The Scope and Limits of Overimitation in the Transmission of Artefact Culture

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Electronic Supplementary Material

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1. Experiment 1: Does Associating a Competitive Cost with Overimitation Eliminate the Effect?

1.1. Experiment 1 Methods

1.1.1. Experimental Condition

Participants and physical set.
Participants in the experimental condition were 64 four- and five-year-olds (mean age 57 months) tested at 11 Southern Connecticut preschools. To minimize distraction, testing was conducted in separate rooms specifically set aside for the purpose. The physical set centered around a small “cabana” structure (ESM Fig. 1) which concealed a hidden experimenter. This experimenter was responsible for controlling the competitor character, Felix, using a simple puppetry rig. A closed-circuit video monitor inside the cabana displayed a live side-view of the participant and the Puzzle Object, enabling the hidden experimenter to animate Felix in a highly contingent manner.

A second experimenter sat with the child and supervised the overall progress of the study. This main experimenter could use a folding cardboard screen to block children’s view of the cabana, thus preventing unnecessary distraction during the initial phases of the experiment. This screen was in place when children first entered the testing room.
ESM Fig. 1. The cabana structure used in Experiments 1 and 2. The interior is large enough to accommodate a hidden experimenter responsible for controlling Felix’s movements using a simple puppetry rig.
Training phase.

Participants first completed an initial training phase similar to that employed in our prior studies [4]. Stimuli for the training phase were the same familiar, transparent household containers used previously (ESM Fig. 2). As before, children watched as the experimenter retrieved a toy dinosaur from each container using a combination of relevant and irrelevant actions. After each retrieval, children were asked to denote (both verbally and via an action-based response measure) which actions had actually been necessary to get the dinosaur and which had been “extra.” ESM Table I summarizes the way in which verbal and action-based queries were combined across the training objects, as well as the schedule for corrective experimenter feedback.

**ESM Table I: Training Object Presentation Order and Questioning Format**

<table>
<thead>
<tr>
<th>Object Number</th>
<th>Objects Used (Fig. 2 Panel)*</th>
<th>Object Ordering</th>
<th>Type of Questioning</th>
<th>Corrective Feedback?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jar (A)</td>
<td>NA</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2-3</td>
<td>Cylinder (B) and Syrup Container (C)</td>
<td>Random</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4-5</td>
<td>2 of the following: drawer (E), cone (F), aquarium (G), purse (H)</td>
<td>Counterbalanced</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>Cookie jar (D)</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Yes</td>
</tr>
<tr>
<td>7-8</td>
<td>Remaining two objects</td>
<td>Counterbalanced</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Indicates which panel of ESM Fig. 2 depicts the corresponding training object.
ESM Fig. 2. Objects used to train participants on the distinction between necessary and unnecessary actions. The experimenter retrieved the toy dinosaur from each object as follows: (A) Tapping on the side of the jar with the feather, followed by unscrewing the lid. (B) Jingling the bell, followed by unscrewing and removing the top half of the cylinder. (C) Putting on the wristband, followed by lifting the lid. (D) Unfastening and lifting the outer lid, followed by removing the lid from the inner soap dish (this item served as a control in which both of the experimenter's actions were necessary). (E) Pulling out the drawer, followed by removing a Velcro star (not visible) from the back of the drawer. (F) Pressing a small piece of silly putty onto the glass top, followed by removing the top from its base. (G) Making a small dot on the aquarium with the pen, followed by lifting the aquarium's lid. (H) Unzipping the purse, followed by tapping the side of the open purse with the wooden mallet.
While our verbal questioning procedure has been described elsewhere [4], the action-based queries are new. The experimenter began this style of question by remarking, “I got that dinosaur out pretty fast, but I wonder if you can do it faster? Do you think you can get the dinosaur out faster than me?” Children were then allowed to retrieve the dinosaur from the training object themselves. When children skipped the irrelevant steps that they had seen the experimenter perform, they received enthusiastic praise and reinforcement (“Great job! You got that dinosaur out way faster than me. And you know what I noticed? You didn’t do the silly extra thing, did you? Skipping the extra thing made you go way faster.”). When children unnecessarily copied the irrelevant actions, on the other hand, they were first asked to review their response (e.g. “Did you have to take this Velcro star off the drawer? Did that help you get the dinosaur?”), and then offered an opportunity to try again (“This time, I bet you can get the dinosaur out even faster if you don’t do any silly extra things…”).

This action-based questioning helped to increase the power of the training manipulation in two key ways. First, it allowed children to actively practice not copying the adult, thereby further decreasing the likelihood of later overimitation. Second, and perhaps more importantly, it also helped children to establish an explicit causal relationship between skipping unnecessary steps and reaching a desired goals state more quickly. As we will soon see, this facet of training was designed to “teach to the test” phase of the experiment in a very direct way.

As in our prior experiments [4], the experimenter withheld corrective feedback on the final two training items. Children were assigned a training score between 0 and 2 based on the number of times that they successfully ignored the adult’s irrelevant actions while retrieving the dinosaurs from these objects.
Non-competitive phase.

After training children moved directly into the non-competitive phase of the experiment. The experimenter began by removing a screen to reveal the novel “Monkey Box” object (ESM Fig. 3). Modeled on the Puzzle Box used in earlier studies [4], the Monkey Box’s most distinct visual features were the red door on the front of the object (the relevant mechanism), and a red wooden bolt held in a wooden frame on top of the object (the irrelevant mechanism).

**ESM Fig. 3.** The Monkey Box. **(A)** An isometric view of the object. **(B)** From an end-on perspective, the Monkey Box looks very similar to the Puzzle Box used in our prior studies [4]. **(C)** The object consists of two symmetrical halves. A horizontal silver tube runs through the middle of the box, and can be accessed via the red and white door mechanisms on either end of the object. The vertical silver “feeder tube” on top of the object appears to connect directly to the horizontal tube at a junction in the center of the box.

Sitting next to the child, the experimenter remarked, “Do you remember how those other containers had little dinosaurs in them? Well *this* thing has a little toy turtle inside.” He then proceeded to retrieve the turtle from the Monkey Box using a sequence of relevant and irrelevant actions (see next section). After removing the turtle and showing it to the child, the experimenter
unfolded a cardboard screen in front of the Monkey Box (temporarily blocking the child’s view) and reset the object to its original state. The experimenter then removed the screen, and explained to the child that he needed to leave the room for a moment. The experimenter invited the child to interact with the object in his absence, saying “If you want to, you can get the turtle out while I’m gone. You can get it out however you want.” The experimenter then left the room, remaining outside until the child had finished retrieving the turtle.

**Experimenter Action Sequences.**

ESM Fig. 4 illustrates the action sequences that the experimenter used when operating the Monkey Box. Both of the Monkey Box’s mechanisms could be actuated in two distinct ways: the relevant door mechanism could be opened by removing the central red plug or flipping the entire white frame down; the irrelevant the wooden bolt could be removed by pushing from the right or pulling from the left. These dual means of operation were combined into a total of four experimenter action sequence permutations, all of which were used in the study with presentation counterbalanced across participants. Each permutation also included several small tapping actions (not shown in the figure), the purpose of which was to equalize the attention drawn to different parts of the object. For example, when the experimenter removed the Monkey Box’s bolt by pulling from the left, he would first lightly tap on its right-hand end—thus highlighting the fact that the bolt could also be pushed out from that direction. Children often reproduced these “control taps” while operating the Monkey Box, but such tapping alone was not counted as overimitation. Our approach was more conservative, requiring that participants actually remove the irrelevant red wooden bolt from its bracket in order to be scored as overimitating.
ESM Fig. 4. Experimenter actions used to retrieve the turtle from the Monkey Box. (2) The irrelevant bolt is removed, revealing the opening into the box’s empty upper compartment; the want is used to tap on the empty upper compartment’s floor (not shown). (3) The relevant door mechanism is opened, revealing the turtle attached to a blue ribbon. (4) The wand is used to pull out the ribbon/turtle. All 4 possible combinations of relevant and irrelevant actions were presented, counterbalanced across participants.
Competitive phase.

**Introducing Felix.** After children retrieved the turtle from the Monkey Box the experimenter returned to the room. He reassembled the object, again using the folding cardboard screen to obscure the child’s view as he did so. Once the Monkey Box was reset, the experimenter removed a partition that had previously hidden the cabana. The experimenter explained to the child that he wanted to introduce him/her to his good friend Felix the monkey.¹ At this point the experimenter hidden in the cabana raised a curtain covering the structure’s front door and Felix emerged. Felix sat in front of the cabana, face-to-face with the child and opposite the Monkey Box in between them. The main experimenter then spent several moments making sure that the child seemed comfortable with and interested in Felix. This process was greatly facilitated by Felix’s contingent interactivity, including behaviors such as waving, clapping, making happy monkey vocalizations, and otherwise exuding a friendly demeanor. The hidden experimenter controlled all of these actions using a combination of a light weight paddle Velcroed to Felix’s posterior quarters (for gross body movement and orientation), plus two control rods connected to anchor points inside Felix’s hands. Great care was taken to insure that none of these control elements were visible from the child’s vantage point; Felix appeared to be a legitimately autonomous creature.

**Introducing the Racing Concept.** Once the child was acquainted with Felix, the main experimenter directed his or her attention back to the Monkey Box. He explained: “Do you know what Felix loves to do more than anything else? He loves to play with this thing [indicating the Monkey Box] right here.” The experimenter then slowly turned the Monkey Box end-for-end, revealing that it had two identical sides. The experimenter carefully emphasized this feature,

¹ The authors hasten to add that Felix is actually an orangutan (*Pongo pygmaeus*). However, early piloting revealed that children had very firm intuitions to the contrary, and that they strongly preferred to classify Felix as a member of a monkey species.
observing that the child’s side of the box and Felix’s side were “just the same.” He went on to explain: “That’s so you and Felix can have a race! You can both try to get the turtle out at the same time!” Pointing out the vertical feeder tube on top of the object, the experimenter said that he was going to drop a single turtle down the tube, and that it would land in the middle of the horizontal pipe running through the center of the object (ESM Fig. 5). The experimenter explained that he would then count to three, at which point the child and Felix could both attempt to retrieve the turtle by opening their respective ends of the Monkey Box. Critically though, since there would be only one turtle in the object, only one competitor would ultimately be successful.

![ESM Fig. 5](image)

**ESM Fig. 5.** A vertical silver feeder tube on top of the Monkey Box appears to lead down to the horizontal pipe running through the center of the object. The children’s “race” with Felix was premised on the experimenter dropping a single toy turtle down this tube, presumably into the center of the object. Both competitors could then attempt to retrieve the turtle by opening their respective side of the box.

Because this final point was so important, the experimenter paused at this juncture for a manipulation check. He asked the child, “How many turtles are there going to be in the object?” and then, “So, if you go too slowly, who’s going to get the turtle out: you or Felix?” Errant responses were carefully corrected, but in practice most children had little difficulty immediately answering both questions. Following this check the first iteration of the race was begun.
**Race Procedure.** Each iteration of the race followed an identical procedure. The experimenter first positioned a special cardboard screen at the midpoint of the Monkey Box, completely obscuring the child’s view of Felix and Felix’s end of the apparatus. With the screen in place, the experimenter then dropped a single turtle into the feeder tube as the child looked on. He then moved to the door of the room and began his countdown: “1… 2… 3… GO!” On the “Go” signal the main experimenter immediately withdrew into the hallway, such that the child appeared to be unobserved while retrieving the turtle. At the same time though, the hidden experimenter used the closed-circuit video feed inside the cabana to monitor the child’s means of retrieval. If the child was scheduled to lose the current race (discussed momentarily), the hidden experimenter also surreptitiously placed a turtle—identical to the one that the main experimenter had dropped into the box—in Felix’s hand.

Once the child finished opening the Monkey Box the hidden experimenter made a monkey vocalization sound to indicate that the main experimenter could return to the room. The main experimenter came back in and removed the screen at the center of the Monkey Box so that the child could once again see Felix. In cases where the child “won” the race (obtaining the turtle), Felix was crestfallen and the main experimenter praised the child effusively for their skill. In cases where the child had lost (i.e. they found that the Monkey Box was empty), the removal of the screen revealed that Felix was holding the turtle and celebrating his victory. If appropriate the game was then reset for the next round of the competition.

**Winning and Losing.** The question of whether children won or lost a given round was determined by overimitation. All children lost the first round of the race; children who did not overimitate on round $n$ subsequently “won” on round $(n + 1)$. This delay structure was imposed by the logistics of loading turtles into the Monkey Box. Though the main experimenter appeared to do this when he dropped a turtle into the feeder tube at the start of the race, in fact this tube
led only to a dead end. It was the hidden experimenter’s job to actually place turtles inside the object where they could be retrieved, contingent on the child’s prior behavior. So, for example, if a child avoided overimitation on round 1, then the hidden experimenter would surreptitiously load a turtle into the center of the Monkey Box for the child to find during round 2. This loading was performed at the same time that the main experimenter reset the object’s mechanisms between rounds, a process that was blocked from children’s view by the folding cardboard screen.

In order to prevent undue frustration, the maximum number of rounds that children could play was fixed at 3. On the third round of the game children always found a turtle in the object, regardless of whether they had overimitated during the prior round. The game ended whenever children successfully obtained the turtle, either due to avoiding overimitation on the prior round or to reaching the three-round limit.

To summarize: though the behind-the-scenes logistics were somewhat complex, the bottom line for participants was simple. Children who overimitated lost the race to Felix—potentially repeatedly—and were thus faced with mounting competitive pressure to increase their box opening speed. The question of interest was whether overimitation would survive this extreme form of contrary pressure.

1.1.2. Baseline Condition

A second, independent group of participants completed a baseline control condition designed to test children’s average causal understanding of the Monkey Box in the absence of any adult demonstration. Baseline participants \(N = 28\) were age matched to those in the experimental condition (mean age 55 months), and were tested in 4 Southern Connecticut preschools as well as our laboratory. After completing a training phase identical to that in the experimental condition,
baseline participants were presented with the Monkey Box and asked to independently locate the toy turtle inside it. As in the experimental condition, children were unobserved by the experimenter while performing this task. Once children found the turtle the experimenter returned to the room, reset the object to its original state, and asked to be shown what one would “have to do” to get the turtle out. The frequency with which children operated the Monkey Box’s irrelevant mechanism during their subsequent demonstration was then measured.

Baseline testing of the Monkey Box was conducted concurrently with the baseline testing of the Prize Box used in Experiment 2. Baseline participants were presented with both of these objects in counterbalanced order.

1.1.3. Coding of Data

All experimental and baseline trials (N = 92 total) were videotaped by a camera unobtrusively positioned behind participants and above their line of sight. Two independent coders, blind to the actions that the main experimenter had performed, then analyzed the videotapes to determine whether and how participants had operated the Monkey Box’s mechanisms. Each coder analyzed 50% of the trials (N = 46). After this initial analysis, 35% of the trials (N = 32) were randomly selected for double coding, and were re-analyzed by the second coder (i.e. the coder who was not originally responsible for them). Cohen’s kappa values computed for this overlapping set were found to be uniformly high, validating the consistency of ratings between the two coders (ESM Table IV; mean percent agreement = 95%, mean κ = 0.868, all p-values < 0.03).
1.2. Experiment 1 Results and Discussion

1.2.1. Non-Competitive Phase Results

Despite the contrary task demands instilled during training, children were highly overimitative during the non-competitive phase of the experiment. Experimental participants overimitated significantly more frequently than the rate of spontaneous irrelevant action production observed during the baseline (74% versus 12%, $\chi^2(1, n=89) = 51.5, p < 0.001$, odds ratio = 70.9).

Importantly, we also found that overimitation was independent of training outcome ($\chi^2(1, n=64) = 0.2, p = ns$). That is, children who received the highest scores during training were just as likely to overimitate as children who found training more challenging. Though this finding has held in our prior work as well [4], it is made more striking in this case by the addition of action-based questioning to our training procedure. Participants who performed the best on training in the present study were not only able to identify the adult’s irrelevant actions, they were also able to refrain from copying those actions when allowed to act on the same training objects. The fact that these skills did not translate into reduced overimitation on the novel Monkey Box reinforces our contention that the effect may be largely involuntary.

1.2.2. Competitive Phase Results

What of competition? Did associating a competitive cost with overimitation block the effect, or did overimitation persist as predicted by our automatic causal encoding (ACE) hypothesis?

Before we can answer this question we first need to verify two key interpretational prerequisites. Specifically, we need to confirm that (a) participants understood the competitive premise of the racing task, and (b) that overimitation did in fact impose a competitive disadvantage.
Did children understand the competitive nature of the race?

If children understood the competitive, time-critical nature of the racing task, then we would expect that their Monkey Box opening times on the first race would be substantially faster than their times during the non-competitive phase of the experiment. A paired-samples t-test verified that this was indeed the case, and by a considerable margin: on average children opened the Monkey Box more than three times faster during the first round of competition than they did during the non-competitive phase (5.6 seconds versus 18.3 seconds). Just as importantly, this speed increase was very broadly based, and not disproportionately driven by one particular segment of those tested.

This latter fact was verified by dividing participants into “competition effect” ($CE$) groups according to the persistence of their overimitation (ESM Table II).

**ESM Table II: Competition Effect Groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>Non-Competitive Phase Overimitation</th>
<th>Competitive Phase Overimitation</th>
<th>Race 1</th>
<th>Race 2</th>
<th>Race 3$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

$^a$Note that participants who did not overimitate on Race 1 of the competition won on Race 2, and hence did not complete Race 3.

For example, children in the $CE=1$ group overimitated during the non-competitive phase of the experiment, but then stopped on the first race; the $CE=2$ and $CE=3$ groups were defined in
analogous manner. We also defined a $CE=NA$ group for participants who never overimitated (not even during the non-competitive phase), and a $CE=None$ group for children who always overimitated. When times for each group were analyzed separately, we found that all followed the same general pattern as the whole: every group opened the Monkey Box substantially faster on the first bout of competition than during the non-competitive phase (ESM Table III).

**ESM Table III:** Non-Competitive versus Competitive (Race 1) Monkey Box Opening Times for Each Competition Effect Group

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Non-Competitive Phase Time</th>
<th>Competitive Phase (Race 1) Time</th>
<th>$t$-test Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>6</td>
<td>4.7 sec</td>
<td>1.0 sec</td>
<td>1.7</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>19.8 sec</td>
<td>1.8 sec</td>
<td>6.7**</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>20.5 sec</td>
<td>9.3 sec</td>
<td>5.4*</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>18.0 sec</td>
<td>6.0 sec</td>
<td>NA</td>
</tr>
<tr>
<td>None</td>
<td>31</td>
<td>19.7 sec</td>
<td>7.5 sec</td>
<td>6.8**</td>
</tr>
</tbody>
</table>

** $p < 0.001$, * $p < 0.01$**

This finding is particularly important for groups in which children overimitated on the first race ($CE=2, 3,$ and None). The fact that children in these groups did open the Monkey Box significantly faster indicates that their continued overimitation was not due to a failure to grasp the competitive dimension of the task. On the contrary, children in these groups understood the time critical nature of the race, and were clearly making an earnest effort to beat Felix; they failed, however, to hit on the seemingly obvious strategy of simply omitting the adult’s irrelevant actions.
Did overimitation impose a competitive disadvantage?

Did overimitation represent a competitive handicap in the way we intended? The timing data argues that the answer to this question is yes. Though participants as a whole made significant speed improvements on the first round of the competition, those who avoided overimitation (the \( CE=\text{NA}\) and 1 groups) were able to open the Monkey Box substantially more quickly than those who copied the adult’s unnecessary steps (the \( CE=2, 3, \) and None groups) (\( t(51) = 5.3, p < 0.001 \)). The disparity was actually quite steep: overimitators needed more than four times as long as non-overimitators to open the box during the first race (7.7 seconds versus 1.9 seconds).

Competition’s effect on overimitation.

Having verified our interpretational prerequisites, we can now ask what effect the competitive cost of overimitation had on participants. As ESM Fig. 6 illustrates, the beginning of the competition did see reduced overimitation relative to the non-competitive phase of the experiment (McNemar test, \( n = 60, p < 0.001 \)). This finding weighs against the strongest formulation of our hypothesis, indicating that for at least some children, overimitation in the non-competitive phase of the experiment may have been motivated by curiosity rather than by legitimate causal confusion.

However, though overimitation decreased on the first race, ESM Fig. 6 also shows that the majority of children were unsuccessful at avoiding it. In fact, most children continued to overimitate on the second race and even the third, despite mounting pressure to open the Monkey Box more quickly. Most importantly, the rate of overimitation across all three races was a significant 4 to 5 times greater than the rate of irrelevant action production observed amongst baseline participants (Game 1 versus Baseline: \( \chi^2(1, n=85) = 19.8, p < 0.001, \text{ odds ratio} = 13.6; \)
Game 2 versus Baseline: \( \chi^2(1, n=84) = 14.8, p < 0.001, \) odds ratio = 10.0; Game 3 versus Baseline: \( \chi^2(1, n=83) = 13.4, p < 0.001, \) odds ratio = 9.0.

When baseline participants opened the Monkey Box independently, fully 88% of them immediately identified the most efficient means of doing so and completely ignored the irrelevant mechanism. Thus, the Monkey Box truly is causally transparent to children of the age we tested. Yet despite this transparency, once children in the experimental group observed an adult operating the Monkey Box inefficiently, most of them remained “stuck” overimitating, even when doing so subjected them to repeated competitive failure. Overimitation persisted in this way despite experimental participants’ increasing first-hand experience with the Monkey Box itself—something that should presumably have advantaged them over baseline children.

**ESM Fig. 6.** Children continue to overimitate even when doing so disadvantages them in a time-critical race. Though the competitive cost of overimitation did dissuade some participants, most children continued to copy the adult’s irrelevant actions across all three iterations of the contest. Even after the third and final race, overimitation remained 4.6 times more frequent than in the baseline condition.
Finally, it is worth noting that the stubborn persistence of overimitation cannot be explained by positing a lack of competitive motivation on the part of overimitators. Actually, even the most persistent overimitators (CE=None) managed to open the box significantly faster on race #2 than on race #1 ($t(30) = 5.6, p < 0.001$), and were faster still on race #3 ($t(30) = 2.1, p = 0.05$). By the end of the game these children were opening the Monkey Box almost 6 times more quickly than they did during the non-competitive phase of the experiment (3.5 seconds versus 19.7 seconds originally). It seems then that overimitators’ fundamental problem was not lack of motivation to best their simian competitor, but instead a conspicuous inability to see through the adult’s irrelevant actions.

2. Experiment 2: Overimitation and “real-world” competition

2.1. Experiment 2 Methods

2.1.1. Participants

Experiment 2 was performed as a covert follow-up to Experiment 1. Immediately after completing their races with Felix, 25 Experiment 1 participants (mean age 57 months) moved into the competitive condition of Experiment 2, while 32 participants (mean age 58 months) moved into the non-competitive condition.

2.1.2. Competitive Condition

Participants were introduced to the Prize Box (ESM Fig. 7) in the manner described in the main text. As before, participants observed the experimenter opening the object with an action sequence that included an obviously irrelevant component; rather than simply opening the lid of
the Prize Box and reaching inside, he first operated the irrelevant arm mechanism, swinging it 180° from right to left. Because the irrelevant arm had a bell attached to its end, the completion of this action was punctuated by a loud jingling noise.

**ESM Figure 7.** The Prize Box. Note the bell on the end of the yellow arm, a feature that makes operating the irrelevant mechanism a noisy proposition.
ESM Fig. 8. Experimenter actions used to retrieve the bracelet from the Prize Box. (2) The irrelevant arm is grasped, using either the horizontal handle or a vertical post attached to its end, and swung quickly to the left, causing the bell to ring. (3) The lid of the box is opened, making the blue container inside accessible. (4) A bracelet is retrieved from the internal container. All 4 possible combinations of relevant and irrelevant actions were presented, counterbalanced across participants.
After opening the box the experimenter removed a glow-in-the-dark bracelet and handed it to the child as their prize. While the child inspected their reward the experimenter quickly reset the object and positioned it between the participant and the entrance to the cabana. Felix then emerged from the cabana and proceeded to abscond with the child’s bracelet as described in the main text (see ESM Video 4 for an example of this procedure).

The experimenter was momentarily taken aback by this unexpected turn of events. “Oh my gosh!” he exclaimed, “He took your prize! That monkey took your prize!” Fortunately for the child, however, the experimenter quickly recovered his composure. Lowering his voice and leaning closer to the participant (as though to prevent Felix from overhearing) the experimenter explained: “Okay, here’s the thing. I think what happened was that we woke Felix up when we were getting the prize, and that’s why he came out and took it. But there’s another prize in there [indicating the box]. I bet—if you’re really quiet, and careful—that you can get the other prize without waking Felix up.” Having thus explained the task, the experimenter said that he was going to leave the room “so that Felix will think we’re gone.” Reiterating his instructions (“See if you can get the prize without waking up Felix!”), the experimenter exited the room, and the child was left with the task of opening the Prize Box in as stealthy a manner as possible.

2.1.3. Non-Competitive and Baseline Conditions

Children in the non-competitive condition were initially introduced to the Prize Box in the same manner as participants in the competitive condition. The experimenter then explained that he was going to get a prize out for Felix first, and that the child could subsequently retrieve one for him/herself. The experimenter opened the Prize Box as previously described, removed a prize for Felix, and then left the room. Children were then allowed to retrieve a prize for themselves while unobserved. The baseline for the Prize Box, i.e. the extent to which children performed
irrelevant actions when opening the object independently, was determined concurrently with the baselining of the Monkey Box in Experiment 1.

2.1.4. Coding of Data

Two independent coders analyzed trial videos in the same manner described for Experiment 1. Inter-rater agreement was again consistently high (ESM Table IV; mean percent agreement = 91%, mean $\kappa = 0.812$, all $p$-values < 0.01).

2.2. Results and Discussion

Because participants believed that the experiment was over, we predicted that they would act in accord with their basic causal understanding of the Prize Box, stripped of any artificiality that taking part in a “game” or “race” might introduce. Further, the experimental context provided a strong motivation to avoid the irrelevant mechanism if at all possible. If children had any inkling that the noisy irrelevant mechanism might not be causally important, the best strategy would clearly be to try opening the box without manipulating it. Conversely, if children were to continue overimitating in this highly charged scenario, this would constitute powerful evidence that they had indeed encoded the adult’s irrelevant actions as causally meaningful.

Children in the non-competitive condition overimitated 78% of the time. As predicted, we found that this rate of overimitation was not significantly reduced when a competitive dimension was introduced into the task (ESM Fig 9, $\chi^2(1, n=57) = 0.7, p = ns$). Even though the noisiness of the irrelevant mechanism imperiled their covert attempt to retrieve a prize, participants in the competitive condition were just as likely to overimitate as participants in the non-competitive condition.
Experiment 2 participants continued to overimitate even though doing so imperiled their prospects for gaining a highly desirable prize. The rates of overimitation during the competitive and non-competitive phases of the experiment were statistically identical.

The degree to which overimitation persisted was made all the more striking by the results of the baseline condition. When a group of 28 age-matched baseline participants opened the Prize Box independently, not a single one of them operated the object’s irrelevant mechanism (non-competitive condition versus baseline: $\chi^2(1, n=60) = 37.5, p < 0.001$; competitive condition versus baseline: $\chi^2(1, n=53) = 28.0, p < 0.001$). In this sense the Prize Box is actually the simplest of all the puzzle objects used in our experiments. However, just as the automatic causal encoding theory would predict, this simplicity did little to help experimental participants avoid operating the irrelevant mechanism.

Returning to the original motivation for this follow-up study, note that these findings help to resolve any lingering concerns about the interpretation of Experiment 1. Given that overimitation survived the naturalistic competitive task presented here, we can be much more
confident that the persistence of overimitation in Experiment 1 was not a byproduct of children misconstruing the “rules” of the racing game. Rather, the data from Experiments 1 and 2 converge on a single conclusion: children are largely insensitive to the potential costs of overimitation in the manner that the ACE theory predicts. Even when overimitating incurs significant competitive disadvantages, children continue to do so because the observationally induced distortions in their causal beliefs permit no other alternative.

3. Experiment 3: Does Intentionality Constrain Overimitation?

3.1. Experiment 3 Methods

3.1.1. Participants and Stimuli

Participants for Experiment 3 were 27 four- and five-year-olds (mean age 53 months) tested at 8 Southern Connecticut preschools. Participants were tested using slightly modified versions of the Monkey Box and Prize Box objects.

The modified Monkey Box differed from the original in two respects. First, the irrelevant red bolt on top of the object now had a wooden “wing” mounted perpendicularly to its end, such that the two pieces together formed an “L” shape. When the bolt was positioned in its bracket on top of the Monkey Box, the new wing piece extended vertically up and away from the top of object (see ESM Fig. 11). The second modification to the Monkey Box pertained to the implement that the experimenter used to operate the object; a large rectangular paddle with a wooden handle now replaced the small wand used in Experiment 1. The surface of the paddle was covered in a blue foam pad, creating a cushioned striking surface. A narrow projection of Velcro-covered wood, two inches in length and approximately the same thickness as the original
wand, extended from the end of the paddle opposite its handle. This projection could be inserted into the front opening of the Monkey Box and used to retrieve a Velcro-backed turtle in the same manner as the wand.

The new version of the Prize Box also differed from the original in two respects: the bell on the end of the irrelevant arm was removed, and a new implement for operating the object was added. This implement consisted of a cylindrical, red wooden handle attached to a yellow wooden cube on its end. The end of the cube was covered in Velcro such that the implement could be used to remove a Velcro-backed turtle from inside the Prize Box.

3.1.2. Experimental Condition

Experimental condition participants first completed the training procedure used in Experiment 1 and then continued immediately into the test phase of the experiment. The specific action sequences that the experimenter used to retrieve the turtle from the puzzle objects during the test phase are described in the main text and illustrated in ESM Figs. 10 and 11. ESM Videos 6 and 7 further illustrate how these sequences were portrayed as being either intentional or unintentional. Each child saw the experimenter performing an intentional sequence on one of the puzzle objects, and an unintentional sequence on the other. Order of object presentation, object/intentionality combinations, and the specific action sequence permutations used were all counterbalanced across participants.
ESM Fig. 10. The experimenter’s action sequences for the Monkey Box. The same actions were used in both the intentional and unintentional cases. In the unintentional case, however, the back-and-forth waving of the paddle was contextualized as gesturing during the course of a phone conversation.
ESM Fig. 11. The experimenter’s action sequences for the Prize Box. The same actions were used in both the intentional and unintentional cases. In the unintentional case, however, the back-and-forth waving of the wand was contextualized as gesturing during the course of a phone conversation.
3.1.3. Attentional Control Condition

An independent group of age-matched children (N=29) participated in an attentional control condition, the purpose of which was to verify that children were attending to the actions that the adult performed while talking on the phone. After completing the same training procedure as experimental participants, these children watched the adult perform the unintentional version of his actions on one of the puzzle objects. Subsequently, rather than being asked to retrieve the turtle for themselves, they were instead directly questioned about what they had observed. The experimenter asked them: “When I was talking on the phone with my Mom just now, I was waving this thing around [indicating the wand or paddle], and I think I might have accidentally done something to the [puzzle object]. Can you show me what I did while I was talking on the phone with my Mom?” Children were then handed the wand or paddle, and encouraged to demonstrate the actions that the experimenter had performed while on the phone.

In most cases the experimenter simply observed the child’s response at this point. There were three particular circumstances, however, in which the experimenter went on to either reiterate his instructions or to offer a slight clarification. First, if the child initially said that they did not remember what they had seen, the experimenter encouraged them to try, saying “Are you sure? I bet you can remember. What did I do while I was on the phone?” Second, if the child responded by pointing to the irrelevant mechanism (but not acting on it) the experimenter encouraged them to act out what they remembered (“What did I do? Can you do what I did?”). Finally, if the child responded by reproducing the relevant action (but not the irrelevant one), then the experimenter clarified his instructions, saying “That’s what I did after I hung up, but do you remember what I did before that? What did I do while I was still on the phone?”

Each attentional control participant was tested with just one of the puzzle objects, with the experimenter’s action sequence counterbalanced across children.
3.1.4. Coding of Data

Each trial was coded live by an observing experimenter who was not visible to participants. Trials were also videotaped, and a second independent coder (blind to the actions that the experimenter had performed) subsequently re-coded all of the data. Comparison between the offline coding and the live coding revealed very high inter-rater agreement (ESM Table IV; mean percent agreement = 95%, mean Cohen’s $\kappa = 0.883$, all $p$-values < 0.001).

3.2. Experiment 3 Results and Discussion

Data from the experimental condition was initially divided into eight analysis groups based on (a) the intentionality of the adult’s irrelevant action (intentional versus non-intentional), (b) the target object (Monkey Box versus Prize Box), and (c) order or presentation (first versus second). Preliminary analysis showed that presentation order had no effect on overimitation, so the data were subsequently collapsed across this dimension. Overimitation was also found to be independent of target object. In order to avoid confusing within- and between-subjects comparisons, however, we report each objects’ results separately here. All reported $p$-values are two-tailed.

Children showed a strong propensity for overimitation when the adult’s irrelevant actions appeared to be intentional, copying the unnecessary steps 69% of the time on both objects. This far outstripped the degree of irrelevant action production observed amongst baseline participants who opened the objects independently (Monkey Box: $\chi^2(1, n=38) = 13.0, p < 0.001$, odds ratio = 16.5; Prize Box: $\chi^2(1, n=41) = 24.8, p < 0.001$). When the same irrelevant actions were contextualized as being unintentional, however, children’s behavior changed substantially. Overimitation in the unintentional context occurred just 7% of the time on the Monkey Box and 8% of the time on the Prize Box (ESM Fig. 12; Monkey Box: $\chi^2(1, n=27) = 11.1, p = 0.001$, odds
ratio = 29.3; Prize Box: $\chi^2(1, n=25) = 9.6, p = 0.002, \text{ odds ratio} = 24.8$). This significant between-subjects finding was recapitulated in within-subjects analysis; individual participants were significantly less likely to overimitate on the unintentional object than they were to do so on the intentional object (McNemar test, $n = 25, p < 0.001$). Importantly, the residual degree of overimitation that occurred in the unintentional context did not differ from the degree of irrelevant action production observed during baseline testing (Monkey Box: $\chi^2(1, n=39) = 0.2, p = ns$; Prize Box: $\chi^2(1, n=40) = 2.4, p = ns$). In other words, experimental participants were no more likely to overimitate the unintentional irrelevant actions than baseline participants were to produce equivalent actions spontaneously.

![ESM Fig. 12.](image)

ESM Fig. 12. Overimitation is firmly constrained by intentionality. Children will almost completely ignore irrelevant actions that appear to be unintentional (gray bars), even though the same actions presented intentionally trigger high levels of overimitation (black bars).

Before we can argue that these results reflect a constraining property of intentionality, however, there is an alternative possibility that needs to be addressed. Specifically, the very cues that were used to contextualize the adult’s irrelevant actions as unintentional may have had the
side effect of reducing children’s level of attentiveness. That is, since the adult’s phone conversation did not involve them, children may have disengaged from the task and temporarily stopped observing the adult’s actions. This in turn could have led to the substantially diminished overimitation we observed, but for trivial reasons; children may have avoided the adult’s irrelevant actions in the unintentional case simply because they could not remember them.

Fortunately, the results of our attentional control condition argue against this possibility. When children in the control condition were asked to reproduce the irrelevant actions that the adult performed while on the phone, 81% were able to do so for the Monkey Box and 78% for the Prize Box; both of these percentages are actually greater than the percentage of experimental participants who overimitated in the intentional context. It should be noted that these proportions do include participants who (a) initially said that they could not remember the adult’s irrelevant actions but then succeeded when the experimenter encouraged them to try, and (b) who initially reproduced the adult’s relevant actions but were also able to demonstrate the irrelevant actions when the experimenter clarified his instructions. However, even if we adopt a stricter success criterion and count these children as having “failed” the memory test, the essential finding does not change. Even by the most stringent standard—immediate recall of the irrelevant actions without need for clarified instructions—67% of children remembered the unintentional irrelevant actions on the Monkey Box, and 64% on the Prize Box. Neither of these proportions differs significantly from the proportion of experimental participants who overimitated in the intentional case (Binomial tests, \( p = ns \) for both objects). Overall then, children’s memory for the adult’s irrelevant actions was sufficient for overimitation in the unintentional context to have met or exceeded the level observed in the intentional case. The fact that children did not copy the adult’s unintentional irrelevant actions is therefore not simply a
byproduct of wandering attention—it is a legitimate reflection of boundary conditions on overimitation.

4. Inter-rater reliability statistics for Experiments 1-3

**ESM Table IV**: Summary of Inter-rater Reliability Statistics

<table>
<thead>
<tr>
<th>Puzzle Object</th>
<th>Experiment Code Type</th>
<th>N</th>
<th>Percent Agreement</th>
<th>Cohen’s Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monkey Box</td>
<td>Baseline</td>
<td>8</td>
<td>88%</td>
<td>0.750*</td>
</tr>
<tr>
<td></td>
<td>Rel. Action</td>
<td>8</td>
<td>100%</td>
<td>NA(^a)</td>
</tr>
<tr>
<td></td>
<td>Irrel. Action</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exp. 1</td>
<td>Rel. Action</td>
<td>87</td>
<td>97%</td>
<td>0.928***</td>
</tr>
<tr>
<td></td>
<td>Irrel. Action</td>
<td>87</td>
<td>95%</td>
<td>0.926***</td>
</tr>
<tr>
<td>Exp. 3</td>
<td>Overimitatio</td>
<td>27</td>
<td>93%</td>
<td>0.847***</td>
</tr>
</tbody>
</table>

| Prize Box     | Baseline             | 8 | 75%               | 0.636**       |
|               | Rel. Action          | 8 | 100%              | NA\(^a\)      |
|               | Irrel. Action        | 8 |                   |               |
| Exp. 2        | Rel. Action          | 24| 96%               | 0.917***      |
|               | Irrel. Action        | 24| 92%               | 0.883***      |
| Exp. 3        | Overimitatio         | 25| 96%               | 0.918***      |

\(^a\)Cohen’s Kappa statistic could not be meaningfully computed in this case, as both raters assigned the same code to all trials.

***p < 0.001, **p < 0.01, *p < 0.05. All values two-tailed.