Judgment and Decision Making (2024), **vol. 19**:e20 1–10
doi:10.1017/jdm.2024.25

EMPIRICAL ARTICLE

Sunk cost predictions as theory of mind

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Received: 7 March 2024; **Revised:** 6 June 2024; **Accepted:** 8 June 2024

Keywords: sunk cost bias; theory of mind; aspects of mental life; waste

Abstract

People often predict that they, and others, will be biased by sunk costs—they think that investing in an object or goal increases how much one values or wants it. In this article, we use sunk cost predictions to look at people's theory of mind and their conceptions of mental life. More specifically, we ask which mental states and motivations are seen as underlying the bias. To investigate this, participants in two preregistered experiments predicted whether different kinds of agents would be biased by sunk costs, and also assessed the agents' mental abilities. Participants predicted that some kinds of agents (e.g., human adults and children, robots) would show the sunk cost bias and that others would not (e.g., raccoons and human babies). These predictions were strongly related to the participants' assessments of whether the different kinds of agents are capable of seeing actions as wasteful, but also related to their assessments of the agents' capacities to feel regret and frustration.

1. Introduction

People often value items they spent time, money, or effort pursuing. For example, when imagining a situation where they have cooked two identical frozen dinners and must eat one and throw the other away, people predict they would eat the dinner that cost them more (Arkes and Blumer, 1985). Similarly, people are more likely to predict they would drive through a terrible storm to watch a basketball game (instead of staying home to watch it on TV), if they imagine having paid $200 for a ticket compared with if they instead imagine having received it for free (Olivola, 2018; Thaler, 1980).

Both examples suggest people are subject to the sunk cost bias—the tendency to overvalue goals and options simply because past investments have been devoted to obtaining them. People's susceptibility to the bias has attracted great interest because it is often viewed as irrational. For example, choosing to eat the more expensive frozen dinner might seem to offer a way to avoid wasting the money spent on it (Arkes, 1996; Arkes and Ayton, 1999; Arkes and Blumer, 1985; Thaler, 1980). But really, this choice makes no difference—the money remains spent regardless of which dinner gets eaten and which is thrown away.

We suggest the sunk cost bias is also interesting for an entirely different reason. It provides a novel window into theory of mind—people's ability to predict and explain overt actions in terms of agents' underlying mental states, including their beliefs and desires. These judgments incorporate information about physical and social costs and constraints (e.g., Gergely and Csibra, 2003; Jara-Ettinger et al., 2016). For example, people recognize that although they are normally likely to pursue preferred goods

over less attractive ones, they might settle for lesser goods if the preferred ones are especially expensive or would be difficult to get (Jara-Ettinger et al., 2015).

Sunk cost predictions can tell us about theory of mind because they likely require it. After all, the sunk cost bias has mostly been investigated by asking people to predict actions—and people predict actions by drawing on theory of mind. For instance, participants did not really face the prospect of driving through a storm when predicting they would drive to the basketball game.[1] It is true that sunk cost predictions have not been seen as indicative of theory of mind. Perhaps, this is because the bias is usually revealed when people predict their own actions, whereas theory of mind often involves predicting what others will do. Nevertheless, theory of mind is used for thinking about self and other alike (e.g., Gopnik and Astington, 1988; Sobel, 2023). Moreover, adults anticipate that other people will show the sunk cost bias (e.g., Bornstein and Chapman, 1995; Olivola, 2018) and consider sunk costs when morally evaluating others (Dorison et al., 2022). Children aged 4–7 years, by contrast, do not anticipate that sunk costs bias actions (e.g., Sehl et al., 2021, 2024; for earlier studies examining the bias in children, also see Baron et al., 1993; Klaczynski and Cottrell, 2004; Webley and Plaisier, 1998). Thus, the aspects of theory of mind that underlie sunk cost predictions may emerge relatively late.

People's sunk cost predictions suggest they think that when an agent invests in an object or goal, this increases how much the agent values or wants it. People could see this as a basic fact not subject to much further explanation—for example, they could see it as akin to facts like *seeing leads to knowing* (e.g., Pratt and Bryant, 1990; Wimmer et al., 1988) or *willingness to incur costs in pursuing goals depends on their value* (Jara-Ettinger et al., 2015; Liu et al., 2017). If so, they might expect all kinds of agents to show the sunk cost bias. Alternatively, people might see the bias as hinging on particular aspects of mental life. For instance, they might think the bias depends on whether an agent cares about waste (Arkes, 1996; Arkes and Ayton, 1999; Arkes and Blumer, 1985), or whether the agent feels frustrated or upset about sunk costs (Dijkstra and Hong, 2019; Kwak and Park, 2012; Wong and Kwong, 2007; Zeelenberg and Van Dijk, 1997). On this view, people might only expect the bias in agents capable of feeling these things. The finding that people put greater trust in individuals who honor sunk costs (Dorison et al., 2022) is consistent with this idea: The finding suggests that people recognize there are individual differences in whether others will be biased by sunk costs, and that people see these individual differences as informative about other aspects of mental life (i.e., trustworthiness).

To investigate these possibilities, we asked people about which kinds of agents—including humans of different ages, animals, and machines—are subject to the sunk cost bias. People believe that agents differ in their mental capacities (e.g., Callahan et al., 2021; Eddy et al., 1993; Gray et al., 2007; Weisman et al., 2017, 2021; Wilkins et al., 2015). For example, they think that human adults and elephants can experience guilt and pride, but deny these emotions are felt by robots, beetles, and human infants (Weisman et al., 2017). So people might also see these agents as varying in whether they are biased to sunk costs. We also asked people about the mental abilities of these agents, including their capacities to feel certain emotions (e.g., regret) and to care about waste. This allows us to examine if sunk cost predictions hinge on people attributing aspects of mental life to agents.

1.1. General method

Preregistrations, data, stimuli, and code are available on OSF at https://osf.io/q8hsu/. We disclose all measures, manipulations, and exclusions. In the Supplementary Materials (also available at the OSF page), we report three additional experiments, which we summarize in the General Discussion.

[1]Most investigations of the sunk cost bias have asked people to predict behavior in hypothetical vignettes (i.e., the same method used in most investigations of theory of mind). The bias has also been demonstrated with behavioral measures (for a meta-analysis, see Roth et al., 2015), but some researchers suggest that when people make real decisions the bias is unreliable (Friedman et al., 2007) and is sometimes even reversed (Negrini et al., 2022).

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We sought to recruit approximately 100 participants per between-subject condition. Participants were residents of the United States and recruited using CloudResearch. We required a HIT approval rate of 95–100% over at least 100 prior HITS. We used the 'block low quality participants' option, and tested different individuals in each experiment. After the main task, participants answered multiple-choice attention checks and questions about their age and gender.

Analyses were run in R. We used *afex* (Singmann et al., 2015) to run an analysis of variance (ANOVA) and *emmeans* (Lenth et al., 2019) to run pairwise tests comparing responses across conditions.[2]

2. Experiment 1

In this experiment, participants predicted whether a variety of different agents would show the sunk cost bias. We also had participants rate whether the agents can recognize waste and see outcomes as regrettable or frustrating. We asked about waste because the bias has been proposed to arise from people overgeneralizing a 'waste not' rule (Arkes and Ayton, 1999). On this account, people are normally averse to waste and follow principles like *don't spend more on an item than necessary* and *fully utilize purchases* (Arkes, 1996), but also extend such principles to erroneously conclude that honoring sunk costs avoids waste. We asked about regret and frustration because some accounts suggest the bias is connected with negative emotions (Arkes and Blumer, 1985; Dijkstra and Hong, 2019). For example, people might honor sunk costs to avoid the feelings of regret or frustration that would result from abandoning the goal linked with the sunk costs.

2.1. Methods

2.1.1. Participants

The experiment was successfully completed by 90 participants (mean age = 38 years; 42 women, 48 men). An additional 29 participants were excluded for failing at least one attention check.

2.1.2 Procedure

Participants read a vignette where a character named Pax collected two identical-looking rocks (see Figure 1). One rock was easy for Pax to get and the other one was hard to get. Pax could only keep one rock, and participants were asked which rock Pax would keep if Pax were each of seven kinds of agents ('Which rock will Pax keep if Pax is a(n) _____'). For each agent, responded on a 7-point scale with the anchors 'Definitely the easy-to-get rock' (scored 1), 'Equally likely to keep either' (scored 4), and 'Definitely the hard-to-get rock' (scored 7). Hence, higher ratings indicated greater predictions of the sunk cost bias.

Three of the agents were human (adult, 6-year-old child, baby who can crawl), three were animals (elephant, raccoon, and chicken), and one was a robot. As Figure 1 shows, all agents appeared in a matrix grid on a single screen; presentation order of the agents was randomized across participants.

On the next three screens, participants rated the agents' capacities for regret, frustration, and recognizing waste (order randomized across participants). Specifically, they indicated their agreement with the statements 'Pax can see actions as regrettable if Pax is a(n) _____', 'Pax can see situations as frustrating if Pax is a(n) _____', and 'Pax can see actions as wasteful if Pax is a(n) _____'. They responded using 7-point scales with the anchors 'Strongly disagree' (scored 1), 'Do not agree or disagree' (scored 4), and 'Strongly agree' (scored 7). The presentation order of these screens was randomized across participants.

[2]Some analyses in this article differ from those we preregistered. The preregistered analyses are reported in the Supplementary Materials.

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Pax often collects rocks. Pax just saw two rocks that look identical. Pax collected both rocks. One was really easy to get, and the other was really hard to get.

Pax was going to keep both rocks but then found out that won't be possible. Pax can only keep one. Which rock will Pax keep if Pax is a(n) _____?

	Definitely the easy-to-get rock			Equally likely to keep either			Definitely the hard-to-get rock
6 year-old child	○	○	○	○	○	○	○
Elephant	○	○	○	○	○	○	○
Baby who can crawl	○	○	○	○	○	○	○
Chicken	○	○	○	○	○	○	○
Adult	○	○	○	○	○	○	○
Autonomous Robot (not controlled by a person)	○	○	○	○	○	○	○
Raccoon	○	○	○	○	○	○	○

Figure 1. *Main vignette from Experiment 1.*

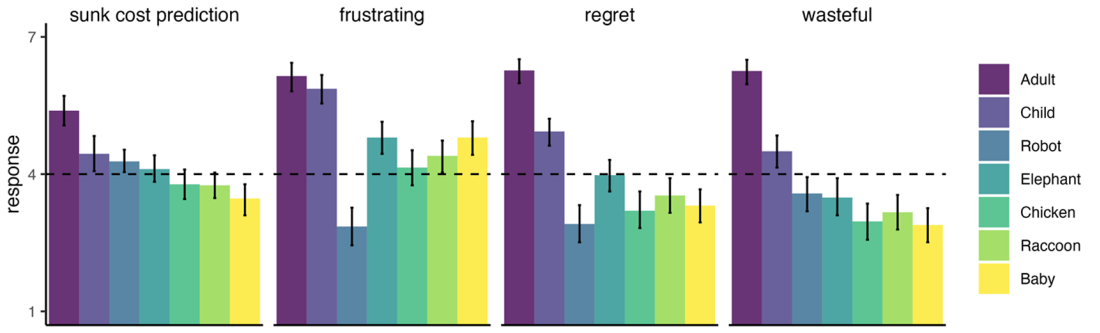

Figure 2. *Mean ratings and 95% confidence intervals in Experiment 1.*

2.2. Results

Figure 2 shows participants' mean responses. A one-way ANOVA found that sunk cost predictions significantly differed by agent, $F(4.32, 384.27) = 22.63$, $p < .001$, $\eta^2_p = .20$. Holm-Bonferroni comparisons with p-values adjusted for 21 tests found that sunk cost predictions were greater for the adult than for all other agents, $ps < .001$; greater for the child than for the chicken, raccoon, and baby, $ps \leq .006$; and greater for both the robot and the elephant than for the baby, $ps = .012$. All other differences were nonsignificant, $ps \geq .070$.

To examine how sunk cost predictions related to the other ratings, we correlated each participants' sunk cost predictions with their other ratings. A one-way ANOVA showed these correlations differed, $F(1.80, 153.02) = 6.99$, $p = .002$, $\eta^2_p = 0.08$. Post hoc comparisons (Holm adjusted for three tests) found that the correlation with waste ($M = .46$) was greater than the correlation with frustration ($M = .32$), $t(85) = 3.18$, $p = .006$. The correlation with regret ($M = .44$) was also stronger than that with frustration,

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$t(85) = 2.71$, $p = .016$. However, the correlations with waste and with regret did not significantly differ, $t(85) = 0.86$, $p = .390$.

2.3. Discussion

Participants predicted that the adult, child, and robot would show the sunk cost bias, and that other agents would not. Predictions of whether agents would show the bias were more strongly related to ratings of agents' capacities to recognize waste and to feel regret than to their ratings of frustration.

3. Experiment 2

We investigated whether predictions about the agents' actions reflect beliefs *specific* to sunk costs. As an alternative, these predictions could reflect beliefs about costs in general. For instance, just as participants expected human adults to care most about honoring sunk costs, participants might likewise expect human adults to care most about minimizing anticipated costs (which have not yet been sunk). To test between these possibilities, we assigned randomly participants to either predict whether agents would be biased by sunk cost, or to instead predict whether they would act to minimize anticipated costs.

As in the first experiment, participants also rated each agent's recognition of waste. We didn't continue to ask about emotions because participants in the first experiment thought the robot would be biased by sunk costs despite strongly denying it could feel regret and frustration. Instead, we looked at ratings of cognitive capacities which people might see robots as having (Weisman et al., 2017): the abilities to anticipate future events and remember the past.

3.1. Methods

3.1.1. Participants

The experiment was successfully completed by 220 participants (mean age = 44 years; 101 women, 117 men, 2 preferred not to give gender). An additional 14 participants were excluded for failing at least one attention check.

3.1.2. Procedure

Participants either read the sunk cost vignette from the previous experiment or a vignette about anticipated costs (manipulated between-subjects): 'Pax often collects rocks. Pax just saw two rocks that look identical. One will be really easy to get, and the other will be really hard to get. Pax can only keep one rock.' The test question then asked 'Which rock will Pax get if Pax is a(n) _____?' and participants responded on a 7-point scale ranging from 'Definitely the easy-to-get rock' to 'Definitely the hard-to-get rock'. In both conditions, participants gave responses for the same seven agents asked about in the previous experiment: adult, 6-year-old child, baby, elephant, raccoon, chicken, and robot.

We coded responses using opposite approaches across the two conditions. In the anticipated cost condition, agents show respect for costs by choosing the rock that can be obtained at a lower cost. So in this condition, we assigned the highest score (7) for choices of 'Definitely the easy-to-get-rock'. By contrast in the sunk cost condition, agents show respect for costs by choosing the rock already obtained at a higher cost, and so here this score was assigned for choices of 'Definitely the hard-to-get-rock'.

On the next three screens, participants rated the agents' capacities for recognizing waste, anticipating the future, and remembering the past (order randomized across participants). Specifically, they indicated their agreement on 7-point Likert scales with the statements 'Pax can see actions as wasteful if Pax is a(n) _____', 'Pax can anticipate future events if Pax is a(n) _____', and 'Pax can remember past events if Pax is a(n) _____'.

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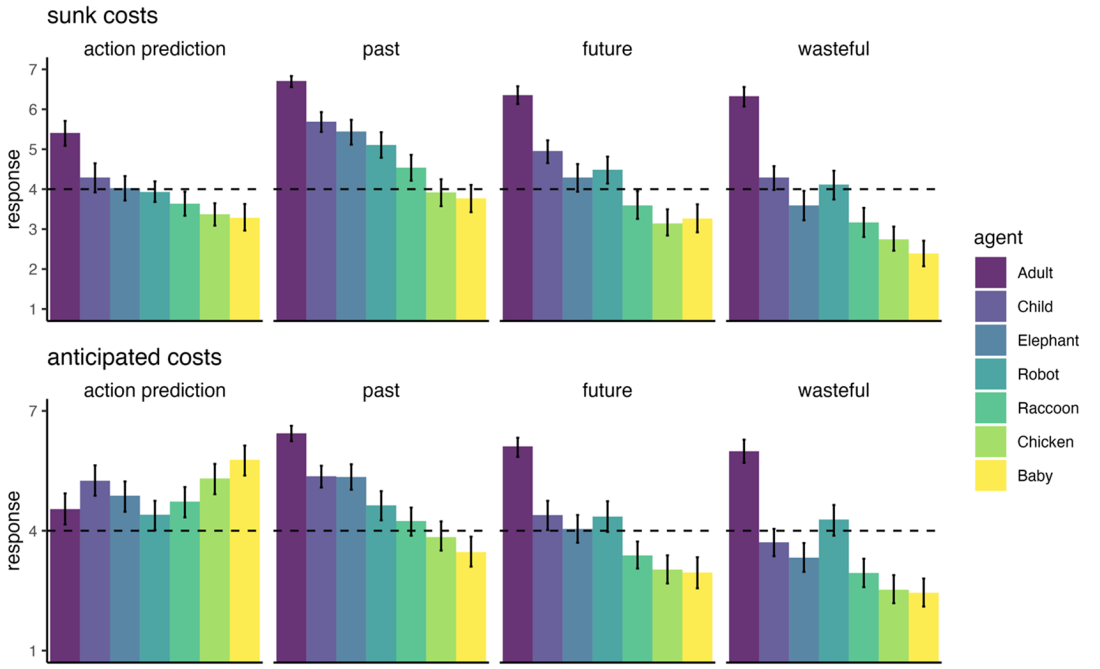

Figure 3. *Mean ratings and 95% confidence intervals in Experiment 3.*

3.2. Results

In our main analyses, we separately analyzed responses from the sunk cost and anticipated costs conditions. Figure 3 shows participants' mean ratings in both conditions.

3.2.1. Sunk costs

A one-way ANOVA found that action predictions significantly differed by agent, $F(4.01, 449.57) = 29.74$, $p < .001$, $\eta^2_p = .21$. Holm-Bonferroni comparisons with p-values adjusted for 21 tests found that sunk cost predictions were greater for the adult than all other agents, $ps < .001$; greater for the child than for the raccoon, chicken, or baby, $ps \leq .023$, greater for the elephant than for the raccoon, chicken, and baby, $ps \leq .036$, and greater for the robot than for the chicken or baby, $ps \leq .012$. All other differences were nonsignificant, $ps \geq .098$.

We again correlated each participants' sunk cost predictions with their other ratings. A one-way ANOVA showed these correlations differed, $F(1.86, 186.09) = 3.92$, $p = .024$, $\eta^2_p = .04$. Post hoc comparisons (Holm adjusted for three tests) found that the correlation with waste ($M = .48$) was greater than the correlation for thinking about the past ($M = .38$), $t(100) = 2.57$, $p = .035$. The correlation with thinking about the future ($M = .43$) did not significantly differ from either of these, $ps \geq .124$.

3.2.2. Anticipated costs

A one-way ANOVA found that action predictions again significantly differed by agent, $F(4.45, 472.16) = 11.70$, $p < .001$, $\eta^2_p = .099$. Holm-Bonferroni comparisons with p-values adjusted for 21 tests found that ratings that agents would minimize anticipated costs were greater for the baby than all other agents, $ps \leq .021$; greater for the chicken than for the adult, robot, and raccoon, $ps \leq .021$; and greater for the children than for the adult and the robot, $ps \leq .050$. All other differences were nonsignificant, $ps \geq .096$.

The correlations between participants' action predictions and their other ratings did not significantly differ from one another, $F(1.91, 1.58.83) = 0.00$, $p = .998$. All three correlations were negative and fairly weak, with rs ranging from −.18 to −.20.

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3.2.3. Potential order effects

This experiment provided an opportunity to test whether participants' follow-up ratings were influenced by their earlier action predictions—for example, whether waste ratings were influenced by whether they had initially given sunk cost or anticipated cost predictions. We tested this by running separate condition X agent ANOVAs with each follow-up rating (waste, future, past) as the dependent variable. Follow-up ratings were *not* affected by condition—in all three ANOVAs, the main effect of condition was nonsignificant, $ps \geq .067$, and the interaction between condition and agent was also nonsignificant, $ps \geq .211$.

3.3. Discussion

We found that predictions of which agents would be the most sensitive to sunk costs are specific to thinking about sunk costs. Participants gave notably different responses when judging whether agents would minimize anticipated costs (though we did not directly compare responses across the conditions). For example, whereas participants thought adults would honor sunk costs and that babies and chickens would not, they thought babies and chickens would be more likely than adults to minimize future costs. Sunk cost predictions were related to ratings of agents' ability to recognize waste, and their abilities to consider the past and future. Judgments about whether agents would minimize anticipated costs were not significantly related to these predictors.

Participants' judgments across the sunk cost and anticipated cost conditions could reflect reality. In discussing the absence of convincing evidence for the sunk cost bias in animals and young children, Arkes and Ayton (1999) suggested that preschoolers and nonhuman animals often take actions that maximize rewards and minimize future costs, whereas older children and adults often act on the basis of additional considerations which can sometimes lead to less-optimal results.

4. General discussion

Participants predicted that some kinds of agents would show the sunk cost bias and that other kinds would not. For example, they expected the bias in human adults and human children, but not in animals or in human babies. Predictions about robots were mixed. Participants in the first experiment predicted the bias in robots but participants in the second experiment did not.[3] We also found that sunk cost predictions were related to participants' assessments of the agents' mental abilities, including their capacities to recognize waste, to feel regret, and to consider future events. In the second experiment, we also found that participants gave quite different predictions when judging whether agents would minimize anticipated costs, and these predictions were not strongly related to ratings of capacities that correlated with sunk cost ratings.

The connection between sunk cost predictions and waste ratings suggests that people may predict whether an agent will show the bias considering whether the agent is averse to waste. This conclusion is broadly in line with claims that the bias reflects concerns with waste (e.g., Arkes, 1996; Arkes and Ayton, 1999). However, sunk cost predictions were also related to ratings of other capacities. There was a strong relation to ratings of regret, which could suggest that people consider this capacity when predicting whether an agent will show the bias. But participants did not appear to see regret as *necessary* for the bias: In the first experiment, participants generally predicted that robots would show bias, despite strongly denying that robots could feel regret (a finding consistent with earlier work looking at beliefs about robots' capacities to feel emotions; Gray et al., 2007; Weisman et al., 2017, 2021). Similar questions apply to the relation between sunk cost prediction and ratings of agents' capacity to think about future events.[4] It could be that participants consider this ability when judging whether

[3] In Experiment S1 in the Supplementary Materials, participants also predicted that robots would show the bias.

[4] Experiment S1 (Supplementary Materials) included a follow-up question about whether each agent could remember which object was the high cost item and which was the low cost one. Higher memory ratings correlated with sunk cost predictions. This

https://doi.org/10.1017/jdm.2024.25 Published online by Cambridge University Press

agents will show bias. But it is also possible that participants just think the capacity for future thinking coincides with other capacities (e.g., ability to recognize waste) which do matter for the sunk cost bias.

Overall, the findings suggest that sunk cost predictions may depend on theory of mind and people's conceptions of mental life. That is, in predicting whether an agent will be biased by sunk costs, people likely assess the kinds of beliefs, motivations, and mental capacities the agent is likely to have. Moreover, the findings suggest these assessments show specificity to sunk costs, since we did not find the same patterns when participants predicted whether agents would minimize future costs. Our findings may also suggest an error in participants' theory of mind—specifically in their judgments about children. Our participants mostly expected that a hypothetical 6-year-old child would be biased by sunk costs. However, in scenarios very similar to those presented here, children did not anticipate that choices would be biased by sunk costs (but they did anticipate minimizing future costs) (e.g., Sehl et al., 2021, 2024). This suggests that participants attributed to children a concern for waste which children themselves may not have (but see Choshen-Hillel et al., 2020; Shaw and Olson, 2012; Sorokowska et al., 2020 for work suggesting young children do care about waste outside the context of sunk costs).

Our studies used within-subjects designs where participants made sunk cost predictions about many kinds of agents. While this approach is typical in research on people's conceptions of mental life (e.g., Gray et al., 2007; Weisman et al., 2017, 2021), it might not match what people normally do when predicting how they or others will act. In the Supplementary Materials, we report the results of two experiments that instead used between-subject designs (Experiments S2 and S3). For example, in one experiment, participants read vignettes where an agent (adult, child, raccoon, or robot) fetched one pinecone from a big hill and another pinecone from a small hill, and then had to decide which to keep. The findings from these experiments differed from those reported here, and from one another.[5] Some of these differences likely resulted from methodological problems (as discussed in the Supplementary Materials), but the differences could also reflect deeper differences between how people make judgments in different contexts (e.g., Hsee et al., 1999). We hope to further explore these issues in future research.

There are further issues with our tasks that can be addressed in future work. We used a correlational approach, which means we cannot be certain, for example, whether assessments of agents' capacity to recognize waste played a causal role in sunk cost predictions. As an alternative, waste ratings and sunk cost predictions might both depend on some common factor which we did not explore. In future work, the agents' mental capacities could be directly manipulated. For example, vignettes could specify whether agents care about waste or feel regret. Another issue with our studies is that participants might have concluded that although the two rocks *looked* identical, they could have differed in other ways (e.g., in terms of weight) and this could have affected participants' predictions. Participants also could have interpreted the questions about the agents' capacities differently for different agents. For example, in affirming that both humans and robots can see actions as wasteful, participants might nonetheless have felt that humans, but not robots, see waste as having a moral dimension.

Another area for further exploration will be to look at predictions for other kinds of sunk cost scenarios. Our experiments exclusively looked at sunk cost predictions in 'utilization' scenarios, where the agent must decide which of two similar items to use or capitalize on. However, the sunk cost bias also occurs in 'progress' scenarios—situations where an agent must decide whether to invest resources in pursuing a goal, and may be more likely to if they have already invested resources in it (Moon, 2001). We might find completely different results for these scenarios. For instance, participants might see different kinds of agents as most likely to persist in pursuing goals, and so their predictions might relate more strongly to other aspects of mental life.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/jdm.2024.25.

connection to memory may have been inevitable. After all, if an agent could not remember which item was which, the agent would have no way of preferentially choosing the high cost one.

[5]For example, in one experiment, participants thought chickens would be more likely than robots to be biased by sunk costs, whereas in the other experiment, participants thought robots would be as likely as adults and children to be biased.

Data availability statement. Preregistrations, data, stimuli, and code are available on OSF at https://osf.io/q8hsu/.

Acknowledgments. This research was approved by the Office of Research Ethics at the University of Waterloo (Project 45038: Assessing People's Expectations of Agents). It was supported by separate grants from the Natural Sciences and Engineering Research Council of Canada awarded to SD and OF.

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Cite this article: Howard, A., Sehl, C., Denison, S., and Friedman, O. (2024). Sunk cost predictions as theory of mind. *Judgment and Decision Making*, e20. https://doi.org/10.1017/jdm.2024.25