
Inducing Schizophrenia in an Artificially Intelligent Story-Understanding System

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Abstract

We propose that the mechanisms that enable humans to tell, understand, and recombine stories are subject to breaks; and the resulting faulty story mechanisms can provide an account of human illnesses associated with human intelligence. We investigate whether faulty story mechanisms may provide a cognitive framework accounting for schizophrenic behaviors. We modeled schizophrenic impairments in Theory of Mind (ToM) and influence of contextual information (CI) as faulty story mechanisms. We then instantiated these faulty story mechanisms in the artificially intelligent story-understanding system Genesis, producing the impaired systems Genesis_{ToM} and Genesis_{CI}. In order to assess emergent behaviors of the Genesis systems, we administered a task battery including psychological tasks known to elucidate schizophrenic behaviors in humans. Unmodified Genesis completed all tasks correctly, reproducing the profile of a healthy human. Consistent with schizophrenic humans, Genesis_{ToM} and Genesis_{CI} each reproduced a range of schizophrenic behaviors when completing differentiating tasks and retained correct completion of control tasks. On the basis of our faulty story mechanism account of schizophrenic behaviors, we suggest novel cognitive therapeutic interventions and future clinical experiments with testable predictions. This research provides initial support for the Faulty Story Mechanism Corollary, provides novel support for the Strong Story Hypothesis, and demonstrates a method for existing artificially intelligent systems and production systems to contribute to mental illness research.

1. Vision

Humans have been characterized as *the primates who tell stories* by experts in biology, psychology, and artificial intelligence (Dawes, 1999; Schank, 1972). Formally, the Strong Story Hypothesis posits that the mechanisms that enable humans to tell, understand, and recombine stories are central to human intelligence (Winston, 2011). We propose a novel corollary:

The Faulty Story Mechanism Corollary: The mechanisms that enable humans to tell, understand, and recombine stories are subject to breaks; the resulting faulty story mechanisms can provide an account of human illnesses associated with human intelligence.

We consider the case of schizophrenia. Prior biology and psychology research indicates the view of schizophrenia as faulty story mechanisms is promising: Xu et al. (2015) showed that the genetic shifts of schizophrenia are linked to human lineage-specific evolution, Crow (1997, 2010) suggested that schizophrenia shares a common evolutionary origin with human language, and Hinzen and Rosselló (2015) showed that schizophrenia can be understood as failures in humans' language-mediated forms of meaning. Further, in contrast to neurobiological and neuropsychological models of schizophrenia, an account of schizophrenic behaviors in terms of errors in story-understanding can provide the basis for novel cognitive therapeutic interventions in which patients learn to identify and interrupt errors.

We investigated whether plausible faulty story mechanisms may provide a cognitive framework accounting for schizophrenia. We present such a cognitive framework, and we demonstrate that it accounts for a range of schizophrenic behaviors. On the basis of our investigation, we suggest cognitive therapeutic interventions and future clinical experiments with testable predictions. We discuss the implications of this work on the Faulty Story Mechanism Corollary, the Strong Story Hypothesis, and the use of artificially intelligent and production systems for schizophrenia and mental illness research.

2. Background

The Genesis System (“Genesis”) is a computational system that primarily reads and understands stories. In prior work, Genesis has read and understood a large corpus of fictional and nonfictional 50-100 line short stories and has provided the basis for models of various aspects of intelligence including anticipation of harm, levels of understanding, question-driven reflection, and hypothetical reasoning (Winston, 2014; Winston, 2018). Figure 1 presents high-level Genesis operation: Genesis is fed a story, commonsense rules, and an optional question, each in English; Genesis then identifies and deploys relevant commonsense rules to interpret the story, embodying its interpretation in an Elaboration Graph; finally, if a question has been posed, Genesis inspects its Elaboration Graph and answers the question in English.

Figure 1 additionally demonstrates four types of commonsense rules understood by Genesis:

- *Deduction rules* insert a new event deduced from a known event
- *Abduction rules* insert a new event that must hold true to allow a known event
- *Explanation rules* connect two known events when one known event provides an in-context explanation for another known event
- When there exists no in-context explanation for a known event, *presumption rules* presume an explanation, inserting a new event to explain the known event

The simplicity of high-level Genesis operation is enabled by lower-level processing of natural language into nested symbolic representations that afford inference even when commonsense rules refer to abstractions of story events. In a similar vein to Young and O’Shea (1981), who successfully modified a production system model of children’s arithmetic to induce children’s most common arithmetic errors, we are the first to modify a symbolic story-understanding system to induce mental illness.

The field of computational psychiatry has produced neurobiological models of various schizophrenic behaviors embodied in connectionist computational systems (Braver, March, & Cohen, 1999; Hoffman et al., 2011); we note that the lack of interpretability of these systems leads to three critical limitations. First, connectionist systems that impressively simulate

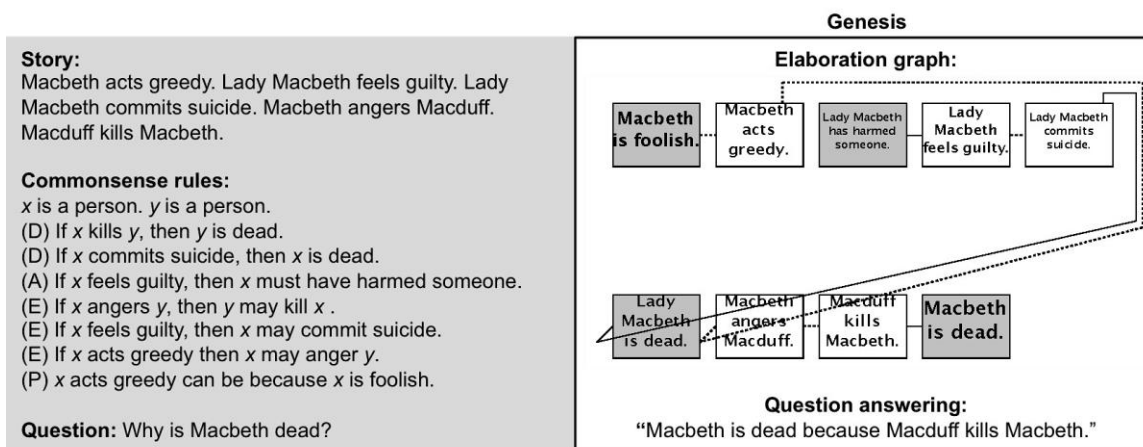


Figure 1. A demonstration of Genesis reading a brief summary of Macbeth. *Left:* Genesis is given the story and given deduction rules (D), abduction rules (A), in-context explanation rules (E), and presumption rules (P). *Top right:* From these, Genesis constructs an Elaboration Graph. In the Elaboration Graph, white boxes indicate events explicit in the story, and connections and grey boxes indicate additional Genesis understanding. *Bottom right:* Asked a question, Genesis inspects its Elaboration Graph and answers in English.

behaviors nonetheless fail to correspond to well-specified explanatory theories (McCloskey, 2002). Second, the systems obfuscate the schizophrenic cognitive distortions that would afford novel cognitive therapeutic interventions. Third, new experimental results documenting healthy or schizophrenic reasoning can be neither compared to nor incorporated into the systems' black-boxed reasoning, impeding interdisciplinary development of models. As Genesis is fully interpretable, we proceed to overcome these limitations.

3. Plausible Faulty Story Mechanisms

3.1 Impaired Theory of Mind

Previous schizophrenia research indicates that many of the deficits in schizophrenia could be dependent on specific impairment of Theory of Mind (Frith, 1992; Brüne, 2005; Langdon, Malle, & Hodges, 2005). Healthy humans readily demonstrate Theory of Mind, which refers to the capacity to represent one's own and other persons' mental states, including thoughts, beliefs, desires, and intentions (Premack & Woodruff, 1978). Following directly from this definition, we introduced the posited impairment of Theory of Mind as a faulty story mechanism in Genesis by initiating a Genesis system policy of disregarding during story-interpretation any representations (events and commonsense rules) containing thinking, believing, or wanting (Fig. 2A). We denote the resultant system Genesis_{-TOM}.

3.2 Impaired Influence of Contextual Information

Previous schizophrenia research also provides evidence that many of the deficits in schizophrenia could be dependent on a weakening of the influence of contextual information (Shakow, 1962; Cohen et al., 1999; Bazin et al., 2000; Chapman, Chapman, & Daut., 1976; Chapman, Chapman, & Miller, 1977). Contextual information refers to surrounding circumstances used to mediate one’s reasoning about an event. Healthy influence of contextual information has a natural correspondence to unmodified Genesis behavior: unmodified Genesis is strongly influenced by context (applying explanation rules first, which provide in-context explanations) before resorting to presumption (applying presumption rules to explain unexplained events). Accordingly, we introduced the posited impairment as a faulty story mechanism in Genesis by altering the order in which Genesis applies rules during story-interpretation such that our modified Genesis system is more weakly influenced by context, presuming (applying presumption rules first) before considering in-context explanations (applying explanation rules to unexplained events) (Fig. 2B). We denote the resultant system Genesis_{CI}.

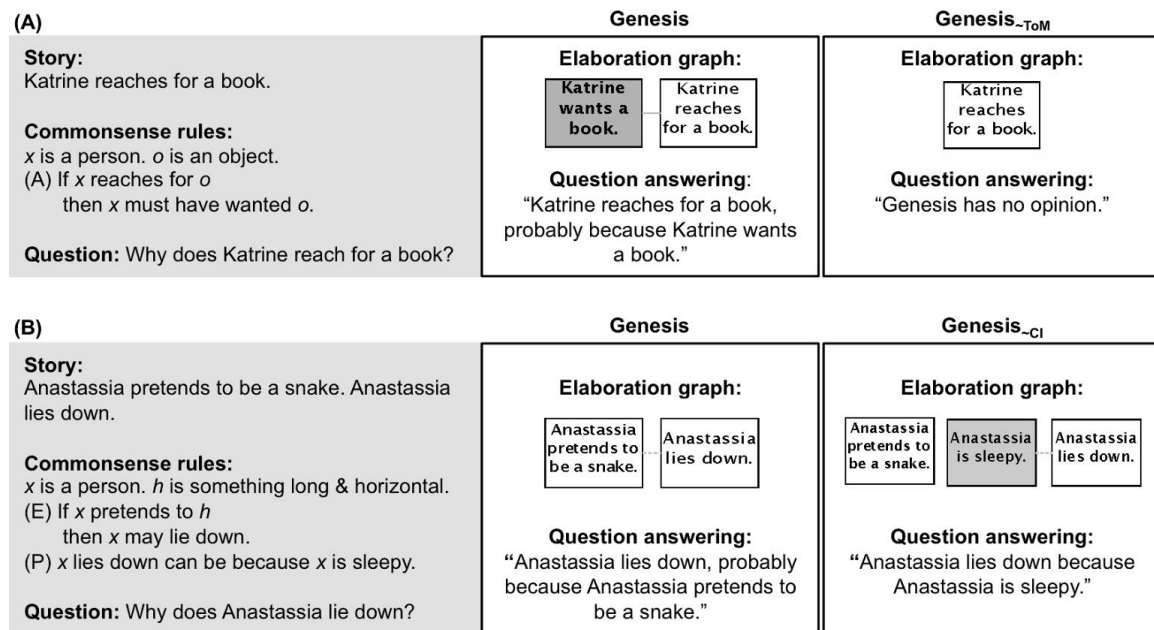


Figure 2. Demonstrative behavior of Genesis with impaired Theory of Mind (Genesis_{ToM}) and Genesis with an impaired influence of contextual information (Genesis_{CI}). *Top*: While unmodified Genesis applies an abduction rule to infer that Katrine must want the book, Genesis_{ToM} does not reason about Katrine’s wants and, consequently, does not understand why Katrine reaches for a book. *Bottom*: While unmodified Genesis understands that Anastassia lies down is explained in-context, Genesis_{CI} incorrectly defaults to the out-of-context presumption that Anastassia lies down because Anastassia is sleepy.

4. Tasks to assess emergent schizophrenic behaviors

Assessing to what degree the Genesis systems behaved schizophrenically required suitable story-based assessments. We drew from neuropsychological studies of schizophrenia evaluating negative symptoms (diminished behaviors) in schizophrenic subjects by designing and administering assessments that first familiarize a subject with a brief third-person story, then ask a multiple-choice question that queries the subject’s perceived key interpretation of the story. From this corpus of short story-based tasks, we compiled tasks that evaluated the schizophrenic failure to reason about intentions of others (2 Intention Attribution Tasks; Sarfati et al., 1997; Brunet et al., 2000), failure to reason about the false beliefs of others (2 False Belief Tasks; Wimmer & Perner, 1983), and failure to reason about hinted speech (2 Hinting Tasks; Corcoran, Mercer, & Frith, 1995). Also from this corpus, we compiled control assessments that evaluated general cognitive competence that is relatively unimpaired in schizophrenic subjects. The control tasks evaluated physical causality reasoning with and without humans present (2 Physical Causality with Objects and Characters Tasks, 2 Physical Causality with Objects Tasks; Brunet et al., 2000). Typically, positive symptoms (atypical behaviors such as delusions) of schizophrenic subjects are evaluated by investigating autobiographical stories, not by administering third-person short-story tasks. Accordingly, we considered the subjective accounts by healthy and schizophrenic subjects as described by Langdon, Ward, and Coltheart (2010) and Cannon (2015) and cast these as brief first-person stories with healthy and schizophrenic interpretations (2 Delusion Tasks). We present sample tasks in Table 1.

Table 1. Sample tasks used to assess schizophrenic behaviors in Genesis. *Top:* An Intention Attribution Task. Samantha, unable to reach the door handle, grabs an umbrella. Healthy subjects predict that Samantha will use the umbrella to pursue her original intention of reaching the door handle. Some schizophrenic subjects favor the prediction that Samantha will use the umbrella to walk in the rain. *Middle:* A Persistence of Delusion Task. Some schizophrenic subjects and no healthy subjects experience extreme paranoia and delusion. *Bottom:* A Physical Causality with Objects and Characters Task. Healthy and schizophrenic subjects correctly predict that the ball hits Alex.

	Prompt	Correct interpretation	An incorrect interpretation
Intention Attribution Task	Samantha tries to reach the door handle. Samantha fails to reach the door handle. Samantha grabs a long umbrella.	Samantha grabs an umbrella because Samantha wants to reach the door handle.	Samantha grabs an umbrella because Samantha wants to go into the rain.
Delusion Task	I have schizophrenia. I feel scared.	I feel scared because I have schizophrenia.	I feel scared because something is wrong in the world.
Physical Causality with Objects and Characters Task	The ball is at the top of the slide. Alex is at the bottom of the slide. The ball rolls down the slide.	The ball hits Alex.	The ball is underneath the slide.

Adhering to usual Genesis operation, we administered each task by feeding the Genesis systems the following: the task prompt, commonsense rules providing knowledge intuitively accessed by healthy humans when reasoning about the prompt, and a question probing for the key interpretation of the prompt. Given the tasks’ source literature does not document the commonsense or inference chains of the subjects, and given the dominant publicly available knowledgebases ConceptNet (Speer & Havasi, 2012) and WordNet (Fellbaum & Miller, 1998) do not contain the commonsense necessary to complete the tasks correctly, we manually constructed the commonsense rules fed to the Genesis systems according to commonsense intuition. Manual construction presents a limitation and a strength: it is a current limitation of our system that manual construction has the potential to introduce systematic biases into the commonsense rules; it is a strength that our system will as easily incorporate each future experimental result documenting the commonsense or inference chain of a healthy or schizophrenic subject, affording evolving, interdisciplinary model development.

5. Results: Schizophrenic behaviors emerged in Genesis

Table 2 summarizes the emergent behaviors. Unmodified Genesis completed all tasks correctly, reasoning about intentions, false beliefs, hinted communication, personal interactions, and physical causality with and without humans present; unmodified Genesis thus reproduced the profile of a healthy human. In contrast, when the battery of tasks was administered to Genesis-_{ToM} and Genesis-_{CI}, social impairment and psychosis emerged. Genesis-_{ToM} failed all differentiating

Table 2. Assessment of emergent behaviors in the Genesis systems. We report whether a system completed the tasks correctly (♦) or failed the tasks (×). In cases of a system failing tasks, we note whether the system failed the tasks by failing to answer (×₀) or failed the tasks by responding with an incorrect answer (×₁). Consistent with the profile of healthy humans, unmodified Genesis completed all tasks correctly. Genesis-_{ToM} and Genesis-_{CI} respectively accounted for all and most task failures by schizophrenic humans. Consistent with schizophrenic humans, Genesis-_{ToM} and Genesis-_{CI} completed the control tasks correctly.

		Healthy behaviors	Genesis	Schizophrenic behaviors	Genesis- _{ToM}	Genesis- _{CI}
Differentiating Tasks	Intention Attribution Tasks	♦	♦	×	× ₀	× ₁
	False Belief Tasks	♦	♦	×	× ₀	♦
	Hinting Tasks	♦	♦	×	× ₀	× ₁
	Delusion Tasks	♦	♦	×	× ₀	× ₁
Control Tasks	Physical Causality with Objects Tasks	♦	♦	♦	♦	♦
	Physical Causality with Objects and Characters Tasks	♦	♦	♦	♦	♦

tasks, unable to answer the task questions. Genesis-_{CI} failed all differentiating tasks except the False Belief Tasks, failing by explicitly responding to the task questions with incorrect answers. As demonstration, in Figure 3 we present Genesis performing correctly and Genesis-_{ToM} and Genesis-_{CI} performing incorrectly on an Intention Attribution Task. Consistent with schizophrenic humans, Genesis-_{ToM} and Genesis-_{CI} both retained correct completion of the control tasks.

6. Discussion

Neurobiological research indicates that, rather than being mutually exclusive, the brain processes implicated by prominent theories of schizophrenia are interconnected influences in schizophrenia onset (Cannon, 2015). Given that multiple illness mechanisms may coproduce schizophrenia, it is most appropriate to interpret our assessment as a noncompetitive evaluation of the Genesis-_{ToM} and Genesis-_{CI} faulty story mechanisms. Conjointly, these faulty story mechanisms accounted for all failures by schizophrenic humans on the administered tasks.

The control tasks in our assessment afforded an opportunity for falsification: if a mechanism were to induce abnormal behavior during a control task, the plausibility of the mechanism would be suspect. That the Genesis-_{ToM} and Genesis-_{CI} faulty story mechanisms specifically impaired performance on differentiating tasks and did not impair performance on control tasks reinforced that these well-specified mechanisms are viable as potential schizophrenia illness mechanisms. Future work can investigate when impaired theory of mind and impaired influence of contextual information may account for schizophrenic behaviors in non-story domains.

The results of our assessment further suggested that Genesis-_{ToM} and Genesis-_{CI} may align with two distinct prominent subtypes of schizophrenia: the lack of interpretive answers by Genesis-_{ToM}, particularly on tasks elucidating negative symptoms, may be related to the Disorganized Subtype of schizophrenia, and the incorrect and absurd interpretive answers by Genesis-_{CI}, particularly on delusion tasks, may be related to the Paranoid Subtype of schizophrenia. Future interdisciplinary work is needed to investigate this link.

In contrast to framing schizophrenia as neurobiological or neuropsychological deficits, by trying to make sense of the way schizophrenic humans interpret events, and the way faulty thinking distorts interpretation, we provide the basis for cognitive therapeutic interventions (Rector & Beck, 2002). In particular, on the grounds of our investigation, it is straightforward to envision therapists and schizophrenic patients monitoring patient inference chains for the Genesis-_{ToM} and Genesis-_{CI} faulty story mechanisms, then using the well-specified mechanism descriptions (Section 3), as well as the examples of healthy and distorted inference chains embodied in elaboration graphs (Figure 3), to recognize, reality-test, and correct distortions. Future interdisciplinary work can develop and assess cognitive therapeutic attempts to interrupt schizophrenic faulty story mechanisms.

Our investigation additionally grounded abstract theories of schizophrenic cognition in computational models that make fine-grained testable predictions. This work motivates new neuropsychological schizophrenia studies: studies that administer a battery of diverse, intentionally crafted short-story tasks to schizophrenic subjects, then query subjects' key interpretations *as well as* subjects' commonsense and inference chains. For example, on the basis

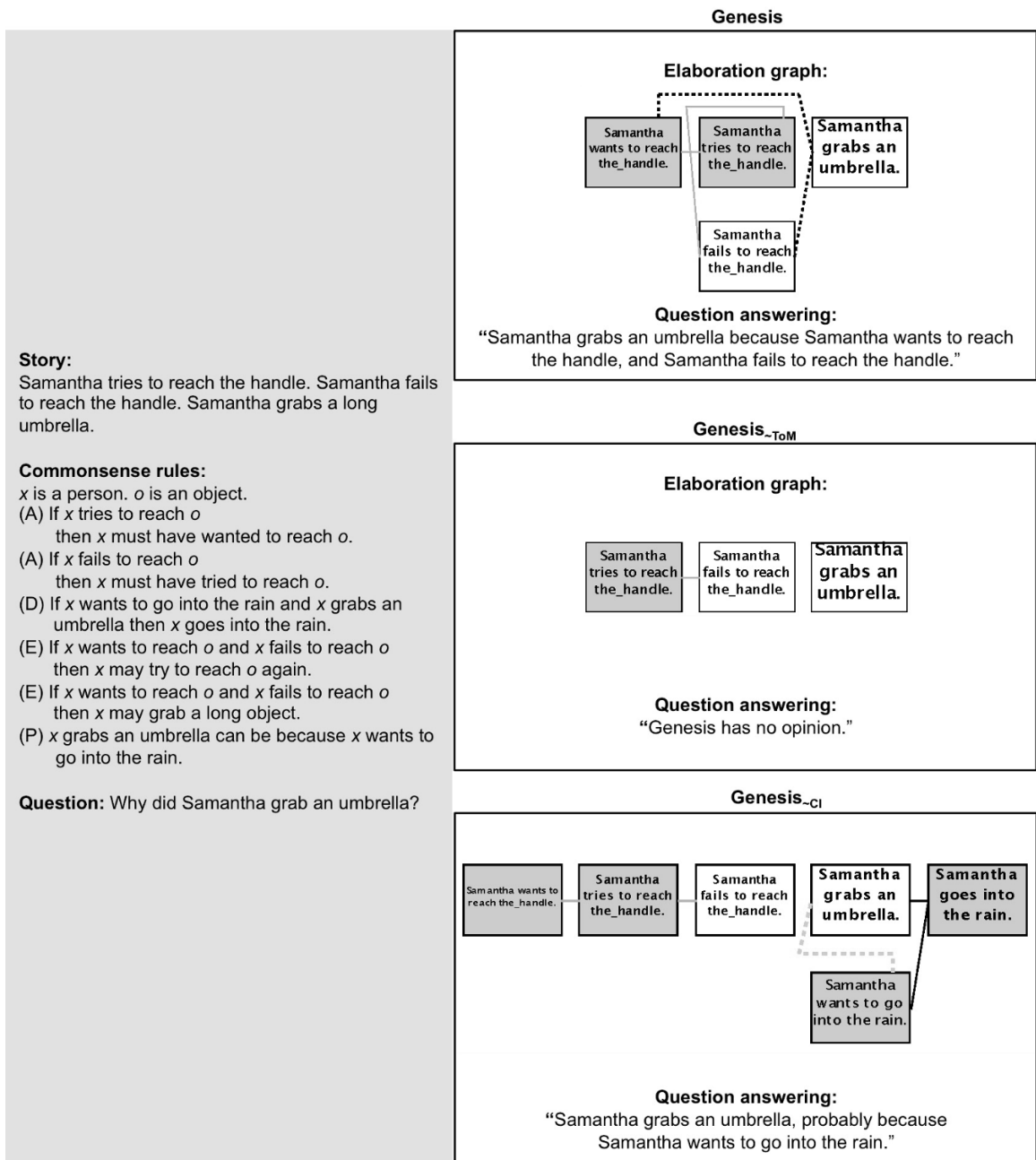


Figure 3. Performance of the Genesis systems on an Intention Attribution Task. *Top right:* Unmodified Genesis completed the task correctly: it abductively inferred Samantha’s intention to reach the handle and recognized that this explains why Samantha grabs an umbrella. *Middle right:* Genesis_{-ToM} prevented any reasoning about Samantha’s intention thus was unable to answer the task question. *Bottom right:* Genesis_{-CI} inferred Samantha’s intention, but never considered this in-context explanation for why Samantha grabs an umbrella, instead defaulting to the presumption that Samantha grabs the umbrella because Samantha wants to go into the rain, an incorrect answer to the task question.

of the computational performance presented in Figure 3, studies administering the Intention Attribution Task about Samantha to schizophrenic subjects can query subjects' agreement with the typically queried key interpretation ("Samantha grabs an umbrella because Samantha wants to reach the door handle"), as well as typically not queried commonsense knowledge (e.g. "A person grabs an umbrella can be because a person wants to go into the rain") and intermediate inference (e.g. "Samantha wants to go into the rain"). The proposed neuropsychological studies would provide more rigorous evaluation leading to refined theories, precisely embodied in computational models, and would expose thus far unknown constraints on schizophrenic cognition and general human intelligence. This line of future work provides an opportunity for synergized computational and neuropsychological schizophrenia research.

By establishing a faulty story mechanism account of a range of schizophrenic behaviors, we provide initial support for the Faulty Story Mechanism Corollary. We thus provide the basis for future work to further investigate the application of the faulty story mechanism framework for understanding and treating schizophrenia and other mental disorders.

Whereas previous work on Genesis has computationally modeled neurotypical human faculties, by applying the faulty story mechanism framework to model a mental disorder in Genesis, this research contributes novel support for the Strong Story Hypothesis and demonstrates how artificially intelligent and production systems can contribute to the investigation and treatment of mental illness.

7. Contributions

In this paper, we:

- Proposed the Faulty Story Mechanism Corollary
- Modeled schizophrenic impaired Theory of Mind (ToM) and impaired influence of contextual information (CI) as faulty story mechanisms and computationally instantiated these faulty story mechanisms in Genesis
- Compiled a battery of neuropsychological short-story tasks known to elucidate schizophrenic behaviors in humans and compiled complementary control tasks
- Demonstrated that unmodified Genesis completes all tasks correctly, reproducing the profile of a healthy human; demonstrated that Genesis-_{ToM} and Genesis-_{CI} account for a variety of failures by schizophrenic humans on differentiating tasks; and demonstrated that, consistent with schizophrenic humans, Genesis-_{ToM} and Genesis-_{CI} retain correct completion of control tasks
- Proposed directions for future synergized neuropsychological and computational mental illness research

This research provides initial support for the Faulty Story Mechanism Corollary, provides novel support for the Strong Story Hypothesis, and demonstrates a contributing role for artificially intelligent and production systems in mental illness research.

Acknowledgements

We thank Michaela Ennis for first suggesting the idea of modeling schizophrenia in Genesis, and we thank the reviewers for their valuable feedback.

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