An Update on DAYDREAMER, A Computer Model of Human Daydreaming

Erik T. Mueller

January 5, 2022 14:22

Abstract

I present an update on DAYDREAMER, a computer model of human daydreaming and emotions. Daydreaming and emotions are important capabilities for artificial intelligence systems because they make it easier for humans to relate to them. I discuss the DAYDREAMER architecture, the history of DAYDREAMER, the impact of DAYDREAMER, and what it will take to build a daydreaming machine.

1 Introduction

Daydreaming consists of recalling past experiences, imagining alternative versions of those experiences, and imagining possible future experiences. DAYDREAMER is a computer model of human daydreaming and emotions (Mueller, 1990).[1] DAYDREAMER is embedded in a simulated real world. It accepts input world states and actions, produces output actions that modify the state of the world, and generates daydreams in English.

Why build a daydreaming machine? Daydreaming serves useful functions of learning, creative problem-solving, and emotion regulation in humans that can also be useful in machines. DAYDREAMER demonstrated its ability to learn, generate creative solutions, and improve its emotional state through daydreaming, just as humans do. More importantly, as we incorporate artificial intelligence into our daily lives, it will be helpful for AI systems to share human characteristics such as daydreaming and emotions so that humans can relate to them.

Here is sample output produced by DAYDREAMER:

REPERCUSSIONS1

Input: *There is an earthquake in Mexico City.*

What if there is an earthquake in Los Angeles? My apartment collapses. My possessions are destroyed. I am killed. I feel very worried.

I have to go to the doorway. I have to get insurance.

[1] DAYDREAMER consists of 18,262 lines of Lisp code and is available at `https://github.com/eriktmueller/daydreamer`

What if there is an earthquake in Los Angeles? I go to the doorway. I get hit by a falling plant. I get hurt. My possessions are destroyed. I feel very worried.

I have to move the plant away from the doorway. I have to buy insurance from some company.

External action: **I go to State Farm. I pay Sally.**

Input: *Sally gives me the insurance.*

I am insured. I feel very pleased.

...

(Mueller, 1990, p. 8)

What has happened since I wrote DAYDREAMER? In this paper, I present an update. I summarize the DAYDREAMER architecture, present a history of DAYDREAMER, and discuss the impact of DAYDREAMER. I conclude with a discussion of how we would go about building a daydreaming machine today.

2 DAYDREAMER Architecture

DAYDREAMER includes the following elements:

- **Personal Goals**: Basic goals to preserve possessions, form friendships, maintain self-esteem, and so on.
- **Daydreaming Goals**: Meta-goals to reduce negative emotional states and learn through daydreaming.
- **Emotions**: Emotions that influence and are influenced by daydreaming.
- **Planning**: Generating a sequence of actions to achieve a goal.
- **Episodic Memory**: A memory of real and imagined experiences.
- **Learning**: Improving future behavior and thought in response to real and imagined experiences.
- **Creativity**: Generating fanciful daydreams, recognizing and exploiting accidental relationships among goals, and generating new possibilities when stuck.
- **Natural Language Generation**: Generating daydreams in English.

2.1 Main Loop

DAYDREAMER generates daydreams by performing processing on behalf of top-level goals. Each top-level goal is associated with one or more emotions. The main loop of DAYDREAMER is as follows:

1. Select the top-level goal with the highest emotional motivation, which is equal to the absolute value of the sum of the values of the emotions associated with the goal.

2. Perform one unit of planning on the top-level goal. This may activate or terminate top-level goals and subgoals, perform imaginary or real actions, modify the values of emotions associated with goals, and associate new emotions with goals.

3. Go to step 1.

2.2 Planning

Planning applies planning rules and inference rules to a goal, in order to generate daydreams as well as to perform actions to achieve goals in the simulated real world.

Planning rules specify how to achieve a subgoal by breaking it down into subgoals and actions. An example planning rule is that, for a buyer to purchase an item from a seller, the buyer must transfer money to the seller, and the seller must transfer the item to the buyer.

Inference rules specify how to generate inferences. An example inference rule is that, if one person likes something that the person believes another person likes, then the first person will like the second person.

2.3 Daydreaming Goals

DAYDREAMER has the following daydreaming goals:

- **RATIONALIZATION**: Reinterpret a failure to reduce negative emotions resulting from the failure.

- **ROVING**: Shift attention away from a failure.

- **REVENGE**: Generate daydreams of revenge.

- **REVERSAL**: Generate daydreams in which a past or imagined future failure is avoided.

- **RECOVERY**: Generate daydreams in which a goal that failed in the past succeeds in the future.

- **REHEARSAL**: Generate possible daydreams for achieving a goal.

- **REPERCUSSIONS**: Explore and plan for hypothetical future situations.

2.4 Learning

Daydreamer stores its real and imagined experiences in episodic memory. The experiences are represented as planning trees. Planning trees are indexed in episodic memory by subgoals, emotions, people, and other features.

Two mechanisms enable learning in Daydreamer:

- Daydreamer learns by adding planning trees to episodic memory and later applying them to new goals. As the system operates, planning trees that might be relevant to the current goal are retrieved from episodic memory using various features. The retrieved planning trees are then used to guide generation of plans for the current goal. Parts of several planning trees retrieved from episodic memory can be combined in a novel way.
- Daydreamer learns by creating new planning and inference rules. After a REVERSAL daydream in which a failure is avoided, Daydreamer creates new rules to prevent similar failures in the future.

2.5 Creativity

Three mechanisms support the generation of creative daydreams in Daydreamer: planning, the serendipity mechanism, and the mutation mechanism.

Planning can generate fanciful daydreams by using low plausibility planning rules. An example of a low plausibility planning rule is that one can become a star by studying to be an actor.

The serendipity mechanism recognizes the unexpected applicability of a planning rule that has just become salient, to some active top-level goal. First, the mechanism conducts an intersection search through the rule connection graph from the planning rule to the top-level goal. Second, valid plans returned by the search are applied to the top-level goal. Daydreamer produces the following daydream using the serendipity mechanism:

LAMPSHADE-SERENDIPITY

> Input: *Lampshade.*
>
> What do you know! I remember the time Karen thought highly of the comedian because she thought he was funny. She thought he was funny because he wore a lampshade.
>
> ...I have to wear a lampshade. ...
>
> (Mueller, 1990, p. 14)

Corneli, Jordanous, Guckelsberger, Pease, and Colton (2020) develop a model for assessing serendipity capabilities in systems and conclude that "the model shows good evidence to support Mueller's assertion that [Daydreamer] does have serendipity potential" (p. 32).

The mutation mechanism helps the system get unstuck when an action cannot be performed. It does this by permuting or generalizing objects of the action or by changing the type of the action entirely.

3 History of DAYDREAMER

I started working on Daydreamer in 1983 at the University of California, Los Angeles, under the supervision of Michael G. Dyer. My original idea was to create a dialogue system that would "think even when you are not talking to it, and also for it to think about other things while you are talking to it, like humans do" (Mueller, email message to Michael G. Dyer, October 4, 1983).

I immersed myself in the psychological literature on daydreaming (Freud, 1908/1962; Klinger, 1971; Singer, 1975; Varendonck, 1921). Working closely with Dyer, Kenneth Mark Colby (who had developed the PARRY chatbot and simulation of a paranoid patient [1975]), and other UCLA graduate students such as Uri Zernik, Scott Turner, John Reeves, and Charles Dolan, I started developing Daydreamer.

The most significant influences on Daydreamer from the field of artificial intelligence were the following:

- Dyer's (1983) computer model of emotion,
- Wilensky's (1983) work on planning and meta-planning,
- Schank and Abelson's (1977) scripts, plans, and goals,
- Minsky's (1977) theory of the mind as a society of intercommunicating and conflicting entities,[2] and
- Meehan's (1976) story generation program TALE-SPIN.

In 1985, I presented papers about Daydreamer at the International Joint Conference on Artificial Intelligence (IJCAI) and the Conference of the Cognitive Science Society (Mueller & Dyer, 1985a, 1985b).

In March 1987, I completed Daydreamer and my doctoral dissertation, *Daydreaming and Computation: A Computer Model of Everyday Creativity, Learning, and Emotions in the Human Stream of Thought* (Mueller, 1987). Ablex later published a revised version of my dissertation as a book, *Daydreaming in Humans and Machines: A Computer Model of the Stream of Thought* (Mueller, 1990).

After graduating, I went to work at Morgan Stanley, where I applied my ideas about daydreaming to creating a system called ExperTik, which hypothesizes the state of the New York Stock Exchange limit order book based on the Consolidated Tape System (CTS) and Consolidated Quote System (CQS) data streams. ExperTik was later incorporated into Morgan Stanley's Aestar algorithmic trading system.

In 2000, I joined the IBM Thomas J. Watson Research Center. There I focused my attention on the problem of commonsense reasoning (Mueller, 2006, 2015), which I felt was the main bottleneck in Daydreamer and many other AI systems.

[2]Minsky's (1986) book-length treatment of these ideas, *The Society of Mind*, was published just as I was finishing my dissertation. A few years later, Minsky (1994) wrote that my ideas on daydreaming "indicate an important direction of research" (p. 312).

4 Impact of DAYDREAMER

DAYDREAMER has been cited by artificial intelligence researchers and computer scientists, including Andreae (1998), Gu, Mishra, and Clark (2021), Newell (1991), Pearce, Meadows, Langley, and Barley (2014), Rapaport (2012), Riley (2021), Rowe and Partridge (1993), Ushida, Hirayama, and Nakajima (1998), Wills and Kolodner (1994), and Winston and Holmes (2018).

DAYDREAMER has been cited by cognitive scientists, psychologists, and social scientists, including Atkinson (1998), Johnson-Laird (1993), Karniol and Ross (1996), Mildner and Tamir (2019), Moffat and Frijda (2000), Pfeifer (1988), Regis (2013), Schimmenti, Somer, and Regis (2019), Sun, Wilson, and Lynch (2016), Tokosumi (2001), Wehrle and Scherer (2001), and Weinstein, Deci, and Ryan (2011).

DAYDREAMER has been discussed in popular books (Davis, 2002; Fries, 2009; Martin, 2004) and in the popular press (BBC Radio 4, 2002; McAuliffe, 1986; United States Information Agency, 1986).

The main contributions of DAYDREAMER are in the areas of cognitive architectures, affective computing, story generation, and night dreaming.

4.1 Cognitive Architectures

A cognitive architecture is a set of process and data elements that work together to perform functions we associate with intelligence such as perception, learning, language understanding, planning, and reasoning.

DAYDREAMER is a more comprehensive cognitive architecture than the architectures that preceded it such as ACT* (Anderson, 1983) and Soar (Laird, Rosenbloom, & Newell, 1986). Whereas previous architectures model rational behavior and thought, DAYDREAMER incorporates emotions and creativity into a model of behavior and thought.

DAYDREAMER influenced the MoCog1 cognitive architecture (Gevarter, 1991), which was developed at the NASA Ames Research Center. Gevarter states that "there has been a dearth of computer programs emphasizing the role of affects" and that DAYDREAMER "is the most sophisticated such program thus far developed" (p. 2). Greco (1994) cites DAYDREAMER as a "step in the direction of model integration" (p. 30) in his article on how to integrate different psychological models.

4.2 Affective Computing

DAYDREAMER is an early work in the field of affective computing, which is concerned with developing systems that can recognize and generate emotions, to make them more user-friendly.

Picard (1997) mentions DAYDREAMER in her book, *Affective Computing*. She states that DAYDREAMER "is not only able to perform reasoning about emotions, but it also uses the appraisal process to generate an internal emotional state that influences the system's planning, learning, recall, and production of hypothetical scenarios, or daydreams, exploiting the influences of mood-congruent memory retrieval" (p. 222). In his book *The Emotional Brain*, LeDoux (1996, pp. 37, 70) cites Dyer (1987), who discusses three computational models of emotion, BORIS, OpEd, and DAYDREAMER, in support of his proposal "to put cognition back into its mental context—to reunite cognition and emotion in the mind" (p. 39).

In his book on instinctive computing, Cai (2016) says:

> In addition to the episodic memory of experiences used by constraint-free planning and rehearsal, remarkably, DAYDREAMER includes an emotion component that updates its emotion states arising from goal outcomes, such as scary feelings while being chased by a monster before the daydream is over; a personality model that provides the style for guiding the constraint-free planning; and the domain knowledge of interpersonal relationships and commonsense. (p. 241).

He adds:

> The daydream research accidentally continued in the Google Research group in 2015. Artificial intelligence researchers trained artificial neural networks to recognize objects in images... When engineers tried to visualize the intermediate results inside the deep layers, they found hallucinating images. ... The research team called the phenomena Deep Dream. (p. 242).

4.3 Story Generation

The field of story generation is concerned with building systems that generate stories. Interactive fiction systems allow the reader or player to participate in and influence the story.

Although DAYDREAMER generates daydreams rather than stories, it is often cited in discussions of story generation systems. Ogata (2016) explains:

> DAYDREAMER is a computer program that simulates the consciousness of daydreaming, with a consistent character and a narrator. ... [A]lthough this system is not a narrative generation system, strictly speaking, it synthetically implements various interesting mechanisms and techniques related to AI and cognitive science that include, in addition to goal-oriented planning associated with emotional states, the generation of external stories (occurring in the external world), creativity processing by serendipity, scripts for detailed expansion of an episode, various narrative knowledge representation techniques using semantic networks and frames, and so on. (p. 20)

Similarly, a review of interactive drama systems mentions DAYDREAMER even though it is "not strictly a story generation system" (Arinbjarnar, Barber, & Kudenko, 2009, p. 24).

Daydreamer is cited in work on Oz, an early architecture for interactive fiction with goal-based, emotional characters (Bates, Loyall, & Reilly, 1992, 1994; Reilly, 1996).

Daydreamer has been cited by other researchers in story generation and interactive fiction, including Guerrero Román and Pérez y Pérez (2020), Ryan (2018), and Ryan, Brothers, Mateas, and Wardrip-Fruin (2016).

4.4 Night Dreaming

Night dreaming shares some similarities with daydreaming. Both involve imaginary events; night dreams tend to be more bizarre (Mueller, 1990, pp. 224–231).

Daydreamer influenced the metaphor-based model of night dreaming of Baylor and Deslauriers (1986). Baylor and Deslauriers (1989) argue that "the kind and quantity of mechanisms that are postulated by Mueller for human daydreaming are also necessary to account for basic processes of night dream construction" (p. 566). Deslauriers and Baylor (1988) state that Daydreamer "must serve as a touchstone for any subsequent theory of dream production" (p. 501).

A prominent researcher of sleep, night dreaming, and daydreaming, Antrobus (1999), calls Daydreamer an "excellent computer model of content sequences in daydreaming" (p. 6). Fisher (2009) states that my "analysis of daydreaming illuminates the literal/figurative difference that would differentiate between a 'daytime' and a dream mode" (p. 148) in his book on logic and figurative thinking.

5 Toward a Daydreaming Machine

How do we go about building a daydreaming machine today? It is still a difficult problem because, as I demonstrated, daydreams have very complex form and content.

Neural language models (Brown et al., 2020; Devlin, Chang, Lee, & Toutanova, 2019; Radford et al., 2019), which are trained on large text corpora, could be fine-tuned on a daydream corpus to generate daydreams.[3] But the resulting daydreams are unlikely to be realistic.

To build a daydreaming machine that produces realistic daydreams requires (1) representations of goals, meta-goals, emotions, autobiographical events, and commonsense knowledge, and (2) processes for planning, creative problem-solving, memory storage and retrieval, learning, and commonsense reasoning. Either the machine has to learn these representations and processes from data, the machine has to incorporate architectural elements that correspond to these representations and processes, or some combination of the two.

Building a daydreaming machine is a difficult problem because daydreams are complex. But, if we wish for computers to be friendly to humans, they will need daydreaming capabilities.

[3] Ahson (2000) proposes a neural model of daydreaming in robots.

References

Ahson, S. I. (2000). Daydreaming robots. In *Proceedings of the Fifth International Symposium on Artificial Life and Robotics* (pp. 342–346). Oita, Japan.

Anderson, J. R. (1983). *The architecture of cognition.* Cambridge, MA: MIT Press.

Andreae, J. H. (1998). *Associative learning: For a robot intelligence.* London: Imperial College Press.

Antrobus, J. S. (1999). Toward a neurocognitive processing model of imaginal thought. In J. A. Singer & P. Salovey (Eds.), *At play in the fields of consciousness: Essays in honor of Jerome L. Singer* (pp. 3–28). Mahwah, NJ: Lawrence Erlbaum.

Arinbjarnar, M., Barber, H., & Kudenko, D. (2009). A critical review of interactive drama systems. In D. Romano & D. Moffat (Eds.), *AI and Games Symposium* (pp. 15–26). London: The Society for the Study of Artificial Intelligence and the Simulation of Behaviour.

Atkinson, G. W. (1998). *Chess and machine intuition.* Exeter, England: Intellect.

Bates, J., Loyall, A. B., & Reilly, W. S. (1992). *Integrating reactivity, goals, and emotion in a broad agent* (Tech. Rep. No. CMU-CS-92-142). Pittsburgh, PA: School of Computer Science, Carnegie Mellon University.

Bates, J., Loyall, A. B., & Reilly, W. S. (1994). An architecture for action, emotion, and social behavior. In C. Castelfranchi & E. Werner (Eds.), *Artificial social systems* (Vol. 830, pp. 55–68). Berlin: Springer.

Baylor, G. W., & Deslauriers, D. (1986). Dreams as problem solving: A method of study — Part I: Background and theory. *Imagination, Cognition and Personality*, *6*(2), 105–118.

Baylor, G. W., & Deslauriers, D. (1989). How are dreams made? Towards a computational model. *Psychiatric Journal of the University of Ottawa*, *14*(4), 566–571.

BBC Radio 4. (2002). *Please do not adjust your set.* Ben Silburn (Host), Adrian Washbourne (Producer), Interview on daydreaming, January 29, 2002.

Brown, T. B., Mann, B., Ryder, N., Subbiah, M., Kaplan, J., Dhariwal, P., . . . Amodei, D. (2020). Language models are few-shot learners. *Computing Research Repository*, *abs/2005.14165*. Retrieved from `https://arxiv.org/abs/2005.14165`

Cai, Y. (2016). *Instinctive computing.* London: Springer.

Colby, K. M. (1975). *Artificial paranoia: A computer simulation of paranoid processes.* New York: Pergamon Press.

Corneli, J., Jordanous, A., Guckelsberger, C., Pease, A., & Colton, S. (2020). Modelling serendipity in a computational context. *Computing Research Repository*, *abs/1411.0440*. Retrieved from `https://arxiv.org/abs/1411.0440`

Davis, M. (2002). *The new culture of desire.* New York: Free Press.

Deslauriers, D., & Baylor, G. W. (1988). The usefulness of the script concept for characterizing dream reports. In *Proceedings of the Tenth Annual Conference of the Cognitive Science Society* (pp. 496–502). Hillsdale, NJ: Lawrence Erlbaum.

Devlin, J., Chang, M.-W., Lee, K., & Toutanova, K. (2019). BERT: Pre-training of deep bidirectional transformers for language understanding. *Computing Research Repository*, *abs/1810.04805*. Retrieved from `https://arxiv.org/abs/1810.04805`

Dyer, M. G. (1983). *In-depth understanding: A computer model of integrated processing for narrative comprehension.* Cambridge, MA: MIT Press.

Dyer, M. G. (1987). Emotions and their computations: Three computer models. *Cognition and Emotion*, *1*(3), 323–347.

Fisher, H. (2009). *Self, logic, and figurative thinking.* New York: Columbia University Press.

Freud, S. (1962). Creative writers and day-dreaming. In J. Strachey (Ed.), *The standard edition of the complete psychological works of Sigmund Freud* (Vol. 9). London: Hogarth Press. (Original work published 1908)

Fries, A. (2009). *Daydreams at work: Wake up your creative powers.* Herndon, VA: Capital Books.

Gevarter, W. B. (1991). *MoCog1: A computer simulation of recognition-primed human decision making* (Tech. Rep. No. FIA-91-23). Moffett Field, CA: NASA Ames Research Center.

Greco, A. (1994). Integrating “different” models in cognitive psychology. *Cognitive Systems*, *4*(1), 21–32.

Gu, Y., Mishra, B. D., & Clark, P. (2021). DREAM: Uncovering mental models behind language models. *Computing Research Repository*, *abs/2112.08656*. Retrieved from `https://arxiv.org/abs/2112.08656`

Guerrero Román, I., & Pérez y Pérez, R. (2020). A methodology to forecast some attributes of an automatic storyteller’s outputs. *Connection Science*, *32*(1), 81–111.

Johnson-Laird, P. N. (1993). *Human and machine thinking.* Hillsdale, NJ: Lawrence Erlbaum.

Karniol, R., & Ross, M. (1996). The motivational impact of temporal focus: Thinking about the future and the past. *Annual Review of Psychology*, *47*, 593–620.

Klinger, E. (1971). *Structure and functions of fantasy.* New York: Wiley-Interscience.

Laird, J., Rosenbloom, P., & Newell, A. (1986). *Universal subgoaling and chunking: The automatic generation and learning of goal hierarchies.* Dordrecht: Kluwer.

LeDoux, J. (1996). *The emotional brain: The mysterious underpinnings of emotional life.* New York: Simon & Schuster.

Martin, P. (2004). *Counting sheep: The science and pleasures of sleep and dreams.* New York: Thomas Dunne.

McAuliffe, K. (1986). The daydream machine. *OMNI*, *9*(3), 60–66, 112.

Meehan, J. (1976). *The metanovel: Writing stories by computer* (Tech. Rep. No. YALE/DCS/tr074). New Haven, CT: Computer Science Department, Yale University.

Mildner, J. N., & Tamir, D. I. (2019). Spontaneous thought as an unconstrained memory process. *Trends in Neurosciences*, *42*(11), 763–777.

Minsky, M. (1977). Plain talk about neurodevelopmental epistemology. In R. Reddy (Ed.), *Proceedings of the Fifth International Joint Conference on Artificial Intelligence* (pp. 1083–1092). Los Altos, CA: William Kaufmann.

Minsky, M. (1986). *The society of mind*. New York: Simon & Schuster.

Minsky, M. (1994). The society of mind (response to reviews). In W. J. Clancey, S. W. Smoliar, & M. J. Stefik (Eds.), *Contemplating minds: A forum for artificial intelligence* (pp. 308–334). Cambridge, MA: MIT Press.

Moffat, D. C., & Frijda, N. H. (2000). Functional models of emotion. In G. Hatano, N. Okada, & H. Tanabe (Eds.), *Affective minds* (pp. 59–68). Amsterdam: Elsevier.

Mueller, E. T. (1987). *Daydreaming and computation: A computer model of everyday creativity, learning, and emotions in the human stream of thought* (Tech. Rep. No. CSD-870017). Computer Science Department, University of California, Los Angeles.

Mueller, E. T. (1990). *Daydreaming in humans and machines: A computer model of the stream of thought*. Norwood, NJ: Ablex.

Mueller, E. T. (2006). *Commonsense reasoning*. San Francisco/Amsterdam: Morgan Kaufmann/Elsevier.

Mueller, E. T. (2015). *Commonsense reasoning* (Second ed.). San Francisco: Morgan Kaufmann/Elsevier.

Mueller, E. T., & Dyer, M. G. (1985a). Daydreaming in humans and computers. In *Proceedings of the Ninth International Joint Conference on Artificial Intelligence* (pp. 278–280). Los Altos, CA: Morgan Kaufmann.

Mueller, E. T., & Dyer, M. G. (1985b). Towards a computational theory of human daydreaming. In *Proceedings of the Seventh Annual Conference of the Cognitive Science Society* (pp. 120–129). Hillsdale, NJ: Lawrence Erlbaum.

Newell, A. (1991). Metaphors for mind, theories of mind: Should the humanities mind? In J. J. Sheehan & M. Sosna (Eds.), *The boundaries of humanity: Humans, animals, machines* (pp. 158–197). Berkeley and Los Angeles, CA: University of California Press.

Ogata, T. (2016). Computational and cognitive approaches to narratology from the perspective of narrative generation. In T. Ogata & T. Akimoto (Eds.), *Computational and cognitive approaches to narratology* (pp. 1–75). Hershey, PA: IGI Global.

Pearce, C., Meadows, B. L., Langley, P., & Barley, M. (2014). Social planning: Achieving goals by altering others' mental states. In *Proceedings of the Twenty-Eighth AAAI Conference on Artificial Intelligence* (pp. 402–409). Palo Alto, CA: AAAI Press.

Pfeifer, R. (1988). Artificial intelligence models of emotion. In V. Hamilton, G. H. Bower, & N. H. Frijda (Eds.), *Cognitive perspectives on emotion and motivation* (pp. 287–320). Dordrecht: Kluwer.

Picard, R. W. (1997). *Affective computing.* Cambridge, MA: MIT Press.

Radford, A., Wu, J., Child, R., Luan, D., Amodei, D., & Sutskever, I. (2019). *Language models are unsupervised multitask learners.*

Rapaport, W. J. (2012). Semiotic systems, computers, and the mind: How cognition could be computing. *International Journal of Signs and Semiotic Systems*, *2*(1), 32–71.

Regis, M. (2013). *Daydreams and the function of fantasy.* Basingstoke, UK: Palgrave Macmillan.

Reilly, W. S. N. (1996). *Believable social and emotional agents* (Tech. Rep. No. CMU-CS-96-138). Pittsburgh, PA: School of Computer Science, Carnegie Mellon University.

Riley, J. (2021). Will machines ever think like humans? *Ubiquity*, *2021*(June), 1–26.

Rowe, J., & Partridge, D. (1993). Creativity: A survey of AI approaches. *Artificial Intelligence Review*, *7*(1), 43–70.

Ryan, J. (2018). *Curating simulated storyworlds.* Doctoral dissertation, Computational Media, University of California, Santa Cruz, Santa Cruz, CA.

Ryan, J., Brothers, T., Mateas, M., & Wardrip-Fruin, N. (2016). Juke Joint: Characters who are moved by music. In *Experimental AI in games: Papers from the AIIDE workshop.* Palo Alto, CA: AAAI Press.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures.* Hillsdale, NJ: Lawrence Erlbaum.

Schimmenti, A., Somer, E., & Regis, M. (2019). Maladaptive daydreaming: Towards a nosological definition. *Annales Médico-psychologiques, revue psychiatrique*, *177*(9), 865–874.

Singer, J. L. (1975). *The inner world of daydreaming.* New York: Harper & Row.

Sun, R., Wilson, N., & Lynch, M. (2016). Emotion: A unified mechanistic interpretation from a cognitive architecture. *Cognitive Computation*, *8*, 1–14.

Tokosumi, A. (2001). A computational literary theory: The ultimate products of the brain/mind machine. In T. Kitamura (Ed.), *What should be computed to understand and model brain function?* (pp. 43–51). Singapore: World Scientific.

United States Information Agency. (1986). *Giving machines some thought.* Meyer Odze (Director and Writer), Interview and demo of DAYDREAMER.

Ushida, H., Hirayama, Y., & Nakajima, H. (1998). Emotion model for life-like agent and its evaluation. In *Proceedings of the Fifteenth National Conference on Artificial Intelligence and Tenth Conference on Innovative Applications of Artificial Intelligence* (pp. 62–69). Menlo Park, CA: AAAI Press.

Varendonck, J. (1921). *The psychology of day-dreams.* London: George Allen & Unwin.

Wehrle, T., & Scherer, K. R. (2001). Toward computational modeling of appraisal theories. In K. R. Scherer, A. Schorr, & T. Johnstone (Eds.), *Appraisal processes in emotion: Theory, methods, research* (pp. 350–368). New York: Oxford University Press.

Weinstein, N., Deci, E. L., & Ryan, R. M. (2011). Motivational determinants of integrating positive and negative past identities. *Journal of Personality and Social Psychology*, *100*(3), 527–544.

Wilensky, R. (1983). *Planning and understanding: A computational approach to human reasoning.* Reading, MA: Addison-Wesley.

Wills, L. M., & Kolodner, J. L. (1994). Explaining serendipitous recognition in design. In A. Ram & K. Eiselt (Eds.), *Proceedings of the Sixteenth Annual Conference of the Cognitive Science Society* (pp. 940–945). Routledge.

Winston, P. H., & Holmes, D. (2018). *The Genesis Enterprise: Taking artificial intelligence to another level via a computational account of human story understanding* (Tech. Rep. No. CMHI 1). Cambridge, MA: Center for Brains, Minds, and Machines, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology.