COGNITIVE SCIENCE
A Multidisciplinary Journal

Cognitive Science 46 (2022) e13112

ISSN: 1551-6709 online
DOI: 10.1111/cogs.13112

An Analogical Model of Pretense

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Received 3 October 2017; received in revised form 23 September 2021; accepted 21 January 2022

Abstract

We argue that pretense can be viewed as analogical projection: a structural comparison between the pretend scenario and its real-world counterpart that leads to inferences about the pretend scenario. For example, in pretending to make a phone call with a banana, a number pad might be projected on the banana's surface. We model two empirical studies of early childhood pretense, and show how successful pretense requires making and accepting such inferences, while failed pretense can be traced to failure of such projection. Other models of pretense, both theoretical and computational, and their relationships to our model, are discussed.

Keywords: Pretense; Pretend play; Analogy; Cognitive modeling

1. Introduction

Play is a vital part of childhood. In particular, pretend play, or pretense, has been implicated as crucial to the development of a variety of cognitive and social skills. As children play pretend, and as their ability to understand and participate in pretense scenarios improves, so does their understanding of—among other things—theory of mind, counterfactual reasoning, and symbolic understanding (e.g., Bach, 2014; Flavell, 1999; Lillard, 1994; Weisberg & Gopnik, 2013; see Weisberg, 2015).

Children begin to engage in some aspects of pretense at a very young age, and their ability to engage in pretense becomes increasingly sophisticated over time (see Thompson & Goldstein, 2019; Weisberg, 2015). Specifically, object substitution precedes use of imaginary objects, which precedes creation of imaginary friends. That is, a young child might use a toy cell phone to place a call to a person she knows, while an older child may hold a toy car—or even an empty hand—to her ear to call an imaginary friend. More complicated pretense requires an increasingly more complicated understanding of the world (see

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Van de Vondervoort & Friedman, 2017), and the ability to make increasingly more difficult substitutions. Pretense is easier when there is structural and/or functional similarity between stand-in objects and the objects they represent: Bigham (2010) showed that children with autism spectrum disorder "lack competence for some types of pretense." Specifically, they performed worse when objects used in pretense were not functionally or structurally similar to the objects they represented. It is easier to pretend to make a call from a toy cell phone than a toy car or a nonexistent handset.

Although a child who uses a toy phone to call Grandma is taking less of a leap than the child who calls via a toy car, both children are recreating a telephone conversation—an event that they have seen numerous times and which we can assume has become schematized. We propose that pretense involves making analogies between the situation in front of the child and schemas, treating the real objects as if they were the kinds of things found in the schemas. Thus, when the pretend objects are more similar to those in the schema, pretense should be easier, since there is more support for the mapping between the pretend event and the schema. Both the child who calls Grandma via a toy phone and the child who uses a toy car are aligning real-world objects with those in their schema, but in the second case, the alignment and inferences made by the child are more complex, due to the reduced object similarity.[1]

In this paper we argue that, at all levels of difficulty, pretend play recruits analogical processes—specifically, analogical projection to determine and accept inferences between pretend objects and events and their real-world counterparts. We also propose, but do not model, an interactive feedback loop: engaging in pretense leads to better analogical projection, and better analogical projection leads to more complex forms of pretense. That is, as a child pretends, she becomes better at analogical projection; as she becomes better at analogical projection, the complexity of pretend play that she participates in increases.

2. Psychological studies

Recently, empirical research into pretend play has focused on establishing the role of pretense in development of other skills (e.g., self-regulation, Whitebread & O'Sullivan, 2012; emotional control, Goldstein & Lerner, 2018; language competence, Kızıldere et al., 2020), determining children's preferences during play in general (e.g., Taggart et al., 2018), or tracking the depth of children's pragmatic understanding of pretend play (e.g., Sobel & Letourneau, 2018). One exception to this is Thompson and Goldstein (2020), who found that the modality of pretense—observation, partial participation (i.e., via puppet), or full participation (i.e., via a costume)—does not affect how well children understand it.

We are interested in the processes underlying the act of pretense in children—and, in particular, the causes of failure in these processes. Pretense failure has been studied at length in the context of the pretense–reality distinction (i.e., when children seemingly confuse the contents of pretense with the real world; see Bourchier & Davis, 2000a, 2000b). We leave modeling such studies, which tend to focus on conditions which lead to particular types of errors, to future work, and instead model two studies (Fein, 1975; Onishi et al., 2007) that manipulate young children's ability to engage in pretense at all. Although we note that the

Table 1
Experimental conditions in Fein (1975). Prototypical objects are marked with (p)

	Horse	*Cup*
Anchor	toy horse (p)	cup (p)
Condition 1A	toy horse (p)	clam shell
Condition 1B	metal object	cup (p)
Condition 2	metal object	clam shell

pretense in these studies is prescribed and does not include the full depth of pretense in older children, we believe that the underlying processes (i.e., analogical projection) are the same. In this section, we explain the results of the Fein and Onishi et al.'s studies through the lens of analogy. In section 4 below, we show how our model's results support this view.

2.1. *Fein (1975) Overview*

Fein (1975), examined mental representations in childhood pretense. In her view, pretense occurs when a child uses analogy to mentally transform an object into something else—a seashell into a cup, for example, or a toy horse into a real one. Here, Fein tested children's ability to perform multiple transformations. First, children were presented with a highly prototypical toy horse, one that convincingly looked like the real thing, and a highly prototypical cup. The experimenter then pretended to feed the horse and asked the child to "pretend he's still hungry. You give him something to drink." This was considered the baseline trial, and children who did not give the toy horse a drink from the cup were excluded from the experiment. This baseline also "anchored the analogy by explicitly proposing a highly prototypical reference point" (Fein, 1975). In other words, it told the children that the toy horse can be transformed into a real horse for the purposes of pretense and that the toy cup can be transformed in a similar way.

The experimental portion of the study was divided into three conditions (Table 1). In the first two, one of the highly prototypical objects was replaced with a less prototypical version. In Condition 1A, the cup was replaced with a clam shell; in Condition 1B the toy horse was replaced with a metal horse-shaped object. In the third condition, Condition 2, both substitutions occurred. Otherwise, the procedure mirrored the baseline trial.

Consistent with Fein's hypothesis, more children were able to "give [the horse] something to drink" in Conditions 1A and 1B, when only one item was replaced, than in Condition 2, when two items were replaced at once. Fein interpreted these results to suggest that "an easy transformation (toy animal to living animal) can support a more difficult one (empty shell to full cup)" and that such anchors are necessary for transformation in difficult pretense.

2.2. *Onishi et al. (2007) Overview*

This study examined the response of 15-month-olds to violations in pretense. Experiments were performed under three conditions[2] (Table 2). In the first, an experimenter presented a child with two empty cups and an empty pitcher. The experimenter pretended to pour from

Table 2
Experimental conditions in Onishi et al. (2007). Conditions with a familiarization trial are marked with (f)

	Poured Into	*Drunk Out Of*
Condition 1A	cup1	cup1
Condition 1B	cup1	cup2
Condition 2A	shoe1	shoe1
Condition 2B	shoe1	shoe2
Condition 3A (f)	shoe1	shoe1
Condition 3B (f)	shoe1	shoe2

the pitcher into one of the cups. Children saw one of two events: in the expected event condition (A), the experimenter pretended to drink out of the cup that she previously pretended to pour into; in the unexpected event condition (B), the experimenter pretended to drink out of the second cup. Children looked significantly longer in condition B than in condition A. In Condition 2, the same procedure was followed as in Condition 1, but with a single change: cups were replaced by shoes.[3] With this change, the looking time differences disappeared. When a familiarization trial was introduced in Condition 3—that is, the experimenter pretended to drink from a shoe, then followed the protocol from the prior experiments—the look time differences were once again significant. Specifically, children looked longer when the experimenter pretended to drink out of the shoe that she had not previously pretended to pour into than when she pretended to drink out of the other shoe.

Onishi et al. (2007) interpreted these finding to suggest that children expect consistency in pretense. They expect pretense actions to follow a script and are surprised (i.e., look longer) when pretend actions do not align with the script—in this case, when the experimenter drinks from something not typically used to drink liquid. Onishi et al. further suggest that the children in Condition 2 were "distracted by the novelty or incongruity of seeing the actor 'drink' from a shoe," and that Condition 3 shows that removing such novelty returns the child to an expectation of consistency to a script.

3. Modeling pretense via analogy

Our model combines aspects of the explanations proposed by Fein and Onishi et al., unifying them in terms of analogical processing. We agree with Fein that pretense takes place via analogy, and with Onishi et al.'s idea that pretense involves following a script. Specifically, we assume that the process of analogical generalization, as explained below, is used to construct schemas, and it is these schemas that are retrieved and mapped onto real-world objects during pretense. We view Fein's transformations as analogical projections via analogical inferences: an object that is mapped to a telephone in a "making a phone call" schema is assumed, for the purpose of pretense, to be a telephone. That some transformations are easier than others follows from the well-known object bias in analogical matching by young children: early in development, children tend to focus on surface-level properties, whereas structure-level properties become more important as children acquire more relational knowledge (Christie et al., 2016; Gentner & Rattermann, 1991). Accepting these transformations, even tentatively, is a form of analogical projection. We explain Fein's notion of anchoring in terms of doing an easier mapping first, and then doing a second mapping using the results of the first one, which serves as a scaffold. Our model suggests that the familiarization trial in Onishi et al.'s Condition 3 serves a similar anchoring function.

We next briefly review the analogical processes upon which our model is based. Then we describe the model itself, followed by two simulation studies covering the Fein (1975) and Onishi et al. (2007) experiments.

3.1. Analogical processes

We define analogical processes with respect to structure-mapping theory (SMT; Gentner, 1983). SMT views analogy and similarity as the process of aligning two structured, relational representations. These representations can include object attributes as well as relationships between objects. Attributes can be perceptual (e.g., color), category information (e.g., Horse), or functional. Similarly, relationships can be perceptual (e.g., above), causal, functional, or evidential. The alignment process constructs a set of *correspondences* between the entities and statements in the two descriptions being compared. Based on these correspondences, *candidate inferences* consisting of information that can be projected from one description to another are proposed (e.g., that a small plastic object that a child can heft actually is a horse; see Fig. 2). Analogy constructs candidate inferences, but their evaluation is left to processes outside the matching process itself. Alignments follow a set of constraints defined by the theory, which have received considerable psychological support (e.g., Gentner & Clement, 1988; Markman, 1997).

The structure mapping engine (SME) (Falkenhainer et al., 1989; Forbus et al., 2016) is a computational model of this structure-mapping process. The two structured descriptions it takes as input are called the *base* and *target*. The set of correspondences, candidate inferences, and a numerical *similarity score* constitute the *mappings* produced as SME's output. SME typically only produces one mapping but can produce up to three if they are very close. Candidate inferences provide the means for analogical projection, or "seeing as" in pretense (e.g., a toy car is not actually a telephone but can be used as one in a pretense scenario). We assume that processing and accepting candidate inferences takes effort, and argue that this effort leads to differing performance during pretend play.[4]

For the purposes of this model, we assume that schemas are constructed via analogical generalization from multiple alignable events. Such schemas can be stored in long term memory (*generalizations*; McLure et al., 2010) or as temporary schemas in working memory (*interim generalizations*; Kandaswamy et al., 2014). Generalizations are created by the SAGE algorithm, which incrementally accumulates generalizations and outlier examples for concepts. Each concept is modeled via a *generalization pool*. When a new example is added, the most similar generalizations and examples are found via analogical retrieval (Forbus et al., 1995). When sufficiently similar, the new example is assimilated into a prior generalization, or a new generalization is formed by merging it with a prior example, depending on

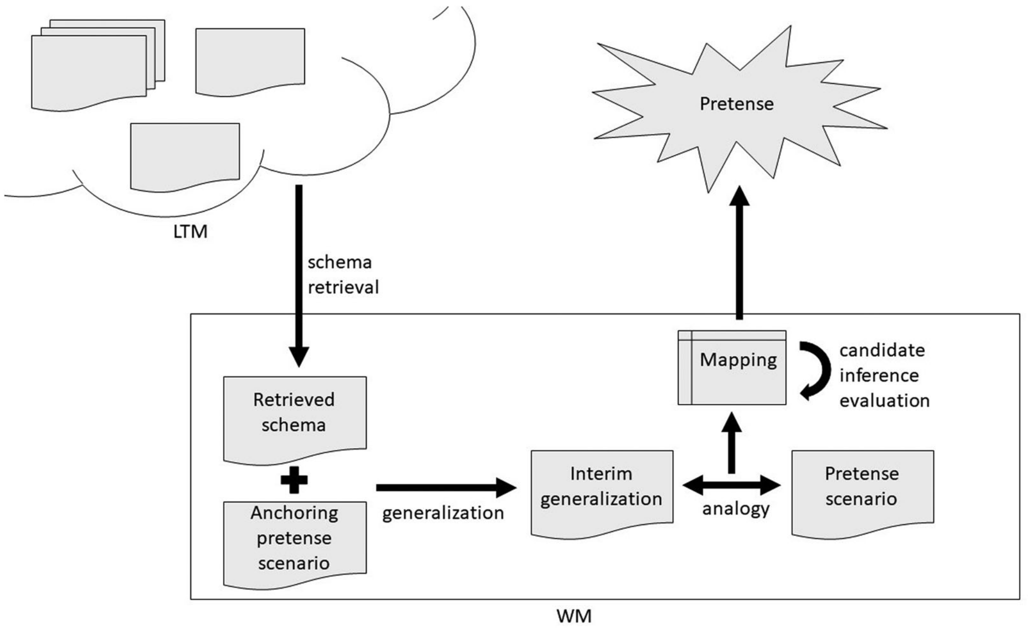

Fig. 1. Model diagram of pretense by analogy. An event schema is retrieved from long term memory (LTM). It forms an interim generalization in working memory (WM) with the anchoring pretense scenario (if present; see Fig. 2). The interim generalization is then used to create an analogical mapping with the ongoing pretense. For pretense to continue, candidate inferences from the mapping must be accepted

what was retrieved. The merge process replaces nonidentical entities with more abstract entities but does not introduce logical variables. It also updates frequency information for every statement in the generalization, thereby automatically creating probabilistic schemas that can be applied to new situations via analogy. Interim generalizations are formed in a similar way and stored in working memory; retrieval is based on similarity and biased via recency: a more recent (or ongoing) pretense event is more likely to be retrieved than an older one.

3.2. Model description

We propose that pretense takes place via a series of analogical operations between the pretense event and a retrieved schema. A model diagram can be found in Fig. 1. When a pretense event is initiated—verbally, by watching someone else perform a pretend action, or by the presence of a toy—we believe that the child first retrieves a schema from long-term memory. In structure mapping terms, this schema would originally have been created via analogical generalization from earlier experiences. In the case of placing a pretend phone call, the schema would be based on telephone calls the child had witnessed previously. While we believe that retrieval occurs via structure mapping in many cases,[5] our model is agnostic to the specific mechanisms of schema retrieval.

This retrieved schema is mapped onto the observed situation, which we call the *scenario*. Some of the overlaps between relationships in the scenario and the schema will suggest

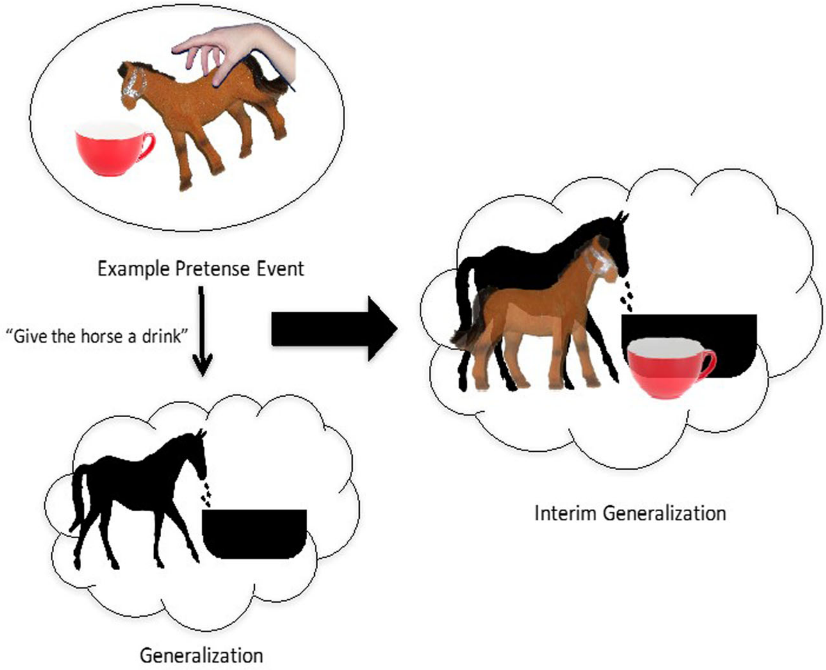

Fig. 2. An interim generalization created from a generalization of a horse drinking and a single pretend event wherein a toy horse drinks from a cup

potential correspondences whose candidate inferences serve as suggestions for possible transformations.[6] When an inference is generated and tentatively accepted for reasoning, analogical projection has occurred. For example, the telephone schema would suggest that the object the child is holding is a telephone. Each such inference has some associated probability, computed based on the evidence in the mapping (e.g., being a telephone might be 1.0, whereas its color might be black with 0.5, silver with 0.5). If the object is a toy telephone, it should both be relatively easy to produce inferences, and any inferences produced should be more compatible with the object—and so, the transformation should be easier to accept—whereas for a toy car, they should be less so. We are agnostic as to the process by which this evaluation takes place—it might be a recursive analogical match against a schema for the type of object involved, for example, or involve reasoning about conflicts between visible properties/prior knowledge with the projected properties, such as knowing telephones do not have wheels. In any case, we assume that the more similar the pretend objects are to their real-world equivalents, the easier this process of evaluation is, and the more likely the child is to generate and accept the proposed mapping. If the mapping and corresponding inferences are accepted, then the pretense continues. If they fail, the pretense ends.

When an anchoring event is observed, it is stored together with the pre-existing schematic event in working memory (see Fig. 2). This combination schema is represented via an interim generalization, which allows the pretense to continue more easily via direct mapping, since the candidate inference has already been accepted (i.e., the toy car is already viewed as a telephone, so the child will more likely be willing to use it to make a pretend call). We show how this works with the Fein (1975) and Onishi et al. (2007) studies next.

3.3. Model procedure

We assume that children are able to retrieve an appropriate schema out of long-term memory, as failures in pretense tend to manifest as a lack of pretense rather than unexpected pretense; Fein (1975) did not report any children pretending to make a phone call using the toy horse, for example. Furthermore, these studies were controlled such that unexpected pretense was unlikely. For this reason, and the impossibility of accurately modeling all of the generalizations in a child's long-term memory, we simply provide an appropriate schema to the model as one of its inputs. Since, again, modeling the sequence of experiences that a child might experience fully is impractical to impossible, we instead use *synthetic generalizations* to create input schemas. Synthetic generalizations are made by approximating the probability of facts in hand-constructed schemas based on plausible assumptions about the distribution of experiences that someone might see.[7] For example, a child may have seen a telephone call being placed using a smartphone 50% of the time, an older cellular phone 20% of the time, and a wireless home telephone 30% of the time. Varying the distributions did not affect model outputs.

To model each study, we use synthetic generalizations to represent schematic events (e.g., taking a drink), automatically constructed interim generalizations between the synthetic generalization and the anchoring event to represent the combined schema in working memory (e.g., taking a drink from a shoe), and single events to represent individual expected pretense scenarios. In each case, the pretense scenario is the target, and the generalization or interim generalization is the base. We interpret candidate inferences relevant to schema satisfaction (i.e., the horse involved must be a real horse, but it does not necessarily need to be brown) suggested by SAGE as necessary in order for pretense to continue.

4. Simulations

We test our model using the results of Fein (1975) and Onishi et al. (2007). In the model, transformations as proposed by Fein are candidate inferences that must be accepted for pretense to continue. Scripts, as suggested by Onishi et al. are represented as schemas produced via analogical generalizations from prior experiences. The process of anchoring is based on an initial comparison between a schema and a situation, producing an interim generalization which will match better to subsequent pretense scenarios.

4.1. Experiment 1: Modeling Fein (1975)

Recall that this study sought to elicit pretense in 4-year-old children by providing them a horse stand-in and a cup stand-in and asking them to give the horse a drink Fein (1975). Following a baseline anchor trial with a highly prototypical horse and a highly prototypical cup,

Table 3
Candidate inferences (CIs) needed for successful pretense in Fein (1975)

Condition	*CIs Required*	*Total CIs Required*
1A	shell_1 is a cup	1
1B	metal_object1 is a horse	1
2	the shell_1 is a cup metal_object1 is a horse	2

children were tested under one of three conditions: 1A, in which the horse stand-in remained highly prototypical, but the cup stand-in was replaced by a nonprototypical item; 1B, in which the cup stand-in remained highly prototypical, but the horse stand-in was replaced by a nonprototypical item; and 2, in which both the cup stand-in and the horse stand-in were replaced by their respective nonprototypical versions (see Table 1).

4.1.1. Model inputs

We model the experiments in this study as a schematic example of a horse drinking probed by the expected pretense of the horse stand-in drinking out of the cup stand-in. Since children who failed to pretend in the baseline trial were dismissed from the rest of the experiment, we assume that the toy horse and cup were part of the remaining children's interim generalization.

Predicate calculus representations used in the model can be found in Supporting Information Appendix A.

4.1.2. Simulation results

According to our model, pretense is possible in all the conditions tested by Fein. Condition 2, however, requires accepting more candidate inferences than do Condition 1A and Condition 1B. The inferences required by our model for successful pretense can be found in English in Table 3 and in predicate calculus in Supporting Information Appendix A. Specifically, when a child is first presented with the toy horse and seashell in Condition 1A, he is able to match the horse as the drinking entity since this is how the horse was portrayed during the baseline trial. The remaining candidate inference is of the seashell as a cup. Similarly, when a child is presented with a metal horse and toy cup in Condition 1B, she is able to match the toy cup to the item to be drunk out of but must now accept the candidate inference of the metal object as a horse. In Condition 2, on the other hand, we see two candidate inferences (CIs): that the metal object is a horse and that the seashell is a cup; the child must accept both. Failures happen when children are not able to accept these CIs, perhaps because they find that two simultaneous inferences are implausible.

4.2. Experiment 2: Modeling Onishi et al. (2007)

Recall that this study measured infant looking times when an experimenter pretended to drink out of cups (Condition 1) or shoes (Conditions 2 and 3). Each condition had a control and experimental trial. In the control, the experimenter pretended to pour water into the

Table 4
Candidate inferences (CIs) needed for successful pretense in Onishi et al. (2007). Conditions marked A correspond to control trials; conditions marked B correspond to experimental trials

Condition	*CIs Required*	*Total CIs Required*
1A	pitcher1 is full cup1 is full	2
1B	pitcher1 is full cup1 is full cup1 is poured into	3
2A	shoe1 is a cup pitcher1 is full shoe1 is full	2
2B	shoe1 is a cup pitcher1 is full shoe1 is full shoe1 is poured into	3
3A	pitcher1 is full shoe1 is full	2
3B	pitcher1 is full shoe1 is full shoe1 is poured into	3

cup/shoe she then pretended to drink out of (A); in the experimental trial, the experimenter pretended to pour water into a different cup/shoe (B; see Table 2).

4.2.1. Model inputs

To model Conditions 1 and 2, we gave the model a schema for drinking with pretense scenarios corresponding to the control and experimental conditions (i.e., the object that is poured into is versus is not the object that is drunk out of). For Condition 3, an interim generalization—generated from the previous schema with the addition of drinking out of a shoe, based on the study's familiarization trial—was provided; pretense scenarios were reused from Condition 2.

Predicate calculus representations used in the model can be found in Supporting Information Appendix B.

4.2.2. Simulation results

The candidate inferences required for successful pretense by our model for each of Onishi et al. (2007) experiments can be found in English in Table 4 and in predicate calculus in Supporting Information Appendix B.

In the control trial of Condition 1, pretense is easy: the only necessary candidate inferences are that the pitcher is actually full, and that it causes the cup to become full after pouring. On the other hand, in the experimental condition there is an additional candidate inference. The child must accept the that the cup being drunk out of had been poured into—or that the cup that had been poured into is being drunk out of.[8]

This additional candidate inference accounts for the looking time difference between the control and experimental conditions; both cases of pretense are plausible, one is just more difficult. Condition 2, however, requires accepting even more candidate inferences: the child must additionally accept that a shoe can play the role of the object being drunk out of (i.e., that it can be a cup). This is much harder for the child to accept, as it requires changing the category of the item. For this reason, pretense fails. This is true of both the control and the experimental conditions. Finally, Condition 3 shows the importance of interim generalizations. Since an experimenter demonstrated the act of drinking from a shoe to these children, they were able to create the interim generalization that shoes can be drunk out of. Because of this, they did not have the additional CIs as in Condition 2 and were able to accept the pretense again. While pretense is possible in all scenarios, it is substantially harder in Condition 2; so much so, that infants are unable to participate in the pretense. As such, both looking time differences (in Conditions 1 and 3) and lack thereof (Condition 2) can be explained by the number and plausibility of candidate inferences.

4.3. Discussion

The results of modeling both the Fein (1975) and Onishi et al. (2007) studies support our hypothesis that pretense occurs via analogical processes. In both studies, the model shows that children's failures in pretense under various conditions can be explained as failures of analogical projection.

In analyzing our model, it is important to note that our representations are simplifications of the full pretense scenario. In addition to accepting candidate inferences to describe the objects involved in pretense, children must also accept candidate inferences relating to events. Such inferences, however, are common to all pretense, so we chose to omit them for clarity. Including more inferences and richer representations of events would not change the conclusions and predictions drawn from our model.

5. Related work

As noted above, one of the first to suggest analogy in pretense was Fein (1975). Although our account differs from Fein's, we agree that analogical processing—in our case, structure-mapping—is central to pretend play. However, several other theoretical (e.g., Harris et al., 1993; Langland-Hassan, 2012; Nichols & Stich, 2000) and computational (Bello, 2012) models of pretense have been proposed. We briefly discuss how our account interacts with the theoretical models first, then address the computational model.

5.1. Pretense as story comprehension

Harris et al. (1993) argue that pretense is best understood by analogy to story comprehension. Each instance of pretense, which they call a pretend episode, can be viewed as a story. The child must keep track of the events and characters in a story. Similarly, she must follow the pretend identities of objects and people, as well as events that may or may not actually occur. In both stories and pretend episodes, objects and referents come into and out of focus, and both require "elaborative causal inferences that integrate successive parts of an episode." Harris et al. also introduce the concept of pretense flagging, wherein objects are flagged according to their role in the pretend episode.

Our model is consistent with Harris et al.'s account. We represent each pretend scenario as an individual event. Events and object identities are tracked via interim generalizations. Our model's analogical projection mechanisms can include elaborative causal inferences, though the studies modeled in this paper do not require or showcase this capability. While we do not currently flag objects as pretend, our representation allows for their introduction. Although the current model was successful without these flags, we allow that more complicated pretense scenarios may require them.

5.2. *Pretense as addition to two-state cognitive architecture*

Nichols and Stich (2000) extend the two-state account of cognitive architecture to explain pretense. The original account separates the human mind into beliefs, controlled by perception and inferences from prior beliefs (Belief Box [BB]), and desires (Desires Box [DB]), controlled by body monitoring (e.g., thirst, hunger, etc.) and practical reasoning. Nichols and Stich add a third module, possible worlds (Possible World Box [PWB]). PWB can be viewed as a sketchpad where pretend scenarios are created and played out. It has full access to the contents of BB, mediated only by an UpDater, which Nichols and Stich view as an extension of the inference mechanisms that control BB. The UpDater prevents beliefs about the real world (from BB) and the pretend world (from PWB) from contradicting each other by updating beliefs held in the PWB as the pretend scenario changes. In postulating a separate PWB, the Nichols and Stich account differs from our proposed account, in which pretense occurs by a direct analogy between the child's schema and the situation in the real world. That is, in our model, reasoning about the pretend scenario is not isolated from other memories and beliefs. However, the two accounts are parallel in that Nichols and Stich argue that BB includes general schemas that "can provide general structure for many pretense episodes," and that the remaining details can be filled out by prior pretense and background knowledge.

5.3. *Pretense as special case of belief and desire*

In contrast to Nichols and Stich (2000), Langland-Hassan (2012, 2014), argues that pretense can be satisfactorily represented within the standard two-state architecture (i.e., using only the DB and BB, without a separate PWB). According to Langland-Hassan (2012), the PWB is redundant for explaining the processes of pretense.

The crux of Langland-Hassan's proposal is that pretending that something is true does not require considering the possibility that it really is true, which allows it to be represented and reasoned about using the same processes as beliefs and desires. In fact, pretense events can be represented as a set of beliefs and desires: beliefs about how scripts typically play out, desires to participate in pretense, etc. An important aspect of this account is children's ability to represent counterfactual beliefs (e.g., "if you had done X, Y would now be true"). Such a belief allows a child to act as if X had actually occurred, thus allowing her to continue the pretense.

From a representation standpoint, this account differs from ours, as we do not explicitly treat pretense as a combination of beliefs and desires. Nor do we explicitly represent counterfactuals. However, our use of candidate inferences and interim generalizations shares important properties with the kinds of counterfactuals Langland-Hassan's account relies on. In effect, by projecting a schema onto the real-world scenario, the analogical processes described in our model allow the child to reason as if the schema were true in the real world.

5.4. *Pretense as second world*

Bello (2012) models pretense by assuming that a child maintains two distinct contexts (or worlds), the real world and a pretend world, similar to Nichols and Stich's separate PWB, but without explicit separate contexts for desires and beliefs. Properties of the pretend world are inferred from the real world, using nonmonotonic inferences. Probabilities are given to events in each world, such that a child's actual actions are based on a calculation stemming from the probability that such an action would occur in the real world and the probability that it would occur in the pretend world. For example, Bello argues that, given a mud pie, a child would only pretend to eat it, since the probability of mud being inedible in the real world is too high to allow actual eating. (Of course, some children do eat mud, but that may be explained by other factors.) What is not clear from Bello's model is how failures in pretense occur. Is the probability of a metal horse drinking from a seashell simply too low? What, then, allows for the same metal horse to drink from a toy cup or a toy horse to drink from the same seashell?

Bello (2012) also proposes that there are six core features of pretense, three of which our model addresses. The first feature is "an agent who is doing the pretending": the child (Fein, 1975) and/or experimenter (Onishi et al., 2007) in our case. Second, "a reality that is being pretended about" must exist; in our model, this is represented by the schema or interim generalization base of the analogy. Our target represents what Bello calls an "explicit mental representation(s) that guide the pretense."

Of the remaining features, "projection of pretense onto reality" and "external manifestation of the pretense via action" are inherently in disagreement with our model: we do not believe that, as Bello argues, pretense occurs in a separate mental world from reality. Similarly, we do not argue that it is necessary to act in order to participate in pretense. Rather, active pretense is just one of the modalities of children's pretense (see Thompson & Goldstein, 2020) that we model. Our model is equally successful at modeling observatory pretense in the Onishi et al. (2007) study.

The Onishi et al. (2007) study also brings to question Bello's final point: that "intentional initiation and maintenance of pretense" must exist. Intentionality is difficult to determine in 15-month-old infants. Yet, it might be argued that a child must intentionally accept or reject a pretense scenario, and especially the candidate inferences within it, in order for pretense to be successful. Since Bello's model does not seem to handle failures in pretense, we view the question of intentionality within failed pretense as open.

6. General discussion and predictions

Our model replicates the pattern of results for both the Fein (1975) and Onishi et al. (2007) studies. This provides evidence that analogical projection with judgment of candidate inference plausibility provides an explanation for children's failures and successes in pretense. Our results suggest that more advanced pretense reflects more advanced analogical projection abilities. We posit that this relationship is self-reinforcing—the more children play pretend, the better they become at analogical projection; the better children become at analogical projection, the more they are able to play more advanced forms of pretense.

We have also discussed several alternative models of children's pretense. Yet another possibility is that children's failures in pretense stem from simply not yet knowing the norms of pretend play. That is, the children in the Onishi et al. (2007) study may not know that it is permissible to pretend that shoes are cups, and the familiarization trial shows them that it is. If this were true, then simply telling children the rules of pretense (i.e., that any object can be another when pretending) should lead them to be able to pretend at adult levels. While we are not aware of any findings that suggest children can learn pretense so directly, such findings would not contradict our model. Indeed, a child who learns that any object can stand in for any other object during pretense would learn to accept all candidate inferences—perhaps leading to not filtering out extraneous ones. We would expect this to cause problems when engaging, for example, in mutual pretense with someone who does not have such a rule.

The relationship between pretense and analogy leads to several additional predictions. First, we predict that progressive alignment (Kotovsky & Gentner, 1996) will bootstrap children's pretense. That is, by participating in a series of pretense scenarios wherein the objects that must be transformed become progressively more distant from their target, children will be able to participate in more complex pretense than they would otherwise. Fein's (1975) findings directly support this prediction—anchoring can be viewed as a short-term form of progressive alignment. Furthermore, progressive alignment has previously been modeled as online re-representation in interim generalizations (Kandaswamy et al., 2014). This suggests that similar mechanisms are involved in learning via progressive alignment and in pretend play.

We further predict that pretend play will be more difficult when the entities in the pretense scenario are cross-mapped, or when an entity in the pretense scenario is more similar to a different entity in the real world scenario than the one it is intended to be mapped to (Gentner & Toupin, 1986). For example, a child playing making a family of stuffed animals should prefer to pretend that larger animals are the parents, while smaller animals are the children. In a more extreme example, if the experimenter in Fein's (1975) anchoring condition had fed the cup using the horse, rather than the other way around, we predict that the children would not have been able to carry on the pretend play by giving the cup a drink from the horse—and certainly would not have transferred the cross-mapping to the test conditions.

Our final prediction has to do with the relationship between pretense and other types of reasoning. For example, Langland-Hassan (2014) has argued that the differences between nonpretense imitation and pretend play is in intent, rather than process. In his view, nonpretense imitation is a more constrained version of pretense, in that the imitator intend to successfully complete the object of the imitation eventually, whereas pretense has no such requirement. Otherwise, there is little distinction between the two. Likewise, Weisberg (2015) argues that pretense shares processes with theory of mind reasoning and counterfactual reasoning, among others, while Harris and colleagues (see Harris, 2001) have suggested that pretense allows children to reason about ideas that are unfamiliar or which do not reflect their experience. Models that postulate an independent mechanism for pretend play are not consistent with such accounts. However, because our model uses the general process of analogical reasoning and does not isolate pretense from other cognitive processes, it is consistent with Langland-Hassan's, Harris's, and Weisberg's accounts. Further, it makes the corresponding prediction that, as a child's ability to pretend improve, so should other complex reasoning skills.

7. Conclusion and future directions

We have shown that young children's failure to recognize pretense scenarios can be explained as failures in analogical projection. Specifically, when children find that candidate inferences necessary for the pretense scenario are not plausible, they are unable to continue pretending. This is evidenced by the model's ability to capture both the Fein (1975) and Onishi et al. (2007) studies.

Our findings suggest that by pretending, children are practicing reasoning analogically. Why might this be important? It has been suggested (e.g., Bach, 2014; Leslie, 1987) that pretense is a gateway to theory of mind. It has also been suggested that a developing theory of mind involves analogical reasoning (Hoyos et al., 2015, 2020; Meltzoff, 2007; Rabkina et al., 2017, 2018). In future work, we will consider how analogical projection strategies are learned via pretense, and how these strategies may help lead to a complete theory of mind.

Acknowledgments

We thank Dedre Gentner, Laura Hiatt, and Ian Horswill for their comments on this work. This research was supported by the Socio-Cognitive Architectures for Adaptable Autonomous Systems Program of the Office of Naval Research, N00014-13-1- 0470.

Conflicts of interest

The authors have no conflicts to disclose.

Data availability statement

All representations used in this work are provided in supplementary materials. The Structure-Mapping Engine can be found at https://www.qrg.northwestern.edu/software/sme4/index.html.

Notes

1 Younger children are especially likely to focus on object similarity (Christie et al., 2016).
2 Each condition corresponds to an experiment in the original study (i.e., our Experiment 2, Condition 1A is Onishi et al.'s Experiment 1A, etc.).
3 For some children, the cups were replaced by tubes rather than shoes. Since the results between these conditions did not differ, only shoes are discussed here.
4 This assumption is consistent with previous studies (e.g., Chen et al., 2020; Kuehne et al., 2000), which postulated that the evaluation of candidate inferences takes longer when inferences are inconsistent.
5 In the Onishi et al.'s study, for example, the experimenter's arm moving to her mouth may invoke an actual drinking event and retrieve the appropriate schema. In the Fein study, on the other hand, retrieval of the appropriate schema is likely aided by the verbal cue to "give [the horse] a drink."
6 Note that such a mapping can be made even when the scenario and the schema have match score that is below threshold for assimilation into the SAGE generalization, as is likely to be the case for most pretense.
7 To reduce tailorability, we used an off-the-shelf knowledge base, NextKB, and translations from words in its lexicon to formally represented concepts and relationships to constrain the representations constructed.
8 SME returns two equivalent mappings here. We assume that the child entertains only one, although the looking time difference may be attributed to the multiple potential mappings, as well.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supplementary material