An Enactive Characterization of Pretend Play

Conference Paper · June 2015

DOI: 10.1145/2757226.2757254

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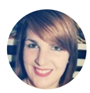

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ABSTRACT
This paper presents the results of an empirical study of 32 adult dyads (i.e. groups of two people) engaged in pretend play. Our analysis indicates that participatory sense-making plays a key role in the success of pretend play sessions. We use the cognitive science theory of *enaction* as a theoretical lens to analyze the empirical data given its robust conceptual framework for describing participatory sense-making. We present here five enactive characteristics of pretend play that appear to be necessary and sufficient for the emergence and maintenance of successful pretend play – mental preparation, meaning building, narrative enaction, narrative deepening, and flow maintenance. This enactive formalization is used to propose a computational model of pretend play that can be used to inform the design of an agent capable of playing in real time with human users.

Author Keywords
Pretend Play; Creativity; Computational Creativity; Co-Creative Agents

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Play is a fundamental aspect of human existence. Although play predates any concept of human culture or society [14, 22] – animals engage in play as children and adults without any formal cultural context – it is an important part of the human condition within familial and social groups. Play serves to strengthen social ties within groups, increase affect between individuals, and allow meaningful learning and practice at creative problem solving [7]. While play has been categorized by multiple efforts, it has yet to be formally understood in terms of the processes and actions participants execute to create a story world together, make stories, and establish shared meaning. Studying the fine grained behaviors of individuals engaged in pretend play can therefore inform us both about play at a deeper level as well as provide insight into how to formally represent such behaviors in computational systems. These formal representations can in turn help the design of various technologies to support, facilitate, and teach playful behavior.

C&C '15, June 22 - 25, 2015, Glasgow, United Kingdom
© 2015 ACM. ISBN 978-1-4503-3598-0/15/06…$15.00
DOI: http://dx.doi.org/10.1145/2757226.2757254

This article describes our current efforts to characterize successful playful behavior between adult dyads (groups of two people) with an aim towards informing intelligent agents that are capable of playing with human collaborators for entertainment, learning, and play therapy. Our current specific focus is on studying the socio-cognitive capabilities involved in third person pretend play between adult dyads (i.e. play between two participants who physically control objects and characters) [26,29,32]. We present a theory of pretend play based on our empirical observations viewed through the lens of the *enactive theory of cognition*.

The enactive approach in cognitive science emphasizes the "social and intersubjective nature of human understanding" [23]. While our analysis may have employed other cognitive theories, such as embodiment, distributed cognition, situated action, social cognition, or information processing, enaction provides a framework that unifies elements of each of these approaches together, which helps provide a systemic perspective of pretend play. In particular, enaction emphasizes the role that emergent and dynamic social coordination plays in guiding and facilitating perception and action [28]. We leverage the robust conceptual framework and vocabulary of enaction to formally represent participatory sense-making in the domain of pretend play.

Enactive cognition explains *interaction dynamics*, striving primarily to understand how perception and action are coordinated with the environment and other agents in that environment through emergent and continuous interaction known as *structural coupling* (or simply *coupling*). In this theory, stable relationships between perception and action characterize co-constructed meaning in the environment (i.e. the 'rules of the game' that help guide behavior and frame expectations to facilitate successful interaction) [13].

In his work detailing the enaction paradigm, Vernon [30] describes sense-making as the process by which "emergent knowledge is generated by the system itself [as] it captures some regularity and lawfulness in the interactions of the system, i.e. its experience." Our empirical study of play, as described in this paper, suggests that the primary process or mechanism that drives dyadic pretend play can be described as participatory sense-making (multiple agents engaged in coordinated sense-making), per the enactive theory of cognition [13].

We contend that successful pretend play requires players that are willing to a) co-construct shared meaning, b) enact a narrative based on that shared meaning, and c) deepen the narrative in a coordinated manner to maintain the flow of the emergent play experience. There are many communication, interaction, and cognitive strategies and processes recruited in successful pretend play, but our primary contention is that *participatory sense-making is the fundamental phenomenon that gives rise to successful dyadic adult pretend play*.

This article begins by briefly reviewing research on pretend play and similar technical projects in other creative domains working towards developing co-creative agents that improvise with humans in real time. It then describes our empirical investigation into dyadic pretend play and presents our enactive characterization of pretend play. Qualitative examples are provided throughout the characterization to demonstrate the utility of the enactive concepts to account for the success or failure of play. Finally, it presents a visual convention for representing the interaction dynamics of participatory sense-making. We describe how data collected using this novel convention can inform a computational model of pretend play.

RELATED WORK

A multitude of empirical studies of play have revealed its fundamental importance for development, in terms of cognition, communication, and emotion [6,19,24]. However, as Sutton-Smith has argued, the next step to understanding play is the development of detailed processual accounts of play [29] - of which there are few. Indeed, formal models of the socio-cognitive processes involved in play are fewer still. Zook et al. previously presented a formal computational model of pretend object play, but focused almost entirely on the process of substitution between real and pretend objects as opposed to any interactional aspects of play [32]. Bello presented a formal model of pretense as counterfactual logical reasoning within the PolyScheme cognitive architecture [3]. Nichols and Stich also offer an architectural model of pretense referring to a Possible Worlds Box as a separate mental workspace used during pretense [20]. However, all three models differ fundamentally from the work presented here by relegating interactions between agents playing pretend to future work. In contrast, our work focuses strongly on the interaction between agents engaged in pretend play.

While some researchers in the field of social robotics have begun to look into how robots can interact with humans to collaborate in socially appropriate and meaningful ways, this work remains outside the field of play research [1]. Outside of social robotics, the majority of agents capable of creative collaboration with human partners have come from studies of music improvisation [4,12,18], collaborative drawing [11], contemporary movement improvisation [16], and theatrical improvisation [17]. Magerko et al.'s Digital Improv Project employs the concepts of offers, iconicity, and shared mental model negotiation in order to create agents capable of playing improv games, such as Three Line Scene and Party Quirks [2,21]. Davis et al.'s Drawing Apprentice takes an enactive approach similar to the one advocated in this paper to implement an enactive co-creative agent that is able to collaborate on a drawing in real time with human users [11]. All of these agents demonstrate a capacity for creative collaboration to build an artifact, either a piece of music or performance, but fail to address many of the larger problems involved in creating an agent capable of interacting effectively in open ended interactions, such as pretend play.

EXPERIMENTAL DESIGN

We conducted an observational experiment to investigate pretend play during which we recruited adult dyads (i.e. groups of two) to play together in different conditions. Overall, 32 dyads were recruited, with a total of 64 participants. Recruiting advertisements specified to bring a partner to the study (i.e. participants were not playing with strangers). Participants were recruited from the student population of the Georgia Institute of Technology (age range 18-24; n=33 male, n=31 female). Of the 32 pairs, 16 consisted of male/female pairings, and the other 16 were pairings of the same gender (male/male, female/female).

Before beginning their experimental play sessions, participants were asked to complete three warm-up activities to get them into a playful mood and comfortable in the play space provided: *Zip-Zap-Zop* (a fast paced language game), *One Word Story* (players take turns adding one word to a story), and *Animalistics* (acting out an animal using a toy without talking). Next, participants completed two pretend play sessions lasting five minutes each, which were recorded, resulting in 64 play sessions to analyze. As shown in Figure 1, the play sessions took place on a large play-mat laid out over tables to allow players to stand while playing. Toys were kept in a box on the edge of the table containing primary-colored foam blocks and a varied selection of toys, such as those shown in Figure 1.

Participants were randomly assigned one of four scenario prompts to guide their play. To determine what the most popular scenarios would be given the toys we provided, an Amazon Mechanical Turk study was conducted. The four most common play scenarios suggested from that study were "Drag Race", "Car-Smash-A-Thon", "Monsters Attack", and "Zoo Visit".

During the first play session both participants were given the same (randomly-selected) prompt to guide their play, while during the second session, their prompts differed (referred to as session A and B in data analysis, respectively). Half of the 32 dyads groups were asked not to talk (sound effects were permitted) during their sessions in order to investigate the effect of verbal communication on pretend play. In all conditions (talking and non-talking), participants were encouraged to play together and find a way to use both of their prompts in the same play story. After each session, we administered a retrospective protocol analysis during which participants were shown their filmed play session and asked to describe their motivation, intention, and general thoughts on the actions they took during the play session.

Figure 1: Experiment setup of toys and play mat with two participants from the adult dyad study.

DATA ANALYSIS

Since relatively little is formally known about the sociocognitive processes of pretend play, we designed our data analysis method as an exploratory investigation to characterize playful behavior. We utilized a grounded theory [14] approach to the data analysis that began by reviewing the video records from the pretend play studies and coding the data to identify prominent concepts and categories. Initially, we framed our analysis purely in terms of identifying all the observable behaviors involved in human dyadic pretend play to embrace the bottom-up, data-driven approach of grounded theory. Through gradual iteration, we devised a categorization and coding scheme that described actions and related concepts at a fine level of granularity. Example categories included: Player, Object Type, Object Role, Play Action, Communication, Narrative Development, and Milestones.

Within each category, there were often many nuances and subcategories. Communication and narrative development had the most compelling and complex subcategories. Communication, for example, had several elements, such as whether the communicative act was verbal versus non-verbal, performed in character (diagetic) versus breaking character (non-diagetic), and the context of communication, i.e. whether the communicative act was utilized as a play offer, acceptance, or negotiation. The motivation for selecting a communication strategy seemed to be related to previously established co-created meanings, which subsequently helped guide the narrative going forward. It was therefore not as productive to look at individual actions as much as at the flow of actions and interactions through time (i.e. the interaction dynamics of the players).

As our analysis continued, it became clear that the dynamic and flowing nature of participant interactions could not be explained by any one action or combination of actions. The success of play appeared to be correlated to some emergent property of multiple factors. After comparing our empirical play data to the processes described in enactive literature on sense-making, we hypothesized that pretend play and participatory sense-making feature a similar process of social coordination utilizing the history of interactions, negotiated meaning, and feedback from verbal and non-verbal communication. With this observation and insight from the initial coding set, we iterated on our coding scheme once more by leveraging the concepts of participatory sense-making in enaction that help describe interaction dynamics.

We scoped our research question as a means of operationalizing our data-driven insights and reframed the investigation to ask: *what are the minimal requirements to enable an agent to successfully play?* To answer this question, we framed our analysis using concepts from the theory of enaction and focused primarily on a) continuously evolving interaction (rather than discrete actions and cognitive scripts) and b) different ways of coupling and coordinating interaction between agents to build meaning in a way that leads to successful play.

This type of analysis required an event level description of what types of perceptions and actions players used to make sense of the current interaction throughout the play session. This included a description of what actions the players performed and what analysts inferred they were trying to achieve with those actions given the current and historical context. To acquire this data, we performed an event level textual description of all the videos by carefully watching and transcribing an *intentional description* of what analysts inferred participants were trying to accomplish, a *behavioral description* of the how participants performed the actions to accomplish their intention, and an *evaluation* examining how this particular interaction related to the perceived success or failure of the play session.

Examining the data through the lens of enaction theory - in particular the concepts describing the sense-making process – facilitated our conceptualization of what could be happening during play. We composed a list of core and causal mechanisms controlling key sense-making processes during pretend play. We then employed these enactive characteristics observed in successful pretend play to further quantify the relative success of each of the sessions. We assigned a score of 3 if all 5 characteristics were present, a score of 2 for 3 if 4 of the characteristics present, and a score of 1 for 1 to 2 of the characteristics present.

Two analysts independently scored the data, achieving an inter-rater reliability score of .80 (joint probability agreement) with a Cohen's Kappa of .69 (substantial agreement). Of 64 total sessions, approximately 18 sessions were given a score of 3, 29 sessions were given a score of 2, and 20 sessions were given a score of 1. We performed a t-test (alpha of) to compare the success rates of talking and non-talking sessions. A t-test revealed there was no significant difference between the evaluation scores of talking and non-talking sessions (alpha of < 0.05; t-value of 0.36). A second t-test was performed on the scores for different vs. same play prompts. No statistically significant difference was found in the scores for sessions in which the experimental task involved the same play prompt and different play prompts (alpha .05; t-value of 0.80).

ENACTIVE CHARACTERIZATION OF PRETEND PLAY

Our data suggests that there are five critical ingredients required for two agents to successfully play: 1) Enter into a 'playful mindset,' willing to engage in imagination; 2) Negotiate a set of rules and roles that constitute a nucleus activity; 3) Embody characters and interact through them in a shared narrative world; 4) Introduce creative actions and elements to make the narrative more interesting; 5) Ensure coordination by negotiating timely additions to the narrative. Each of these ingredients is described in detail below referring to empirical data from the play session, as it is helpful to describe the characteristic. The play sessions are numbered 1-32 and denoted with an A or B depending on whether they were the first or second play session of the experiment, respectively.

Prepare the Mind

Enter into a 'playful mindset' to frame the interaction and set expectations. While pretend play typically comes easily to children, adults may feel self-conscious and perhaps even silly playing with toys and creating an imaginary story world. For play to be successful, participants should be open and willing to 'suspend their disbelief' and work to fully immerse themselves in the narrative world. Preparation strategies observed in the data include taking on the persona of a character and beginning to interact with the environment through that character. Actions that signal a player is attempting to 'embody' the persona of a character provide evidence of mental preparation. For example, participants often lowered their voice and moved more slowly when controlling large monster characters, such as Godzilla.

Players who failed to prepare themselves during the warm-up activities also tended to fail to immerse themselves in play, as was the case for Session 25. During Session 25, Player 1 appeared uninterested in playing, as evidenced by minimal participation in the warm-up games; that player attempted to gloss over each game by doing the bare minimum required to finish the game or let the timer run out. Based on our observation, this player was not open and willing to become immersed and play in an imaginary world. The data indicates that the more immersed players become, the easier it is to generate actions to perform, which can lead to more successful play (as shown in examples in the next subsection).

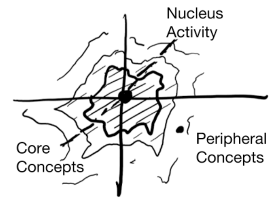

Figure 2: Depiction of nucleus activity

Build Meaning

Negotiate a set of rules and roles that constitute a nucleus activity and shape interaction. Players co-construct a new reality, a shared narrative world, by physically and conceptually structuring the environment in meaningful ways, taking control of characters, and providing details and specifications of characters that help enact the narrative [27]. Without a basic foundation of shared meaning, the participants don't know the 'rules of the game,' so to speak, and therefore cannot enact a narrative and successfully pretend play. We define this minimal seed of shared meaning as a *nucleus activity*, which is the most clearly defined and agreed upon elements of a story world and their most prototypical associations (i.e. prototype theory of categorization [25]). By definition, nucleus activities contain at least one role for each player and one rule to guide and shape interaction in some manner (see Figure 2).

The nucleus activity consists of a solidly negotiated core with peripheral concepts that are tangentially related for either participant. The strategies participants use to build meaning and co-construct nucleus activities vary drastically. The number of elements used to add onto the nucleus activity and build the narrative world, for example, does not seem to necessarily correlate with the success of the play session (as one of our initial hypotheses suggested). Rather, the quality or depth of meaning attached to each of those elements influences success. Assigning more details to further specify the role of their characters facilitates a deeper character embodiment. As players become more deeply immersed in the narrative world, they subsequently interact more naturally through that character.

Session 24A provides a good example of a nucleus activity serving as the seed from which complex interactions emerge. The players in this session initially worked together to construct a tower and other structures while making casual dialogue about the construction process. Then, Player 1 quickly grabs Tiger the toy box and performs a large jumping motion while roaring, and said "Giant Tigger. Giant Tigger attacks!" Her dialogue suggests that she specified a more detailed role for her character as a *giant* Tigger, a particular type of Tigger, that has the tendency to attack, which is the first ingredient for a nucleus activity. Player 2 acknowledges the attack (a precondition for negotiating a solid nucleus activity) when he said, "…and everyone is dead already…" Player 2 then goes in the box to retrieve a large character of his own and says, "Now, what do the monsters do?" Player 1 exclaims: "They fight each other!" and Player 2 responds, "Of, course!" and he laughs, indicating he agrees and is entertained and engaged by the decision. That sequence of dialogue sets up the 'monsters fight each other' nucleus activity that grows and transforms throughout the rest of the play session. Next, they added an additional rule to the nucleus activity of characters 'dying' after they are attacked by the monster. After a character died, the players would go to the box to recruit the next character for battle. Each time a new character was brought in front of Player 1's Tigger character, she would have it attack that character, including multiple pounces and roars.

There were several interesting narrative developments that were born from the simple nucleus activity identified here. Each action was rationalized with respect to the 'monsters fighting each other' nucleus activity as well as the individual capabilities and nuances of each character.

This example demonstrates that the quality of meaning that is co-constructed and applied to elements in the play space is more influential that the number or type of elements used in the play session. Individuals that were obviously not immersed in the narrative tended to have less qualitatively meaningful elements in the narrative world, which suggests that *preparing the mind and being consciously open and willing to immerse oneself in an imaginary world is correlated with the depth and complexity of meaning co-constructed in the narrative world*.

Enact the Narrative

Embody characters and interact through them in a shared narrative world. Once a nucleus activity is well established, players perceive the real objects of the environment (i.e. blocks and toys) through a 'perceptual logic' [10,11] that filters perception with respect to the co-created meaning structures of their nucleus activity. Examples of perceptual logic that could account for interaction patterns in pretend play include character motivations, character play affordances, narrative trajectory, environmental constraints (e.g. the setting), and feedback (e.g. other players).

Actions are not generated solely from a narrative or cognitive script. Rather, actions emerge through embodying and taking on the persona of a character and performing actions that make sense for that particular character in that particular narrative world (which may happen to draw upon previously learned cognitive scripts). Character definitions, motivations, and tendencies are adjusted based on feedback from their play partner. Narrative is an emergent quality of pretend play that arises as players work together to make sense of their respective actions (both retroactively and proactively) in the context of meaning structures established thus far in the play session. We propose that this "social coordination through interaction" is a form of participatory sense-making and a key component of describing pretend play.

For example, once the players in Session 24A defined the nucleus activity of 'monsters fighting each other' it was easy for them to focus on interacting with each other and creating interesting and funny variations on that initial nucleus activity. One type of variation on a 'rule' in the nucleus activity involved varying the type of action used in this particular type of monster fight, which was largely dominated by Tigger during the first half. As a result of Tigger's tendency to bounce, the monster fighting was generally accomplished in a bouncy and circular type path. At one point, when Player 2 is controlling a small plastic Godzilla, the participants form a tightly coupled action loop where Player 2 would try to jump on top of Tigger; Player 2 would then bounce Tigger on top of Godzilla.

The pattern repeated as participants laughed and made comments about it. Player 1 remarked, "You can't keep a Tigger down!" and player 2 replied, "You can! I just haven't bounced on his tail yet!" Player 2's last statement suggests the formation of a new rule in the nucleus activity that relates Tigger's tail to his ability to bounce. According to this logic, damaging Tigger's tail should limit his ability to jump, thus leading to a 'winning' scenario for Player 2's character. Player 2, however, cannot think of a way for his Godzilla character to reasonably damage the tail of Tigger at this point in the play session. He allows Godzilla to be defeated and returns to the box to find another candidate.

Later, Player 1 finds a super hero, and introduces it to the play session, "…wait…wait…a super hero!...I guess it's wolverine or something…come to save the day!...even though the people are already dead, but…" At this point Player 2 takes over Tigger, while Player 1 controls the Wolverine character she just took from the box. When Player 2 controls Tigger, he tries to further specify the character saying "He is made of rubber, so you can't stab him." However, Player 1 disagrees he is made of rubber and thinks he can be stabbed. Player 2's assertion that Tigger as 'rubber' makes sense given Player 2's initial contention that the only way to hurt Tigger was by damaging the tail.

Both participants generally agreed upon the basic nucleus activity of 'monsters fighting' and its rules about characters dying, but through the process of enacting the narrative participants explore the search space of the nucleus activity and pushed its boundaries. When participants disagreed, it was because there was a further specification that was assumed by one player given the agreed upon nucleus activity, but that assumption was not shared by the other player. This was evidenced by the disagreement about the circumstances under which the Tigger character can be defeated. Disagreements typically spur negotiations that provide opportunities to deepen the narrative and make it more engaging.

Deepen the Narrative

Introduce creative actions and elements to make the narrative more interesting. Purely enacting a basic narrative is engaging for a short period of time. To maintain creative engagement for an extended period of time, it seems necessary for players to add additional details and elements to the story world. This aspect of participatory sense-making no doubt has different strategies. We observed one strategy in particular that appears to be a recipe for success.

First, a nucleus activity is negotiated during initial setup. That nucleus activity can contain different amounts of complexity and detail. It can be negotiated using a variety of methods, but it minimally involves a definition of rules and roles. Those rules and roles have relevant knowledge associated with them, which should be considered as being included in a 'shared conceptual search space' of the co-constructed nucleus activity. Each action players perform has a certain semantic distance (degree of relatedness between concepts) from the core of this nucleus activity. Actions that are further away from the core are defined as more creative.

Creative actions require more explicit forms of negotiation because they might fundamentally change the nucleus activity and narrative world based upon it. When distant creative actions are not successfully negotiated, "siloed" play may occur as each player's mental model of the narrative world diverges. Successfully negotiating creative actions expands the core of the nucleus activity, as shown in nucleus activity expansion phase of Figure 4. Since the conceptual space of the nucleus activity is by definition a shared search space, its expansion increases the possibilities for relevant interactions, which tends to make it easier for individuals to play successfully.

Questions and actions that help clarify and add specificity to elements of the nucleus activity help to enact a narrative. For example, as players in 33A walked their character around the zoo, they questioned how the animals were caught, which provided an opportunity to provide an interesting back-story. Player 1, as his Godzilla character asked, "How did you manage to catch this giant tiger?" Next, Player 2 responded with a witty retort, "With a lot of cat nip…" When players rationalize their selections with respect to the nucleus activity, they tend to help make the narrative world more robust, interesting, and creative.

Maintain the Flow

Ensure coordination by negotiating timely additions to narrative. The creativity of participants and the actions they perform must be paired with the ability to maintain the flow of the play session through time. Successful sessions typically featured players that were attentive to their partner and strived to include them in a meaningful way. Depending on the demands of the situation, this can include subtle gestures, such as seeking feedback using eye contact. More active attempts maintenance activities involve explicitly engaging their partner, such as directing actions and dialogue toward them, or asking their partner questions to prompt elaboration. Social skills such as collaboration and empathy are important factors here.

Good players maintain a healthy respect for the rules of the nucleus activity, and will defend actions that violate those rules in some way (while still remaining open to negotiation). When players take creative actions that could be classified in the distant periphery of the nucleus activity, sometimes negotiation is required to ensure the nucleus activity expands properly. For example, in the Session 24A we described earlier, the participants have an interesting negotiation analyzing whether or not Tigger is made of rubber and therefore immune to 'claw' attacks. Player 1 acts as the Wolverine character and stabs Player 2's Tigger character, repeating "…stab, stab, stab…" Player 2 responded, saying "Nope…he is made with rubber so he cannot be sliced through with the claws." Player 1 objected, saying "Yeah he can!"

At this point, the physical play activity slowed down and players faced toward each other to continue the dialogue (while still performing the same attack actions, but with less vigor). Player 1 defends her point by saying, "Rubber can totally be cut with claws, especially when they are hard like him." Player 2 elaborates his initial 'rubber Tigger' addition to the nucleus activity to negotiate further, saying "Well…it self-heals, mostly…" Player 1 is not satisfied, and responded "Pffft, not really…besides-- [Player 1 performs slicing action from her Wolverine character on Tigger's tail]…cut off your tail!"

This turn of events ties back into one of the earliest rules added to this nucleus activity when Player 2 himself defined Tigger's tail as the special damage point that would render the character immobile. Player 1 takes a lead role throughout the negotiation and relies on a previously established part of the core nucleus activity to add a creative twist to the narrative.

Once Tigger's tail is cut off, Player 2 laments, "Oh no! Now Tigger is land-bound and must crawl around like a *normal* tiger, and he tries to eat wolverine, but wolverine is…" Player 1 then finishes Player 2's statement "…wolverine just slashes him up…" Next, Player 1 takes a lead role again and suggests the formation of a new nucleus activity, saying "Time to rebuild the town..." Player 2 agrees, and he continues on that trajectory by saying 'OK, and now wolverine rebuilds the town…' Player 2 interjects, "by himself…amongst all the dead people," referring to the initial play action that started the nucleus activity, i.e. Tigger destroying the town and all of the people dying.

The above example illustrates how Player 1 is guiding the play session and leading the interaction while still allowing

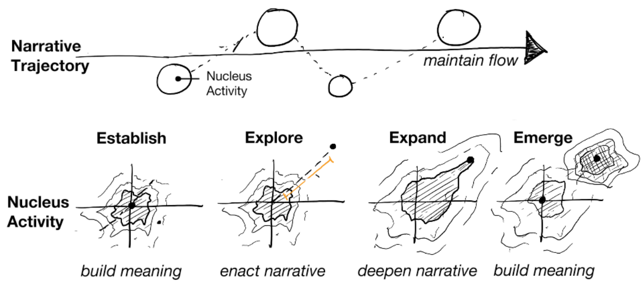

Figure 4: A narrative trajectory emerges from making sense of the current and previous nucleus activities

and encouraging contributions from the other player. Similar to how a good conversationalist knows when a topic is becoming stale, good players consciously maintain the flow of the play experience. Players engage in a coordinated dance of building on and subverting their partner's intentions in the shared narrative world by modulating between enacting and deepening the narrative. This skill involves knowing when to add depth to the narrative world and how to include your partner in that process. Through time, creative activities expand nucleus activities into new domains that might require slightly more rule definition and specification, eventually forming an independent nucleus activity, as shown in emergent nucleus activity phase in Figure 4.

Successful play sessions tend to have relatively well defined leader/follower roles that naturally switch over time as players come up with new ideas and strive to implement them in the story world. Oftentimes, the most successful play sessions involved players who handed off leadership to each other as their narratives progressed. Players that exhibit leadership in play tend to work to 'make sense' of both their and their partner's play actions by developing a common thread tying together the various nucleus activities constructed throughout the play session, termed the 'narrative trajectory' and shown in Figure 4.

AN ENACTIVE MODEL OF PRETEND PLAY

Enaction helps provide concepts like participatory sense-making that are useful for producing the above descriptions of successful pretend play, but how do we transition from this framework to a formal representation that informs the design of an intelligent agent that can play with humans? In the following section, we formalize the ideas of participatory sense-making to develop a computational tractable model of interaction dynamics in pretend play.

Interaction Dynamics of Participatory Sense-Making

As part of our ongoing analysis, evaluation, and formalization of the enactive characterization of pretend play, we developed a visual convention for graphing the interaction dynamics of social coordination in participatory sense-making. A graphical convention to represent the interaction dynamics would support comparative analysis of

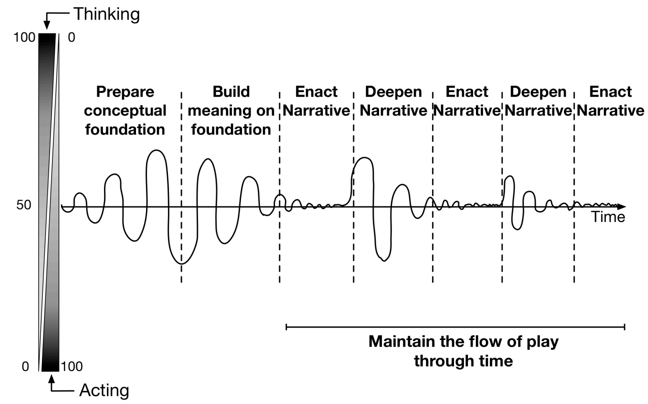

Figure 3: The enactive characteristics of pretend play mapped onto a sense-making curve

multiple pretend play sessions to further formalize our enactive characterization of pretend play. For example, determining how well participants worked together to *maintain the narrative* involves understanding several temporally contingent factors, such as the fluid nature of turn taking and leadership (i.e. whether players actively worked to include their partner), the degree to which participants are immersed in a shared narrative world, and what type of cognitive processing players employ throughout their interactions. From these empirically derived features, we devised the following requirements for graphing interaction dynamics in pretend play. The visual representation should:

1. Distinguish between neatly delineated turns and fluid coordination
2. Distinguish between high and low degrees of cognitive effort
3. Distinguish the approximate type of cognitive processing a player is engaged in, i.e. whether the player is devoting attention resources to mental activity (i.e. developing mental models and forming hypotheses to *build meaning*) or physical activity (i.e. performing and adapting actions to *enact the narrative*).
4. Represent the temporal distribution of these three features through time in a quantifiable manner

Figure 3 shows a sense-making curve using the graphical convention we developed for modeling interaction dynamics in pretend play. When the sense-making curve is plotted through time, the direction and manner of its progression characterizes the approximate narrative trajectory or flow of narrative experience through time.

The horizontal axis shows the progression of time during a play session, while the vertical axis corresponds to the distribution of the agent's limited attention resources at that point in time, i.e. the agent's cognitive load. The top quadrant corresponds to the general category of cognitive processing associated with thinking, while the bottom quadrant corresponds to the type of cognitive processing emphasized during performing actions.

As the player expends more cognitive resources thinking (i.e. building narrative meaning by forming models and hypotheses about co-constructed narrative elements), this curve would rise above the horizontal axis. Conversely, as the agent attends to their environment during the performance and negotiation of actions (i.e. performing the rolling motion associated with driving a toy car), the curve would fall below the central line.

The magnitude of the deviation in either the top or bottom quadrants corresponds to the approximate degree of cognitive effort exerted by the agent. Our graphing convention defines the zero points for the two vertical scales of thinking and acting at the top and bottom of the graph, respectively. This convention creates an inverse relationship between two overlapping scales. This method is preferred over two distinct linear processes with zero beginning at the central horizontal line given the fundamental assumption of enaction that humans think through action and act in order to facilitate thinking [13]. With this convention, the central horizontal line represents a roughly 50% distribution of cognitive resources between thinking and acting. For example, in session 24A (see Maintain the Flow section) players generated new modifications to their characters (i.e. imbuing Tigger with the quality of 'rubber' to deflect incoming attacks) at the same time as performing actions with those characters. In this circumstance, we might find several instances where the player's cognitive load could be described as 70% action and 30% thinking or some fluctuation thereof.

A section of the sense-making curve would correspond roughly to Csikszentmihalyi's definition of *creative flow* [9], where an individual is 'in the zone' and does not have to think or plan their creative contributions. Rather, Csikszentmihalyi reports that individuals experiencing flow often report an effortless execution of task and complete immersion in the activity. Conversely, an agent actively making sense of their environment would fluctuate around the central line in a slow percept-action feedback loop, as seen in preparation and building sections of the sense-making curve in Figure 3.

Modeling interaction dynamics using sense-making curves also helps formalize the role an agent might play in participatory sense-making in the context of pretend play. For example, the data shows how nucleus activities gradually grow in an organic and emergent manner through coordinated negotiations (described in the Maintain the Flow section). However, the question remains as to the exact processes and procedures utilized during this sense-making procedure. The sense-making curve provides a tool to make quantifiable predictions and hypotheses about the types of interaction dynamics and negotiation strategies that are observed to influence successful pretend play.

Nucleus Activities as a Shared Search Space

The empirically derived concept of nucleus activities suggests a design principle for conceptual search spaces that can potentially increase the feasibility of designing an agent that effectively 'plays' in real time. Based on our enactive characterization, we propose an approach to knowledge acquisition and learning in a pretend play agent by defining several nucleus activities over time that each serves as a separate conceptual search space for the agent. While a narrative thread connects these nucleus activities, the agent's computational processing (i.e. action recognition, action selection, and action modification) can be constrained to each individual nucleus activity as an independent search space during that particular phase of the pretend play session.

Within the confines of each individual nucleus activity, the agent can perform a constraint satisfaction process to generate and adapt actions in real time. Below are four initial constraints in the pretend play domain based on unique features of play (i.e. toys, partners, narrative, etc.) as well as features that were helpful in analyzing interaction dynamics in the pretend play data.

1. The literal physical constraints and affordances of the environment based on the player's body (i.e. how easily grasped toys are, the plushness of their texture, etc.).
2. The pretend constraints and affordances of the environment and the characters the players are actively using (i.e. whether a player's character can climb over, see, or reach various elements in the play world).
3. The narrative trajectory and flow of the play experience, i.e. bias search results toward those interactions that would somehow extend the current nucleus activity or link to previously defined nucleus activities.
4. Partner feedback, such as verbal communication, turn rhythm, eye contact, smiles, laughter, and looks of confusion or boredom.

The difficult and interesting computational challenge in this context is defining how an agent might be able to successfully negotiate a seemingly incongruous object into the narrative through negotiation and in real time. Given the observations from the pretend play data, successful negotiation includes gradual negotiation of an idea, including modification and elaboration of the seed idea. Negotiation includes multiple strategies that could be modeled using algorithms specializing in combinatorial creativity [5,8,31]. To account for the largely distinct type of actions generated during the building and enacting phases of pretend play, it is useful to delineate separate constraint satisfaction processes for co-creative pretend play agents.

The first constraint satisfaction process can be employed to determine a seed idea. This constraint satisfaction process corresponds roughly to the enactive characteristic *building meaning*. It deals large with constraints 1-3 identified above. Next, the agent works to negotiate that new idea into the existing nucleus activity or start a new nucleus activity. The initial seed action itself can be relatively simple, but the agent needs to be equipped with strategies and skills that enable negotiation and participatory sense-making. For example, the agent should be able to 'test out new ideas' through experimentation.

Encoding a large knowledge base for the agent to search through to select seed actions is less important than providing the agent with the ability to modify actions effectively. We see evidence of tightly coordinated and successful play interactions that evolved from relatively basic nucleus activity and seed idea. For example, Session 24A began with the seed idea of 'Business Man Zoo Visit.' The selection of 'business man' and 'zoo' played less of a role in constraining action selection than subsequent modification, elaborations, and specifications of the nucleus activity, as described in the Maintain the Flow section. Interactions that leverage existing nucleus activities fall into the category of enacting the narrative. While a co-creative agent is actively engaged in enactive the narrative, resources should be dedicated to interpreting feedback and social cues from the play partner for use in the modification and elaboration of elements of the nucleus activity.

Thus, the ideal co-creative pretend play agent should be capable of learning to: 1) select appropriate seed actions to build new meaning; 2) modify and elaborate seed action through real time negotiation and interaction; and 3) employ 1 and 2 at the appropriate time to help maintain the flow of the play session. These high level system needs demonstrate how the enactive characteristics can be employed to inform the design of co-creative pretend play agents.

FUTURE DIRECTIONS

The next steps in our research agenda include further quantification of our empirical play data by manually graphing each play session using the conventions of the sense-making curve presented earlier. Multiple analysts will be recruited to review each session to plot a sense-making curve for each player describing their approximate interaction dynamics throughout the play session. The granularity and the precision of the graph can change based on the needs of the analyst and the stage of analysis. For example, in early stages of data analysis, researchers can sketch rough depictions of the entire session at a low resolution for coarse-grained analyses and comparisons. In particular, this procedure benefitted the authors given the particular complexity of open-ended creative tasks and the large number of interconnected variables that all subtly influence the creative process.

The current method of manually plotting sense-making curves by hand is slow and imprecise. We are currently developing a research tool to optimize the process of producing sense-making curves from data in real time. This tool presents video data from the play studies along with a joystick interface and a real time plot of the joystick output visualized in a sense-making curve. This tool will enable researchers to rapidly produce sense-making curves to support exploratory and comparative data analysis.

The sense-making curve data will enable us to evaluate hypotheses generated by our enactive characterization of pretend play. For example, given the prevalence of participatory sense-making, we predict that turn frequency would gradually increase as participants solidified a shared activity. Further, each new nucleus activity could spawn another participatory sense-making process during which users work to gradually assimilate the new contribution to the narrative world. We plan to conduct another round of coding using the sense-making curves

Concurrently, we have begun implementing a co-creative play agent that attempts to build nucleus activities through negotiation and feedback, as observed in the pretend play studies. As the results from the sense-making curve analysis are formalized, these insights will be leveraged to help answer hypotheses generated from our enactive characterization of pretend play. These results will help further formalize and model the interaction dynamics of participatory sense-making in pretend play. This degree of formalizing will help inform what type of interaction dynamics and machine learning algorithms might be effective in co-creative pretend play agents.

CONCLUSIONS

This paper reports on an empirical investigation into pretend play between adult dyads. We used the cognitive science theory of enaction as a lens to analyze our empirical data and developed an enactive characterization of pretend play. In particular, we propose five characteristics of play that all rely on participatory sense-making: preparing the mind, building meaning, enacting the narrative, deepening the narrative, and maintaining the flow of the play session. The enactive concept of participatory sense-making was proposed as the key mechanism of pretend play. We developed a novel graphical convention called sense-making curves to model and represent interaction dynamics over time. Our future work includes conducting another round of data analysis to plot sense-making curves for all the pretend play sessions. This data will help evaluate the predictions and hypotheses generated by our enactive characterization of pretend play.

ACKNOWLEDGEMENTS

This work is supported in part by NSF IIS grant #1320520.

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