *ImprovBot Design*

ImprovBot, depicted in figure 3b, is a mobile robot with a 1.1 meter tall cylindrical body. This height is 2/3 the average human height, thus allowing for a human-like presence without being overbearing. The robot's front has a tape mark so participants can identify robot orientation. We designed this simplistic form to ensure participant interpretation of the robot was primarily based on motion. Such a minimalist robot design leverages on our past work in robot communications [7], [8] and is common in social robotics experiments [6], [9].

ImprovBot's speed, movement, and timing are controlled wirelessly by an off-stage wizard, thus maintaining human-in-the-loop control over all movement. This was done because previous work in robotic furniture [6], [8] has demonstrated the benefits of wizard control, especially when conducting exploratory research studies into robot behavior.

ImprovBot's omni-directional platform facilitates rotation in place, independent movement in the X and Y directions, and max speeds of 1.5 m/s. This is more agile than previous platforms [16] which led one participant to comment "the variability of turning and speed made it unique." They further said, "because of its quick turning, its sudden breaking and going, there was more for me to interpret."

V. Study Procedure

This section describes our test procedure which is represented in Fig. 4. It involves preparing the improviser, two narrative scenes, isolated movement demonstrations, and a post-test interview.

A. *Test Preparation*

We start by providing the participant with consent forms and instructions on the game. To enhance the improviser's understanding of how the game works, a practice round is issued before the narrative scenes. The practice round has the improviser reference the X once (the first offer), after which ImprovBot reacts with a single forward motion. Located offstage, the wizard controls the robot with a full view of all interactions.

B. *The Narrative Scenes*

Next, we begin our narrative scenes. The human performer starts in a taped square to stage right with ImprovBot oriented towards, and approximately ten feet left, of the X. There are two scene conditions: predefined-sequence (our control), and wizard-selected. Each participant does two scenes, one of each condition. Scene order is randomized and participants are not informed of variations to scene conditions. Each scene is also followed by a verbal interview.

In the **predefined-sequence**, the wizard follows the motion sequence depicted in Fig. 5, regardless of what the human performer does. This approach is selected over randomized motions for both logistical and narrative reasons. For example, random moves in the same direction result in ImprovBot running out of stage room. We also want to see how many stories can come from a single motion sequence. Our hypothesis is that this condition will make ImprovBot less creative, inflexible, and an uncooperative robot.

The second condition is **wizard-selected**. This is where the wizard can move the robot however they deem appropriate for the scene. It is important to note that our

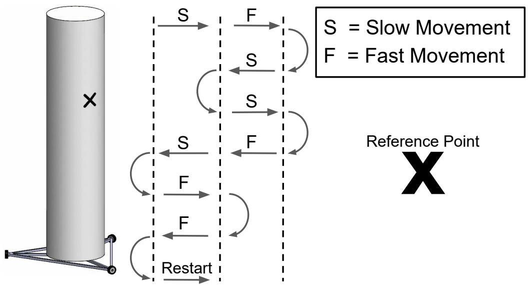

Fig. 5: Predefined-Sequence Condition: Robot followed motions in top to bottom order. Note that the robot only moves towards/away from X (not forward/back on stage). This contrasts the wizard-selected condition in which all motions are allowed at any time.

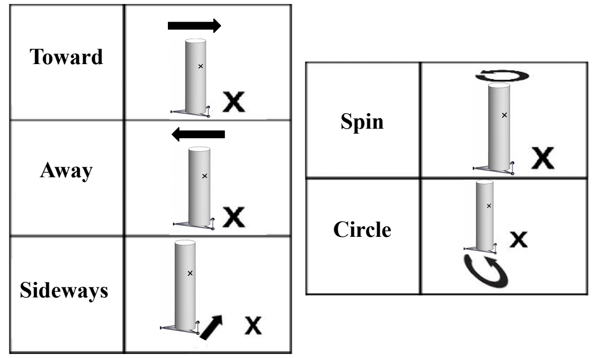

Fig. 6: These isolated movements are shown in random order to each participant. They are shown a move, asked what they think the motion means, and then shown the next move.

wizard is also an improviser, meaning he recognizes what motions would make a good offer. He can also recognize cues for when participants expect ImprovBot to move. Cues from the participants include eye contact with the robot, completing a statement, or falling silent. Our hypothesis is that the wizard-selected condition will make ImprovBot more creative, flexible, and cooperative.

Each scene is followed by a short interview, as shown in figure 4. Each interview has five questions that look at how the improviser viewed ImprovBot. The questions are:

1) *Who Carried Who in the Scene?*
2) *Who Took the Lead?*
3) *Was the Robot Surprising or Unsurprising?*
4) *Was the Robot Flexible or Inflexible?*
5) *Was the Robot Creative or Uncreative?*

C. Isolated Movements

After the two scenes, we progress to isolated movements where ImprovBot demonstrates the five motions depicted in figure 6. These motions were selected because of their simplicity and variance in both orientation and speed. These non-contextual moves provide a good contrast to the narrative scenes, wherein the motions would always be interpreted within the scene's context.

The participant is told to stand on the X and close their eyes. When they open their eyes, the robot does one of the five selected moves. The participant describes their interpretation of what the move means and is encouraged to share the first idea that comes into their head. This process is repeated for all five motions, with the motion order randomized for each participant.

D. Post-Test Interview

The final interview is an open discussion of the performer's opinions about ImprovBot and experiences playing *Relativity*. The questions we ask include what their overall impression of ImprovBot is, their summary of what happened in each scene, what characters ImprovBot portrayed, and which motions were memorable. We use the data from all these steps to seed the scene results in Section VI, and movement results in Section VII.

VI. Scene Results

The improvisational scenes varied from quarrelsome brothers trying to fix a car, mermaids working together to escape fishing hooks, and strangers having moral disagreements after finding vacation tickets on the ground. Of the eight participants, the first four were given one scene interview after finishing the two scenes, while the last four were given two interviews, one after each scene. This section presents quotes (Fig. 7-11) from the last four because those provide a comparative view between the two scene conditions. While this is a small sample size, we emphasize that this is an exploratory study, so the quotes and trends provide a rich range of concepts for future exploration.

A. Can ImprovBot Develop a Scene?

This subsection considers participant answers to two questions: *who carried who?* and *who took the lead?* These questions help us understand ImprovBot's role in co-creating the scene's narrative. When asked, *who carried who?* (Fig. 7) for the predefined-sequence condition, three of the four participants said they carried ImprovBot. However, this flipped for the wizard-selected condition where three of the four participants reported that ImprovBot helped carry them.

	Improviser	Robot
Predefined Sequence	"I was explaining all the moves. The robot was doing stuff, but I was explaining everything, so I was carrying the robot." "I was carrying the scene, I was making a lot of aggressive moves." "I was the one giving out suggestions and it was just running around."	"At the beginning it was me [carrying], and then it flipped. I felt by the way it turned that it was upset and saying, "I don't want to talk to you," its turning away made me change."
Wizard-Selected	"Me, I was leading with questions and looking for reactions."	"The robot was much more engaging this time with movements, it pressured me more." "It saw the cues I was giving." "There were definitely times I couldn't think of much, so I was using the robot's reactions to inspire me."

Fig. 7: Four participants were asked after each scene, *"Who Carried Who?"* Answers were divided by scene type (row) and binary answer (column). Gray shows the predominant answer

	Improviser	Robot
Predefined Sequence	"I took the lead...in the role that I chose, I was the higher rank than him." "Me. I was trying to figure out how to not interact with it by just asking questions."	"I started off kind of leading, but with it turning away, it kind of led it."
Wizard-Selected	"I took the lead, I was the one calling him out and he was trying to justify himself." "I took the lead because I felt I had to do something...I don't know how it [robot] could communicate to me what the next thing we're building is." "I led because I was referring to the story. It did acknowledge the story in a sense, but I had to keep leading it along."	

Fig. 8: Four participants were asked after each scene, *"Who Took the Lead?"*

	Surprising	Unsurprising
Predefined Sequence	"Surprising, I didn't realize how much inspiration I could get from the movements." "Surprising, but I felt that played into the scene well. That became his persona: sloppy but surprising." "Surprising because it would just do stuff."	"I'd say unsurprising."
Wizard-Selected	"Surprising if the reactions fit what was going on in the scene." "It was surprising in its closeness. It startled me, but in a good way." "Surprising, but I liked it. I didn't think it was going to turn around when I took it [the improvised object]...but then it turned around and that added to the scene."	"It reacted appropriately to what I was putting out there, so unsurprising because it felt like we were on the same wavelength."

Fig. 9: Four participants were asked after each scene, *"Was the Robot Surprising or Unsurprising?"*

For example, one participant in the wizard-selected condition said, "There were definitely times I couldn't think of much, so I was using the robot's reaction to inspire me." Conversely, in the predefined-sequence condition, the same participant said they were "giving out suggestions and it [robot] was just running around." It makes sense that ImprovBot's non-sequitur behavior decreases scene support because the improviser must struggle to justify ImprovBot's movement within the scene's context.

We then asked a subtly different question, *"who took the lead?"* With one exception, all participants reported that they took the lead (Fig. 8), often because they were the one speaking. One participant said, "I was explaining all the moves" and that this created an obligation to lead. In one scene where ImprovBot and the participant built a playground, the improviser later commented, "I don't know how it would have communicated with me what the next thing we're building is." This all implies that ImprovBot can support an improviser in scene development but rarely takes the lead. This supportive role was explained by a participant who said, "I thought that the robot was more of an assistant, not a super main character, like a very good sibling."

However, there was one instance where ImprovBot became the scene leader by abruptly turning away. The improviser later explained that ImprovBot was upset and communicated, "I don't want to talk to you." While we would need more data points, we suspect that strong displays of conflict can transfer ImprovBot from supporting the improviser's direction to leading their own direction.

B. Is ImprovBot Surprising?

For both scene condition, three of the four participants said ImprovBot was surprising (Fig. 9), with surprise generally occurring when ImprovBot deviated from preconceived expectations. As one participant put it, "I had an expectation in my head about how the robot may react." We found that movement in accordance with expectations made ImprovBot unsurprising. Movement not in accordance with expectations made ImprovBot surprising, but in either a good or bad way.

Good-surprising is when ImprovBot deviates from a mental expectation in a way that fits the scene's context. In one scene, both improvisers were strangers who found tickets to Hawaii on the ground. The participant led the scene such that both improvisers turned and walked away from the tickets. However, when the human improviser crept back to steal the tickets, ImprovBot turned around and caught him red-handed. The participant later described his surprise by saying "I didn't think it was going to turn around when I took it... but then it turned around and that added to the scene."

Bad-surprising is when ImprovBot deviates from a mental expectation in a way that does not fit with the scene's context. Such unexpected moves are "surprising because it would just do stuff." Participants reflected on these bad-surprises by saying, "it caught me off guard," that it "appears the robot is ignoring me," and that this can "derail a scene very quickly."

Interestingly enough, this "bad-surprising" is not always bad for the scene. In one scene with a sword fight, the participant created a persona for ImprovBot defined as "sloppy but surprising." The participant's character had a difficult time attacking because he could not predict ImprovBot's moves. He later described ImprovBot as, "Surprising, but I felt that played into the scene well."

Others were surprised by their own emotional reactions to ImprovBot's reactivity, mobility, or proximity. One said, "it was surprising in its closeness. It startled me, but in a good way." We feel this shows further potential for both ImprovBot and *Relativity* because the novelty has inherent aspects that are surprising to participants.

C. Does ImprovBot Stymie or Spur Creativity?

These next questions assess how effective ImprovBot is at creatively adapting to the offers provided. We ask, *is the robot flexible or inflexible?* and *is the robot creative or uncreative?* When asked about flexibility, all participants in the wizard-selected condition answered yes, while participants were split for the predefined-sequence (Fig. 10). This question was a manipulation check, i.e., did participants notice when the robot was in one condition vice the other. We view the condition switch to be noticeable considering half the improvisers labeled the predefined-sequence as inflexible.

In one wizard-selected scene, ImprovBot was a police officer while the improviser was a witness. The improviser implied they were unwilling to provide information. In the scene's context, ImprovBot appears to turn to intimidation

	Flexible	Inflexible
Predefined Sequence	"Flexible because I was throwing a lot of stuff at it in the scene." "It was flexible in the whole dynamic of it turning and jolting quicker while I was talking. I felt that was very flexible."	"It ended up continuing the bit about how we couldn't get along. It was too repetitive to be flexible." "It was acting independently, making its own decisions rather than making a decision based off what I was trying to get it to do."
Wizard-Selected	"The robot was more willing to go along with what I was doing." "It was flexible in a way that, I could feel its reactions to what I said." "Pretty flexible, it felt like there was [in the robot] an emotion conveyed there." "Pretty flexible. Whatever task I gave it, it was there."	

Fig. 10: Four participants were asked after each scene, *"Was the Robot Flexible or Inflexible?"*

	Creative	Uncreative
Predefined Sequence	"Still creative [compared to wizard-selected]. Like when I talked about the car, it suddenly approached." "Creative. I could imagine what it would say just by its movements. I felt that really gave me something to work with."	"I was carrying the creativity because I took control of the scene. I was making everything, all the new things." "Uncreative. I might just be hard on the scene because I didn't like it as much as the previous one."
Wizard-Selected	"Creative...it did feel like a real scene there with another person" "It played the role of an aggressive police officer pretty well, so I felt it was creative." "I think the robot was creative...there were decisions being made there." "Down the middle, it wasn't uncreative, it wasn't super creative..the [robot's] reactions to what I was doing, they were the right actions, but I don't know what else they could have been."	

Fig. 11: Four participants were asked after each scene, *"Was the Robot Creative or Uncreative?"*

by using sharp movements and invading personal space. The improviser responded by providing information and confessing he had tampered with the crime scene. The participant later said, "I could feel its reactions to what I said, by how harsh it was in its movements." Another participant mentioned how, during his scene as an old man, he enjoyed ImprovBot's flexibility. He said, "It saw the cues I was giving with being old and rickety...I thought it was a good give-and-take."

We also see flexibility in the predefined-sequence, with one participant saying, "It's not just a move once with the same motion, it was flexible in the whole dynamic of it turning and jolting quicker." This implies that the participant found the motion sequence in figure 5 to be a dynamic range of reactions. This bodes well if future versions of ImprovBot use predefined-sequences. While such a version will at times be seen to "act independently and make its own decisions," there will still be instances of perceived flexibility.

Next we asked, *"Is the robot creative or uncreative?"* In this case, all participants agreed that the wizard-selected condition was creative. However, they were again split between creative and uncreative for the predefined-sequence condition (Fig. 11). This distribution indicates that the relationship between flexibility and creativity is highly correlated. We saw this correlation in one scene about two mechanics. The participant described the robot as creative because "when I talked about the car, it suddenly approached." Note that even though this was a predefined move, the perception of flexibility in the robot was associated with creativity.

Another improviser described ImprovBot as creative because the movements provided inspiration. After a scene where they enjoyed a beautiful view from a mountaintop, the participant said, "I could imagine what it would say just by its movements. I felt that really gave me something to work with."

Only the predefined-sequence condition led improvisers to describe ImprovBot as uncreative. One said, "I was carrying the creativity," and later elaborated, "that may be because of the role I chose for it. Like being a subordinate in the scene makes him less able to be creative." In the other scene labeled uncreative, ImprovBot was a Goodwill employee helping a customer find sports equipment. The participant said, "I was trying to figure out how to not interact with it by just asking questions, but I couldn't really think of anything because its the way I set up the scene." He further said, "I kept asking it open-ended questions like, *how much does this cost?* but then realized there's no way it can answer that." We think scenes with ImprovBot may require some practice at avoiding scenes that stymie creativity. One tip may be to place ImprovBot in higher or equal status roles.

VII. Isolated Movement Results

We next explored if improvisers can expand our understanding of robot expressive motion. Our eight participants stated what they thought the robot's movement meant for each of the five movement demonstrations in figure 6. For easier clustering, we assigned their responses to positive, negative, or neutral valence (Fig. 12-14), which allowed us to create a visual representation of common answers. Although this is early work, our first pass reveals three possible categories for expressive motion interpretation: **low variance**, **tendency**, and **high variance**.

A. *"Low Variance" Interpretations*

Motions in this category, such as away and sideways, had very consistent interpretations. For these motions, the participants leaned heavily towards negative interpretations (Fig. 12). For example, away was mostly associated with fear, or at best, a simple desire to leave. Sideways was labeled with negative words such as "creepy" and "adversarial." Even the more neutral words could have a slightly negative connotation such as "mischievous" and "distracted."

Spatial interactions are often expressed via orientation or path shape of one individual in relation to another [16]. Thus, if a robot is moving away or sideways relative to an interaction partner, it could easily be interpreted as anti-interaction. In other words, the negative connotation may be explained by the fact that the spatial distance increases between robot and performer.

B. *"Tendency" Interpretations*

Motions in this category have interpretations across the spectrum with a strong tendency towards one side. In this

	Positive	Neutral	Negative
Away		Wants to Leave Wants to Get Away "I'm Out of Here"	Anxious/Shocked Scared/Nervous Fearful Intimidated Threatened
Sideways		Shy Stealthy/Mischievous Slowly Getting Away Interested, yet Distracted	Really Creepy Awkwardly Leaving Cautious/Adversarial Slithering Away

Fig. 12: Low Variance: Isolated movements resulting in similar interpretations.

	Positive	Neutral	Negative
Towards	Wanting to Engage Excited Eager Abrupt Greeting	Giving a Strong Yes or No	Rushed About to Yell Urgency
Circle	Inquisitive Pondering Gentle/Playful	"Look, there's no one else here"	Very Creepy Ashamed Turning a Blind Eye to the Situation Slowly Turning in a Swivel Chair and Saying, "I've Been Waiting For You."

Fig. 14: High Variance: Isolated movements resulting in evenly distributed interpretations.

case, the spin is mostly associated with "excitement" and "joy" (Fig. 13). However, there are two neutral interpretations and only one case of "disappointment," a negative interpretation. This indicates that spinning, or other motions under this category, have the potential to be used in multiple contexts. This reminds us of Ju et al. [17] who found that a shake of a robot trashcan can communicate, *I want trash* or *Thank you* depending on where the robot is in the interaction. Similarly, this data indicates that tendency motions can be interpreted in broader ways depending on the context of the interaction or the imagination of the human.

It is important to note that this was a 360° spin, meaning the robot faces the participant at the beginning and the end. Thus, this move does not have a connotation of escaping the improviser. Considering responses in section VI, half rotations would likely have negative interpretations and a much different social significance.

C. *"High Variance" Interpretations*

The motions in this category have evenly distributed interpretations across the spectrum (Fig. 14). For example, towards was seen as "excited" by one participant but "about to yell" by another. The circle motion saw a similar variation in labeling. They ranged from "inquisitive," and "playful" to "creepy" and "ashamed." Even within the positive labeling, there was a distribution of interpretations to include "gentle," "pondering," or even storytelling concepts such as "look, there's no one else here."

In the towards motion, we also see indications of relationships between ImprovBot and the improviser. Examples include "wanting to engage," "giving a strong yes or no," or "about to yell." With the circle motion, we see indications of storytelling. We suspect this is because the circle is a complex motion, meaning it has movement in more than one direction. Complex motions seem to trigger storytelling, an observation also made by Knight et al.[7]. Descriptions such as "look, there's no one else here," "turning a blind eye," and "I've been waiting for you" are all portions of larger stories.

	Positive	Neutral	Negative
Spin	Excited Joy Super Excited Joyful Excited	Showing Off Has Urgent Information to Convey	Disappointment

Fig. 13: Tendency: Isolated movements resulting in a range of interpretations that favor one side.

VIII. Discussion

This paper began with two research questions. The first was, **can a simple robot be a creative partner to a human improv performer?** As shown in section VI, robots can in fact fill this role. While it may be difficult for ImprovBot to lead a scene, the role of a supportive partner was well within reach. One participant said, "It felt like a real scene with another person." ImprovBot was not a prop, but a co-performer who spurred creativity and inspired the human improviser in narrative development.

Our second question was, **can improvisers expand our understanding of robot expressive motion?** As shown in section VII, improvisers broadened the possibilities for expressive motion. Their diverse perspectives enabled us to better understand how people may perceive five common movements. They showed us that while spinning or moving towards may be seen as excitement for one person, it could be disappointment or a yelling rebuke for another.

It is important to note that while the improvisers expanded our understanding of ImprovBot's expressive motion, they typically seek the creative and unexpected interpretations. As such, improvisers may not be the ideal test subjects if a researcher seeks the average or most common reactions. Instead, the strength of improvisers is in expanding the possibility space for how a given robot motion could be interpreted. Thus, for task-based robots with few expressive goals, traditional user studies may be more appropriate.

We also found that improvisers were eager to use ImprovBot in a live performance, saying, "**I genuinely want to have the robot at a show. I want it so badly.**" They elaborated that improvising with ImprovBot would be "a good gimmick for a one-on-one scene." Thus for future work, we plan to use ImprovBot in live shows. Because the improvisers overall found ImprovBot surprising and enjoyable, we expect audiences will be similarly curious, and hopefully delighted. We could then use the audience as a source for additional data collection.

Another goal is to create an autonomous version of ImprovBot. We plan to program a predefined-sequence of moves considering ImprovBot lacks the ability to select contextually appropriate motions. One challenge will be the scene's rhythm, meaning the timing at which the improvisers take sequential turns. While it will be difficult to design, an autonomous ImprovBot is an important step if human-robot improv performances are to become commonplace.

IX. Conclusion

Our research utilized concepts in improvisational theater, such as suggestions, offers, and teamwork, and used them to develop a game called *Relativity*. This game is played between a human performer and a robot that moves relative to an improvised object. We developed ImprovBot, a minimal robot capable of higher velocities and accelerations relative to previous work in expressive motion. We tested this setup with the help of a human wizard and eight improvisers. They provided insight into narrative development across two motion conditions: predefined-sequences and wizard-selected. Finally, they provided labeling for five independent motions that expanded our understanding of expressive motion.

Overall, we found that ImprovBot and human improvisers were able to work together to create cohesive and entertaining scenes. The contextually appropriate moves in the wizard-selected scenes provided increased support to the participants and caused them to see ImprovBot as flexible and creative. Even when ImprovBot moved with a predefined-sequence, half of the participants still described the robot as flexible and creative.

We also found that improvisers were effective at labeling isolated motions. Their creative perspectives enabled us to cluster interpretations, identify new ways to organize motion, and broaden our understanding of robot movement. These results support the continued value of using improvisational creativity to scaffold the development of social robots.

Improvisers can broaden the way we see expressive motion robots because these performers are adept at finding the unexpected while remaining consistent with the scene's context. They cast a simple cylindrical form as a mermaid, car mechanic, little sibling, and more. They jump to the outer fringes of possibility when given an offer, but always keep in mind the story they are in.

We envision a day when real-world social robots are improved after human-robot testing in improvisational theater. Considering our daily human-human interactions are improvised in the theater of life, robots with an improvisational nature will better integrate with our social world. We believe that service robots, designed with improvisation in mind, will have increased flexibility when handling the unexpected, higher creativity when accomplishing tasks, and the ability to better support humans in collaborative endeavors.

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