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Capuchins (*Cebus apella*) fail to show an asymmetric dominance effect

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Abstract The asymmetric dominance effect (ADE) occurs when the introduction of a partially dominated decoy option increases the choice share of its dominating alternative. The ADE is a violation of regularity and the constant-ratio rule, which are two derivations of the independence of irrelevant alternatives axiom, a core tenant of rational choice. The ADE is one of the most widely reported human choice phenomena, leading researchers to probe its origins by studying a variety of non-human species. We examined the ADE in brown capuchin monkeys (*Cebus apella*), a species that displays many other decision biases. In Experiment 1, we used a touchscreen method to elicit choice-based preferences for food rewards in asymmetrically dominated choice sets. In Experiments 2 and 3, we distinguished between different types of judgments and used a free selection task to elicit consumption-based preferences for juice rewards. However, we found no evidence for the ADE through violations of regularity or the constant-ratio rule, despite the similarity of our stimuli to other human and non-human experiments. While these results appear to conflict with existing literature on the ADE in non-human species, we point out methodological differences—notably, the distinction between value-based and perception-based stimuli—that have led to a collection of phenomena that are difficult to understand under a unitary theoretical framework. In particular, we highlight key differences between the human and non-human research and provide a series of steps that researchers could take to better understand the ADE.

Keywords Asymmetric dominance effect · Decoy effect · Capuchin monkeys · Choice biases

Introduction

The asymmetric dominance effect (ADE) occurs when the addition of an asymmetrically dominated choice alternative (“decoy”) increases the choice proportion of the dominating alternative (“target”) against a third non-dominated option (“competitor”) in a three-option, two-dimensional choice set (Huber et al. 1982). The systematic preference shifts that constitute the ADE violate the independence of irrelevant alternatives axiom (IIA), which holds that extraneous factors, such as the addition of new options to a choice set, cannot affect preferences (Luce 1959). There are two cases of the IIA axiom: regularity and the constant-ratio rule. Regularity holds that the *absolute* preference for an option should not increase when options are added to the choice set. The constant-ratio rule is a weaker form of regularity that dictates that the *ratio* of preferences between choices (i.e., *relative* preferences) should hold constant as the choice set expands. Importantly, violations of the IIA indicate relative, context-dependent utility valuations based on local choice context instead of the global, fixed valuations required by rational choice theory (Shafir 1994; Shafir et al. 1989; Tversky 1969; Tversky and Simonson 1993).

The discovery that humans show an ADE in two-dimensional, numerical, riskless, and monotonically defined choice sets (e.g., Ariely and Wallsten 1995; Dhar and Glazer 1996; Doyle et al. 1999; Huber et al. 1982; Pettibone and Wedell 2000; Ratneshwar, Shocker, and Stewart 1987; Simonson and Tversky 1992; Simonson 1989; Wedell and Pettibone 1996; Wedell 1991) has long puzzled economists who assume that our choice strategies should

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maximize expected utility. The ADE is also puzzling from an evolutionary perspective—organisms that show context-dependent preferences would likely limit their reproductive fitness by forgoing options that maximize utility (although see Santos and Rosati 2015 for a discussion of how context-dependent preferences can be adaptive in some contexts). Thinking about this evolutionary inconsistency has led researchers to explore whether the ADE and its concomitant violations of rational choice axioms are unique to humans or whether similar biases are present in non-human animals (Bateson et al. 2002, 2003; Hurly and Oseen 1999; Latty and Beekman 2010; Morgan et al. 2012; Parrish et al. 2015; Scarpi 2011; Shafir 1994; Shafir et al. 2002; Waite 2001; but see Schuck-Paim et al. 2004 for divergent results). Comparative cognition studies are useful tools for examining whether the ADE emerges in the absence of human-unique experiences, such as familiarity with markets.

Comparative cognition research on the origins of the ADE has revealed that non-human choices appear, at least in some circumstances, to be as context-dependent as those of humans. Indeed, a number of taxa exhibit the ADE: bees (*Apis mellifera*: Shafir 1994; Shafir et al. 2002), birds (Gray jays, *Perisoreus canadensis*: Shafir et al. 2002; Waite 2001; hummingbirds, *Selasphorus rufus*: Bateson et al. 2002, 2003; Hurly and Oseen 1999; Morgan et al. 2012), cats (*Felis catus*: Scarpi 2011), rhesus macaques (*Macaca mulatta*: Parrish et al. 2015), and unicellular slime molds (*Physarum polycephalum*: Latty and Beekman 2010). For example, Shafir et al. (2002) studied the ADE by creating artificial flowers that varied on two dimensions: the volume of the sucrose reward contained in the flower (i.e., quality) and physical distance to the reward (i.e., effort). Individual honeybees chose between a low-quality, low-effort flower (A) and a high-quality, high-effort option flower (B). In addition, the ADE condition included a third decoy flower that delivered either a lower quantity of sucrose at the same level of effort as option A (the A′ decoy) or the same level of sucrose as option B, but at twice the effort (the B′ decoy). The experimenters were interested in whether the bees' relative choice of A over B would change in the presence of the decoy option. Shafir and colleagues found that while the A′ decoy did not increase preferences for flower A, bees' relative preferences for flower B increased in the presence of the B decoy, suggesting that honeybees may show an ADE similar to that of humans.

The body of work on the ADE in animals suggests that context-dependent preferences may extend broadly across phylogeny. At first glance, these studies might also suggest that the mechanisms underlying the ADE in humans may be shared widely across other species. However, there are two potential reasons for caution in this interpretation. First, the non-human animals exhibiting the ADE tend to be distantly related to humans (e.g., slime molds); these species often lack the cognitive strategies that humans employ when making complex decisions. The fact that these distantly related species show preference shifts that look similar to those observed in human ADE experiments raises the question of what mechanisms are at work. One possibility is that human and non-human species use relatively simple mechanisms in ADE choice contexts. Another, however, is that humans may use different mechanisms to make choices than are used in other taxa. Under this view, the similarity of these ADE patterns alone may not necessarily advance our understanding of the cognitive mechanisms that underlie these effects in humans. Second, it is likely that the choice strategies of phylogenetically distant species evolved to solve a different set of environmental problems than the strategies that evolved in humans. In this way, exploring whether distantly related species share human-like ADEs may not fully shed light on the selection pressures that led to these choice biases in humans. Species more closely related to humans, such as those in the primate order, may better inform the origins of the cognitive mechanisms underlying the ADE.

Parrish et al. (2015) explored the ADE in primates by testing whether decoys influenced perceptual discrimination in rhesus macaques (*Macaca mulatta*). Parrish and colleagues' computer-based experiment presented macaques with two or three rectangles and prompted them to select the largest rectangle. In the baseline condition, experimenters showed macaques a horizontal rectangle and a vertical rectangle that were similar in size, and macaques correctly selected the larger rectangle. The ADE condition introduced a third rectangle that was smaller than the original rectangles and was oriented either vertically or horizontally. Macaques were sometimes more likely to judge the rectangle that matched the orientation of the small rectangle as larger than the oppositely oriented rectangle. These findings suggest that primates' visual perception judgments may be affected by decoys, and raise important questions about the nature of the ADE in primates.

The Parrish et al. (2015) study mirrored Trueblood et al.'s (2013) novel test of the ADE in humans, and several features common to both study designs distinguish them from the existing ADE literature. First, both studies involved stimuli defined solely on a perception-based attribute (i.e., rectangle size), whereas conventional human and non-human ADE experiments have incorporated value-based dimensions such as quantity or quality. Second, these studies used unidimensional stimuli, whereas the traditional ADE definition requires at least two dimensions (see Huber et al. 1982). Third, Parrish et al. and Trueblood et al. used significantly higher trial exposures than traditional ADE studies. While the ADE tends to robustly appear in a variety of one-shot spontaneous choice tasks, Trueblood et al. exposed human participants to 720 judgment trials and Parrish et al. exposed each rhesus macaque to either 2000 or 3000 trials. It is possible that high-volume repeated decisions call upon a different set of heuristics than one-shot decisions. For example, Pocheptsova et al. (2009) found that psychological depletion increases the magnitude of the ADE in humans. In addition, the results of Parrish et al. hint that high trial exposure may amplify the ADE in non-human primates. Due to experimenter error, three macaques were exposed to 2000 judgment trials and four macaques were exposed to 3000 trials. While all four participants with a high trial exposure showed some evidence for an ADE, two of the three low exposure macaques showed no effect despite multiple tests for an ADE. Moreover, a replication attempt of Trueblood et al. using only 40 trials instead of the original 720 found no ADE, despite incorporating a larger number of participants (Frederick et al. 2014). These findings are consistent with the general view that effortful tradeoff analyses give way to less effortful heuristic processing under cognitive depletion (Baumeister et al. 1998).

The novel work of Parrish et al. (2015) and Trueblood et al. (2013) highlights that perception-based stimuli can yield an ADE, but it also underscores the complexity of testing the effect. Indeed, Trueblood et al. noted that their findings of the ADE in a visual judgment task could not be explained by existing theories of the ADE in two-dimensional value-based choice tasks. In addition, no work to date has examined whether primates also show the ADE in the realm of choice tasks that have standardly been used in humans and other taxonomic groups. With this context in mind, we examined whether primates show an ADE in a more typical two-dimensional choice task. Specifically, we presented brown capuchin monkeys (*Cebus apella*) with a new test of the ADE that built on Parrish et al. by incorporating both value-based and perception-based choice dimensions.

Capuchins are a widely studied New World monkey species that have long served as a model for the evolution of human cognition (see review in Fragaszy et al. 2004). In particular, capuchins display a variety of human-like decision biases, such as reference dependence and loss aversion (Chen et al. 2006), the endowment effect (Lakshminarayanan et al. 2008), inequity aversion (Brosnan and de Waal 2003), cognitive dissonance (Egan et al. 2007, 2010), and framing effects (Lakshminarayanan et al. 2011). For this reason, we felt that capuchins may be one of the most important primate species in which to explore the ADE.

We initially predicted that capuchin monkeys would show evidence of the ADE by shifting their preferences toward the dominant option (i.e., the target) when faced with ADE choice sets. In particular, we predicted that the introduction of an asymmetrically dominated choice alternative (i.e., the decoy) into a binary choice set would result in violations of regularity and the constant-ratio rule.

We tested this hypothesis in three experiments using choice and consumption tasks. Experiment 1 used a touchscreen method to elicit choices for food rewards in asymmetrically dominated choice sets defined by the value-based dimension of reward quantity and the perception-based dimension of color.

In Experiments 2 and 3, we further adapted the human ADE experimental method to a free selection task and modified our stimuli to investigate a potential confound that might occur with perception-based attributes. The contamination literature suggests that animals generalize the negative properties of one element in a category to all objects in that category, even if the categories are superficial (Rozin et al. 2000). For example, humans are reluctant to eat a piece of fudge candy that resembles feces (Rozin et al. 1986). The negative attributes of feces are applied to any object that superficially falls into a feces-like category, despite our knowledge that the fudge is safe to consume. In this way, it is possible that unattractive decoy options might contaminate the entire category on which it is differentiated. In contrast, ADE requires dominance detection, which necessitates careful comparisons between the attributes of each option (Ariely and Wallsten 1995). Thinking of options as elements of categories instead of attending to the relationship between their specific attributes would likely inhibit dominance detection and diminish the ADE. Thus, in Experiments 2 and 3, we distinguished between *kind* judgments induced by choice dimensions known to prompt primates to generalize on categories and *comparison* judgments induced by dimensions known to elicit comparisons thought to drive the ADE in humans.

Experiment 1

Methods

Participants

We tested one young adult female (HB, 3 years of age), three adult female (HR, 6 years of age; MP, 4 years of age; and HG, 4 years of age), and three adult male (FL, 15 years of age; NN, 16 years of age; and AH, 5 years of age) capuchin monkeys. Our participants lived together in a large social enclosure with a naturalistic environment and previously participated in other choice studies (Chen et al. 2006; Lakshminarayanan et al. 2008; 2011; Santos and Chen 2009).

Apparatus

Experiment 1 used a touchscreen to present and record participants' choices. Capuchins were presented with one or more options on the touchscreen (43.2 cm diagonal, 1024 × 768 resolution), which was mounted on a cart placed at the edge of the participants' mesh enclosure (300 cm w × 300 cm h × 100 cm d) and accessible through a grid of small rectangular openings in the wall of their enclosure. Beneath the touchscreen sat a three-door delivery apparatus (36.8 cm w × 6.1 cm h × 8.9 cm d) with flaps on each door to conceal a square-shaped spoon (7.6 cm w × 5.1 cm h × 8.9 cm d) positioned inside each door. The experimenter used these spoons to deliver rewards to participants (Fig. 1). During all sessions, color photographs of each option were displayed on the touchscreen directly above the corresponding delivery spoon. A maximum of three options could be presented on the screen simultaneously. Participants made their choices by pressing the screen in the location of the desired option. A selection was registered when the participant touched the screen in a success region, which was a square area on the screen (7.6 cm w × 7.6 cm h) with a light gray border (38.8% black) that included the at-scale photograph in the center. Following a selection, a chime played for 2 s to indicate that a choice had been made successfully and the participant's choice remained on the screen for 10 s. For trials in which participants made choices between two or more options, the options that were not chosen were removed from the screen. During this time, the experimenter surreptitiously delivered the corresponding reward from behind the touchscreen via the spoon apparatus. Throughout each trial, the experimenter stood behind the touchscreen and delivery apparatus cart and watched a separate computer screen that mirrored the participant's touchscreen. This allowed the experimenter to know which food reward to deliver while remaining out of the participant's view.

We used two low-quality rewards (lettuce and celery) and two high-quality rewards (Kix® cereal and grapes) in the training trials. Following other ADE studies, we used a set of rewards that varied on the value-based dimension of quantity and the perception-based dimension of color during the main test sessions. Option A was a round green pepper slice (1.9 cm w × 0.4 cm d), option B was a yellow pepper slice of equal size, and decoy options A′ and B′ were identical to the full options but cut in half to form smaller semicircles of the non-decoy options. Note that while some of our capuchin participants may have had dichromatic vision, the color of rewards in all experiments differed in both hue and brightness, which provided sufficient cues for differentiation (Jacobs 1999).

Procedure

Participants engaged in four sets of *training phases* comprising at least 100 trials over at least eight sessions in order to learn the touchscreen method. All training phases involved choices in which one option clearly dominated, and participants repeated each training phase until they selected the dominant option significantly above chance for two consecutive days. The goal of the training phases was to teach participants that pressing the screen led to food rewards. In the first training phase, participants made a set of repeated forced choices in which they received a food reward (a single Kix® cereal) for selecting the

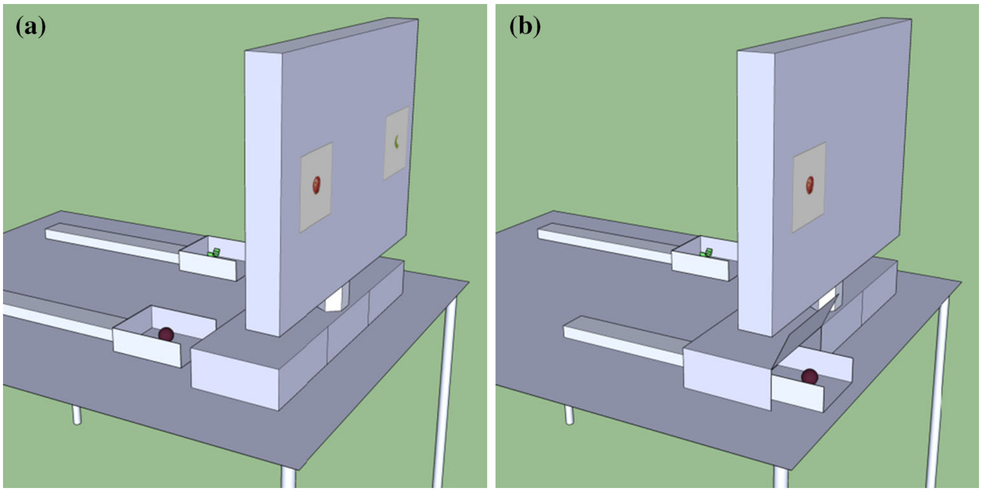

Fig. 1 Graphical representation of the touchscreen and reward delivery apparatus used in Experiment 1. During a trial (**a**), the participant was offered a choice between a grape and a piece of celery. Subsequent to a selection (**b**), the apparatus played a chime, the unchosen option was removed from the screen, and the selected food was provided to the participant through the corresponding delivery box while the image remained on the screen for 10 s

corresponding image of cereal on the touchscreen. Success in the first testing phase was defined as selecting the presented option for twenty trials over two consecutive days. The goal of the second training phase was to ensure that participants recognized and chose the dominant options from multiple alternatives. The second training period allowed participants to make choices between a high-quality (a single grape) and a low-quality (a 1-cm slice of celery) option. The positions of the grape and celery were randomized across the three delivery boxes. Success was defined as selecting the high-quality option in at least 15 of 20 trials ($p < 0.05$, binomial test vs. expectation of 0.5) for two consecutive days. The goal of the third training phase was to ensure that participants could comprehend the task and choose the dominant option even when three choices were offered. During the third training phase, participants made repeated choices between two identical low-quality options (celery) and one high-quality option (grape). The positions of the grape and celery pieces were randomized across the three delivery boxes. Success was defined as selecting the high-quality reward option in at least 15 of 20 trials ($p < 0.05$) for two consecutive days. Despite the fact that there were more pieces of celery on the screen, participants correctly understood that the quantity of food rewards in the box they selected corresponded to the quantity of food they would receive. The goal of the fourth training phase was to ensure that participants could generalize the method and detect dominance even with novel stimuli. We presented participants with another version of the second training phase but used a different combination of food rewards—a single piece of Kix® cereal for the high-quality reward and a piece of lettuce for the low-quality reward.

After completing all four training phases, participants engaged in several *familiarization trials* to learn about the stimuli that would appear in the main experiment. Participants made a set of ten single-option touchscreen selections in which either pepper A or B was displayed on the touchscreen at a randomized location above the delivery boxes. The familiarization sessions were repeated for 2 days. After a participant selected the image of pepper A or B on the touchscreen, the same chime played and the experimenter delivered the participant's selection. Based on participants' previous experience with green and yellow peppers, we assumed they would be indifferent between options A and B, and that the single-option familiarization sessions would allow participants to experience the rewards prior to the main trials.

The goal of the main experiment was to assess participants' choices of the food rewards in both non-dominated and asymmetrically dominated choice sets. Participants were randomly assigned to one of four groups that completely counterbalanced the choice set sequencing.

Each testing session was comprised of four or six *choice set-specific familiarization trials* immediately followed by ten preference trials. The familiarization trials exposed participants to the specific food options that would be offered in the preference trials. Each option was displayed twice in random order at a randomized delivery location on the touchscreen, and only one option was presented in each trial. As in earlier training and familiarization trials, participants selected the option on the screen and received the corresponding food via the delivery spoon underneath the selected image.

The *preference trials*, which immediately followed the familiarization trials, examined whether the presence of decoy options affected monkeys' choices. Participants were presented with a choice between two options defined by color and quantity as in the baseline trials (choice set AB) or a choice between three options that included a decoy for either the A pepper (choice set ABA′) or B pepper (choice set ABB′). The inclusion of the decoy created a choice set with asymmetric dominance on two dimensions, as the smaller pepper was a dominated alternative for the larger pepper of the same color. In this way, participants could trade off their preferences for color against their preferences for quantity. The location of the options was randomized across the three delivery locations. An experimenter delivered the participant's food option beneath the corresponding image after each selection. Each participant made ten selections per session and completed one session of ten choices per day for 2 days in each condition before advancing to the next condition.

Results

Participants successfully completed the training sessions.[1] All seven monkeys completed the first training phase (two sessions total), and the average sessions to complete training phases two, three, and four were 7.83 sessions, 2.16 sessions, and 3.00 sessions. All participants then moved to the main experiment. Overall, decoy choices represented 16.79% of all choices in the ABA′ and ABB′ preference trials. Decoy selection was significantly less than chance (proportion of A′ and B′ choices, $M = 16.79\%$, binomial test, $p < 0.001$), which indicated that participants could likely detect the dominance relationships and actively avoid decoys. However, the distribution of decoy selections was inconsistent across participants; one participant's choices (HB) constituted 31.91% of all decoy selections, while another participant (NN) never selected a decoy. However, our

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[1] Due to experimenter error, participant MP did not complete training session 4 but participated in the main experiment. Her performance did not differ from other participants.

decoy selection rate is consistent with other animal studies (e.g., Bateson et al. 2002, 2003; Shafir et al. 2002).

Participants displayed a significant preference for option B (proportion of A choices, $M = 34.29\%$, binomial test, $p < 0.001$) in the baseline AB choice set. Individual binomial tests on each participant revealed that only three participants had a significant preference for option B (for these three participants, binomial test vs. expectation of 0.5, $p < 0.05$), and none displayed a preference for option A. While we did not expect significant baseline preferences, it is irrelevant to our analysis as the ADE occurs when preferences shift between binary (AB) and ternary (ABA′ and ABB′) choice sets. Indifference between options A and B is not required for ADE.

Following Bateson et al. (2002, 2003), Schuck-Paim et al. (2004), and Shafir et al. (2002), we looked for evidence of the ADE by calculating preference shifts in two ways. First, we examined the change in absolute preferences to identify any violations of regularity. Second, we examined the change in relative preferences to identify any violations of the constant-ratio rule. The absolute proportion for each option was calculated as the number of selections for that option divided by the total number of choices in each choice set, including decoys (Fig. 2). We hypothesized a higher absolute proportion of the target choice in the ternary trials compared to the binary baseline trials, which would constitute a violation of regularity. The mean absolute proportion of A choices was significantly different between the baseline AB ($M = 34.29\%$, $SD = 15.39\%$) and ABA′ ($M = 18.57\%$, $SD = 15.47\%$), but in the opposite direction than predicted (paired t test: $t(6) = 3.45$, $p = 0.01$, 95% CI [0.05, 0.27], Cohen's $d = 1.30$). The mean absolute proportion of B choices was not significantly different between AB ($M = 65.71\%$, $SD = 15.39\%$) and ABB′ ($M = 49.29\%$, $SD = 16.18\%$, paired t test: $t(6) = 1.90$, $p = 0.11$, 95% CI [−0.05, 0.38], Cohen's $d = 0.72$). While it is possible that sweeter yellow peppers may have made the decoy in ABB' unexpectedly attractive, participants consistently found the decoys less attractive than non-decoy options.

We then looked for violations of regularity at the participant level. Upon visual examination of the contingency table counts, we found two candidates for the violation of regularity in ABB′ (i.e., the count of choices for option B was higher in ABB′ than the AB baseline). Subsequent Fisher's exact tests with a Bonferroni correction ($\alpha = 0.05/7$ participants) comparing counts for options A and B in AB and ABB′ revealed no significant differences. Thus, we found no evidence for the violation of regularity at the aggregate or individual levels.

Table 1 displays each monkey's relative preferences, which are calculated as the number of choices for option A divided by the total number of choices for options A and B. Looking for changes in relative preferences is a less stringent test for the ADE. We hypothesized a higher relative proportion of the target option in the ternary trials compared to the binary trials, which would constitute a violation of the constant-ratio rule. A repeated-measures ANOVA found no significant effect of choice set on relative preferences for option A [repeated-measures ANOVA by participant, $F(2,12) = 1.38$, $p = 0.29$, $\eta_p^2 = 0.11$], so the constant-ratio rule was not violated.

Discussion

Although all participants completed the training and appeared to understand our touchscreen choice task, they failed to show any ADE. The presence of a decoy option did not affect monkeys' absolute or relative preferences for option A over B (i.e., there were no violations of regularity or the constant-ratio rule). Based on the findings in other animals and the similarity of our stimuli to many human experiments, the lack of preference shifts induced by the asymmetrically dominating choice sets was unexpected. Thus, we conducted Experiment 2 to explore whether we would observe similar results using a different method.

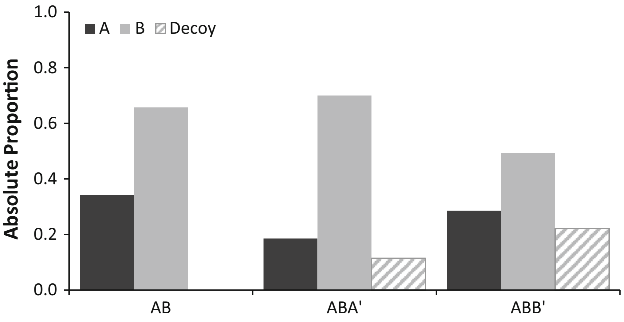

Fig. 2 Absolute preferences by choice set in Experiment 1

Table 1 Relative choice proportions of option A by participant and choice set in Experiment 1

Participant	AB (%)	ABA′ (%)	ABB′ (%)
AH	45.00	10.00	23.53
FL	20.00	21.05	12.50
HB	20.00	13.33	40.00
HG	50.00	38.46	62.50
HR	55.00	58.82	21.43
MP	30.00	10.00	31.25
NN	20.00	5.00	60.00
Average	34.29	22.38	35.89

Experiment 2 also investigated whether a feature of our design may have limited the extent to which capuchins exhibited the ADE. Although tests of the ADE in humans generally involve pairwise comparisons between alternatives, it is conceivable that our design caused participants to attend to the wrong features of the decision task. Specifically, instead of making comparisons between related options, it is possible that our capuchin participants used the perception-based choice dimension to make inferences about the average attractiveness of each kind of option. To see how this sort of strategy could affect our results, imagine that participants facing the ABA′ choice set viewed the full size green pepper (A) and half size green pepper (A′) options as elements of a set or category of green peppers. If participants conceptualized all green peppers as a *kind* of option, then the average result of choosing this kind would be a reward that was worse than the yellow pepper, which was always full size in that condition. If participants perceived our task in this way (as may have occurred in an experiment by Bateson et al. 2002, who found an ADE in the unintended direction)—i.e., if they thought of the decoy and asymmetrically dominating option as a single "kind" of choice—then the entire category of green or yellow pepper might have been contaminated by the addition of the decoy (Rozin et al. 2000). Indeed, previous studies have demonstrated that other primates attend to color more than other attributes (such as shape) for objects in the food domain, and use color as the basis to generalize on categories when making important decisions, such as evaluating the safety of a novel food object (Santos et al. 2001; Santos et al. 2002; Shutts et al. 2009). As a result, presenting capuchins with options differentiated on a dimension known to prompt a *category* or *kind judgment* may have prevented them from conducting comparisons and detecting the dominance relationship, as they may have collapsed all options of the same color into one category. By contrast, presenting options using dimensions known to elicit a *comparison between alternatives* should trigger comparative processes that would likely enable dominance detection and drive the ADE.

Experiment 2 aimed to test this possibility by directly comparing the magnitude of monkeys' ADE (or lack thereof) for options defined on a dimension known to elicit *kind* judgments (such as a color contrast) versus a dimension known to elicit *comparison* judgments (such as size or shape judgments). Specifically, we predicted an ADE when we contrasted different choice options along a dimension known to elicit comparisons—the dimension of shape (Santos et al. 2001). In contrast, we predicted no ADE when we presented different options along a dimension known to elicit kind judgments—the dimension of color. In addition, we wanted to use novel stimuli to ensure that participants' prior food experience would not bias their preferences. It is possible that participants in Experiment 1 may have used color as a proxy for sugar concentration (i.e., quality) from prior exposure to peppers. While this may have enhanced the likelihood of dominance detection through more salient choice differentiation, Experiment 2 used novel stimuli that allowed us to manipulate choice attributes free of any learned associations. As a result, we also replaced the value-based quantity dimension of pepper size with an explicit value-based quality dimension in the form of sugar concentration.

Experiment 2

Methods

Apparatus

Experiment 2 used a new choice method. Instead of presenting choices on a touchscreen, we allowed participants to select options by physically choosing which bottle of liquid to drink. The interchangeable bottle delivery apparatus consisted of three PVC-tube rails affixed to the top of a cart (Fig. 3). A short PVC tube with a fitting to receive juice bottles sat on each rail. A single rod linked all three connectors to allow the entire apparatus to slide forward and backward as one unit. Eight 12-oz water bottles constructed of clear glass and stainless steel were affixed to PVC tubes that fit into the fittings. During a session, the experimenter would select the relevant juice bottles, place them on the delivery mechanism in the left, center, or right position, and slide the options toward the participant. The cart was placed at the edge of the enclosure with a panel that allowed the participant to reach the juice bottle spouts. Two elastic cords held the cart apparatus to the enclosure. This interchangeable system allowed the experimenters to offer a maximum of three bottles to the participant.

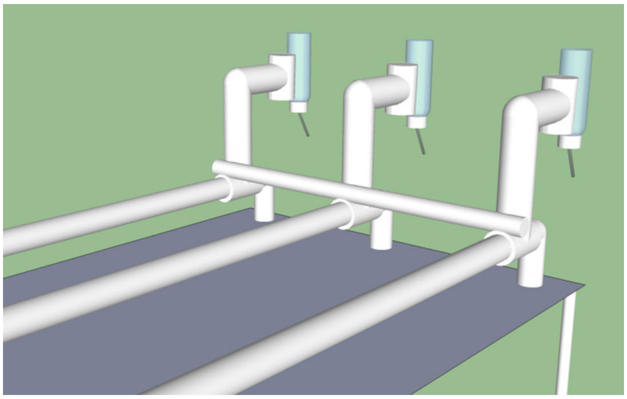

Fig. 3 Graphical representation of the apparatus used in Experiments 2 and 3 with three delivery bottles attached

Experiment 2 explored whether participants would be more likely to show the ADE when options were contrasted on a perception-based dimension known to elicit comparisons (shape) versus one known to elicit kind judgments (color), and added a new value-based dimension of quality (sugar concentration). We therefore tested all participants on both a *comparison* and a *kind* condition. All conditions involved choices between different flavors of Kool-Aid® brand drink that varied on two dimensions, one of which was sugar concentration. In the kind condition, options A and B were a lemon Kool-Aid® mixture differentiated by color (A = yellow, B = blue) as well. Option A was dyed with two drops of edible yellow food coloring, and option B was dyed with three drops of blue food coloring; the two liquids therefore tasted the same and had an identical caloric benefit but were different colors. In the comparison condition, options A and B were a strawberry Kool-Aid® mixture differentiated not by color (all liquid was red), but by a laminated shape (10.2 cm h × 5.1 cm w) affixed to the delivery bottle. The shape was salient and visible to participants. Option A featured an S-shape, and option B featured an O-shape. While this dimension might be less relevant to the value of the options, it is valuable as a visual attribute to differentiate among options. In both the kind and comparison conditions, the decoy option was a less sweet version of the same liquid. In all cases, the non-decoy options contained 113.4 g of sugar for every 1.9 L of water, and the decoy options were half as concentrated at 56.7 g of sugar. The addition of this third weaker decoy option that was similar to but worse than one of the original options created the asymmetric dominance relationship in the ternary choice sets. In the comparison condition, participants traded off shape with sugar concentration, and in the kind condition, participants traded off color with sugar concentration. Importantly, in keeping with traditional ADE studies, the value-based attribute of reward quality was the dimension of dominance. It is worth noting that observed preferences between colors and shapes are irrelevant to the determination of an ADE. The relevant consideration is whether the presence of a decoy option differentiated by color or quality causes participants to shift their preferences in a systematic manner.

Procedure

All participants completed both a kind and comparison condition in random order. Each condition included one session for each choice set (AB, ABA′, and ABB′), which resulted in a total of six sessions per participant. Participants maintained the same counterbalanced groupings from Experiment 1.

As in Experiment 1, each testing session consisted of familiarization trials specific to the choice set and preference trials. Participants never completed more than one testing session per day. The goal of the familiarization trials was to expose the participants to the options that would be offered in the subsequent preference trials. During the familiarization trials, the experimenter placed each liquid option that would appear in the preference trials on the delivery system. The experimenter then slid each bottle forward individually for 10 s. During this time, the participant could sample the option by sticking out their tongue and drinking the liquid. The delivery position and sequential order of each option were randomized. After the familiarization trials were completed, participants entered the preference trials in which all options were offered to the participant for consumption for 2.5 min. After sliding the choices to the participant, the experimenter stayed out of view for the remainder of the trial, which was recorded with a video camera. The dependent variable was the percentage of total drinking time that option A was consumed. A trained individual blind to the hypotheses of this study coded the drinking times for each bottle by position, which were subsequently matched with each trial to compute drinking times for each option.

Results

We first explored the amount of time participants consumed the decoy option as a way to validate our choice task. Overall, participants consumed liquid from the decoy choice only 2.94% of drinking time during the preference testing trials in ABA′ and ABB′, suggesting that they recognized this option was inferior and thus understood the task. Participants did not display significant preferences in the baseline AB comparison condition (proportion of A drinking time vs. expectation of 0.5, $M = 34.17\%$, t test: $t(6) = -1.77$, $p = 0.13$, 95% CI [−0.38,0.06], Cohen's $d = 0.67$) or in the kind condition (proportion of A drinking time vs. expectation of 0.5, $M = 32.70\%$, t test: $t(6) = -1.86$, $p = 0.11$, 95% CI [−0.40,0.05], Cohen's $d = 0.70$).

While the design of the familiarization trials in Experiment 1 standardized energetic consumption across participants by delivering identical food rewards, the design of Experiment 2 did not afford such control. In Experiment 2, participants had 10 s to freely consume each option during the familiarization period before the preference testing trials. As a result, it is possible that participants may have consumed different quantities of sugar during the familiarization trials. Any heterogeneity could theoretically cause energetic state-dependent preferences during the preference testing trials. To evaluate whether participants may have entered the preference trials with a different energetic state, we analyzed consumption variance in the familiarization trials. To account for the 50% lower sugar concentration in the decoy options, we normalized the juice consumption time to a fully concentrated equivalent. A two-way repeated-measures ANOVA on the familiarization trials found no significant main effect of ternary choice set (ABA′ vs. ABB′) on normalized consumption time [two-way repeated-measures ANOVA by participant, $F(1,6) = 2.30$, $p = 0.18$, $\eta_p^2 = 0.03$], no significant main effect of condition [$F(1,6) = 1.72$, $p = 0.24$, $\eta_p^2 = 0.10$], nor any interaction between choice set and condition ($p = 0.99$). We then compared total unadjusted consumption time in the preference trials by condition and by participant (Table 2) and did not find a significant difference (paired *t test*: $t(6) = 0.05$, $p = 0.96$, 95% CI [−44.60, 46.54], Cohen's $d = 0.02$). Thus, the familiarization trials did not induce differential energetic states prior to the preference testing trials, and overall consumption did not vary as a result.

Aggregate absolute preferences by condition are displayed in Fig. 4. We hypothesized violations of regularity and the constant-ratio rule in the comparison condition, but no violations in the kind condition. Contrary to our hypothesis, the mean absolute proportion of A drinking time in the comparison condition (Fig. 4) was not significantly different between the baseline AB ($M = 34.17\%$, $SD = 23.67\%$) and ABA′ ($M = 49.82\%$, $SD = 30.16\%$, paired *t* test: $t(6) = -1.02$, $p = 0.35$, 95% CI [−0.53, 0.22], Cohen's $d = 0.39$). Nor was the mean absolute proportion of B drinking time significantly different between the baseline AB ($M = 65.84\%$, $SD = 23.67\%$) and ABB' ($M = 42.10\%$, $SD = 27.24\%$, paired *t* test: $t(6) = 1.33$, $p = 0.23$, 95% CI [−0.20, 0.67], Cohen's $d = 0.50$). We also found no differences in the kind condition between the absolute proportion of A drinking time in AB ($M = 32.70\%$, $SD = 24.57\%$) and ABA′ ($M = 48.92\%$, $SD = 37.70\%$; paired *t* test: $t(6) = -0.77$, $p = 0.47$, 95% CI [−0.68, 0.35], Cohen's $d = 0.29$). The mean absolute proportion of B drinking time was not significantly different between the baseline AB ($M = 67.30\%$, $SD = 24.57\%$) and ABB' ($M = 57.45\%$, $SD = 23.26\%$, paired *t* test: $t(6) = 0.73$, $p = 0.50$, 95% CI [−0.23, 0.43], Cohen's $d = 0.27$).

Table 2 Total consumption time in seconds (unadjusted) by participant and condition during preference trials in Experiment 2

Participant	Comparison	Kind
AH	419.01	350.97
FL	281.59	275.47
HB	255.75	295.87
HG	412.14	427.03
HR	326.89	322.02
MP	253.76	325.23
NN	390.29	336.04

A visual examination of the individual data in the comparison condition yielded five candidates for the violation of regularity in ABA′ and three in ABB′. Subsequent paired *t* tests that pooled all participants with potential violations found no significant differences. We repeated this analysis in the kind condition, in which we found four candidates for the violation of regularity in ABA′ and two in ABB′, but none were significant. Thus, we did not find any violations of regularity.

Relative preference data are displayed in Table 3 and were calculated in the same manner as Experiment 1. Repeated-measures ANOVAs found no significant effect of condition on relative preferences for option A in the comparison trials [repeated-measures ANOVA by participant, $F(2,12) = 1.11$, $p = 0.36$, $\eta_p^2 = 0.12$] and no significant effect in the kind trials [$F(2,12) = 0.45$, $p = 0.65$, $\eta_p^2 = 0.06$]. Thus, the constant-ratio rule was not violated in either condition.

Discussion

The goal of Experiment 2 was to see whether the lack of an ADE observed in Experiment 1 stemmed from a potential problem in presenting choice options along a dimension

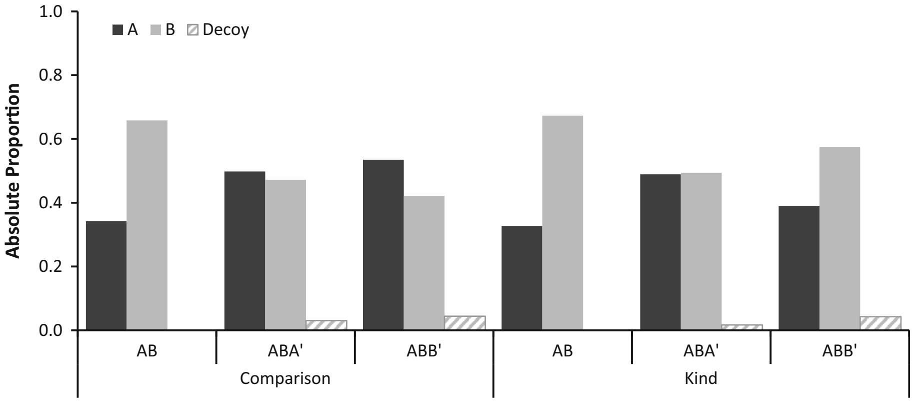

Fig. 4 Absolute preferences by condition and choice set in Experiment 2

Table 3 Relative choice proportions of option A by participant, condition, and choice set in Experiment 2

Participant	Comparison			Kind		
	AB (%)	ABA′ (%)	ABB′ (%)	AB (%)	ABA′ (%)	ABB (%)
AH	17.27	47.82	96.37	76.87	8.52	22.55
FL	9.38	100.00	85.99	2.73	98.40	9.99
HB	44.26	70.03	63.30	42.42	67.63	42.98
HG	5.02	8.37	55.33	8.31	33.84	76.42
HR	63.27	31.11	23.73	36.16	9.99	33.25
MP	59.01	28.49	36.75	36.96	33.77	63.29
NN	40.95	76.68	33.52	25.44	97.39	34.11
Average	34.17	51.78	56.43	32.70	49.93	40.37

known to elicit kind judgments rather than perceptual comparisons. Experiment 2 therefore tested the hypothesis that capuchins would be more likely to show an ADE and associated violations of regularity and the constant-ratio rule when discriminating options along a perception-based dimension known to elicit comparisons (shape) than one known to elicit kind judgments (color). In addition, we sought to avoid the potential confound from Experiment 1 that color could have served as a proxy for sugar concentration. In keeping with other human and non-human animal studies, we added a value-based quality dimension in the form of sugar concentration.

In contrast to our hypothesis, capuchins did not exhibit an ADE in the kind or comparison conditions, and we found no violations of regularity or the constant-ratio rule. We also found no variation in the juice consumption patterns in the familiarization trials and no difference in drinking time by condition, which eliminated any potential concern for a state-dependent preference confound. Importantly, participants successfully understood the nature of the consumption task; capuchins avoided decoys in over 97% of consumption time. Even though participants attended to the dynamics of the task, they still failed to show an ADE.

Although we did not expect an ADE in the kind condition, we were surprised to find no effect in the comparison condition. The failure to obtain an ADE matched what we observed in Experiment 1, but we wanted to further rule out any additional potential confounds. Experiment 3 improved on a feature of how our options were presented. While we randomized all choice orders in all experiments, the fact that participants only completed one session per choice set in each condition prevented us from completely counterbalancing all positions in the baseline AB trials. Experiment 3 eliminated any potential side bias by removing the cost of switching between bottles during the familiarization and preference elicitation trials. Experiment 3 also attempted to eliminate any potential concerns about order effects by symmetrically counterbalancing the baseline trials in the comparison condition so that all participants were exposed to both AB and BA.

Experiment 3

Methods

Procedure

The procedure in Experiment 3 followed Experiment 2 with four improvements. First, participants were tested in a smaller, external cubic enclosure (83 cm w × 83 cm h × 83 cm d) attached to the main enclosure area. The use of the external enclosure in Experiment 3 meant that participants directly faced the juice bottles in the center of the enclosure. Second, participants were removed from the external enclosure and were unable to access or view the juice bottles for approximately 10 s between the familiarization period and preference trials; this feature prevented participants from sticking with the same bottle they had chosen on the final familiarization trial. Third, we added a second AB session to the comparison baseline trials to counterbalance any potential side bias within participants. As a result, participants completed a total of seven sessions in Experiment 3. Fourth, we replaced the drinking time dependent variable with the actual liquid quantity consumed. While drinking time was an appropriate dependent variable, we wanted to evaluate a more direct measure of consumption. Given the layout of our facility, re weighing each bottle after the familiarization trials and before the main trials would have added a meaningful time delay. We were concerned that such a delay would have diminished the impact of the familiarization trials, which were designed to expose participants to the options they would immediately select in the main trial. As a result, we calculated quantity consumed by weighing the bottles on a digital scale before the familiarization trials and after the main preference trials for each session.

Results

We first tested whether the ordering of AB and BA had a significant effect on baseline preferences. A paired *t* test revealed no significant difference in the proportion of A consumption in AB ($M = 53.85\%$, SD $= 27.12\%$) and BA ($M = 52.31\%$, SD $= 23.59\%$, paired *t* test: $t(6) = 0.09$, $p = 0.93$, 95% CI [−0.42, 0.45], Cohen's $d = 0.03$). This pattern reassured us that a side bias was unlikely in Experiment 2 as well. We averaged the counterbalanced baseline trials for the comparison condition in the remainder of the analysis. Consistent with Experiments 1 and 2, participants avoided the decoys, which constituted only 11.41% of total juice consumption.

Participants did not display significant preference in the baseline AB comparison condition (proportion of A consumption vs. expectation of 0.5, $M = 52.97\%$, *t* test: $t(6) = 0.75$, $p = 0.48$, 95% CI [−0.07,0.13], Cohen's $d = 0.28$) or in the kind condition (proportion of A consumption vs. expectation of 0.5, $M = 57.14\%$, *t* test: $t(6) = 1.58$, $p = 0.17$, 95% CI [−0.04,0.18], Cohen's $d = 0.60$). Table 4 displays the total liquid consumption weight. As in Experiment 2, there were no differences in overall consumption between conditions (paired *t test*: $t(6) = -1.20$, $p = 0.27$, 95% CI [−106.40, 36.26], Cohen's $d = 0.46$).

Aggregate absolute preferences by condition are displayed in Fig. 5. As in Experiment 2, we hypothesized violations of regularity and the constant-ratio rule in the comparison condition, but no violations in the kind condition. Contrary to our hypothesis, the mean absolute proportion of A consumption in the comparison condition was not significantly different between the baseline AB ($M = 52.97\%$, SD $= 10.49\%$) and ABA′ ($M = 43.24\%$, SD $= 24.24\%$, paired *t test*: $t(6) = 1.19$, $p = 0.28$, 95% CI [−0.10, 0.30], Cohen's $d = 0.45$), nor was the mean absolute proportion of B consumption significantly different between the baseline AB ($M = 47.03\%$, SD $= 10.49\%$) and ABB′ ($M = 40.09\%$, SD $= 23.41\%$, paired *t test*: $t(6) = 0.91$, $p = 0.40$, 95% CI [−0.12, 0.26], Cohen's $d = 0.34$). We also found no differences in the kind condition between the absolute proportion of A consumption in AB ($M = 57.14\%$, SD $= 12.00\%$) and ABA′ ($M = 51.71\%$, SD $= 24.95\%$; paired *t test*: $t(6) = 0.89$, $p = 0.41$, 95% CI [−0.10, 0.20], Cohen's $d = 0.34$). The mean absolute proportion of B consumption was not significantly different between the baseline AB ($M = 42.86\%$, SD $= 12.00\%$) and ABB' ($M = 44.56\%$, SD $= 22.25\%$; paired *t test*: $t(6) = -0.16$, $p = 0.88$, 95% CI [−0.28, 0.25], Cohen's $d = 0.06$).

Table 4 Total consumption in grams by participant and condition in Experiment 3

Participant	Comparison	Kind
AH	134.00	133.00
FL	204.00	317.00
HB	144.00	202.00
HG	164.00	200.00
HR	230.00	193.00
MP	246.00	178.00
NN	290.00	434.50

After a visual examination of the individual data in the comparison condition, we found two candidates for the violation of regularity in ABA′, but subsequent paired *t* tests that pooled all participants with potential violations found no significant differences. We repeated this analysis in the kind condition, in which we found two candidates for the violation of regularity in ABA′ and three in ABB′, but none were significant. Thus, we did not find any violations of regularity at the aggregate or individual levels.

Relative preference data are displayed in Table 5. Two repeated-measures ANOVAs found no significant effect of choice set on relative preferences for option A in the comparison condition [repeated-measures ANOVA by participant, $F(2,12) = 0.04$, $p = 0.96$, $\eta_p^2 = 0.00$] and no significant effect in the kind condition [$F(2,12) = 0.44$, $p = 0.66$, $\eta_p^2 = 0.05$]. These *de minimis* effect sizes alleviate any potential concerns that our failure to reject the null hypothesis could have been due to insufficient power (see Loftus 1996).

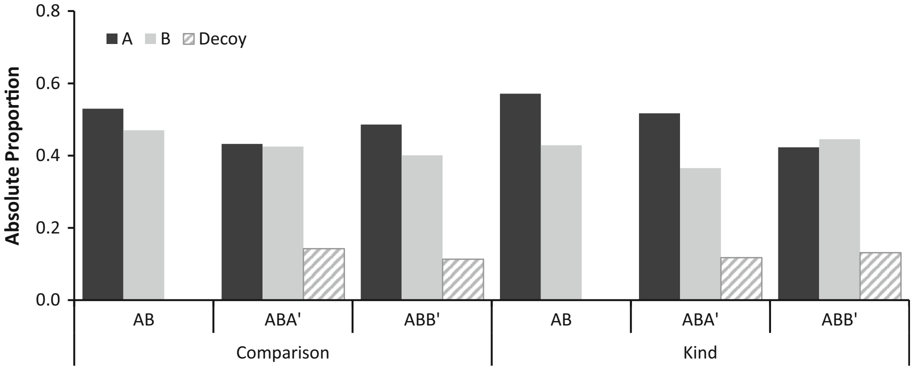

Fig. 5 Absolute preferences by condition and choice set in Experiment 3

Table 5 Relative choice proportions of option A by participant, condition, and choice set in Experiment 3

Participant	Comparison			Kind		
	AB (%)	ABA′ (%)	ABB′ (%)	AB (%)	ABA′ (%)	ABB (%)
AH	54.05	63.16	80.00	65.00	73.33	27.27
FL	59.57	22.58	53.49	56.25	31.82	44.44
HB	39.06	31.03	33.33	46.43	47.37	37.50
HG	52.27	93.75	9.68	35.48	19.35	71.43
HR	61.02	37.50	58.62	64.44	65.63	66.67
MP	39.06	24.14	56.00	65.71	86.21	80.25
NN	65.74	85.71	90.32	66.67	82.98	10.00
Average	52.97	51.13	54.49	57.14	58.10	48.22

Discussion

Experiment 3 made several modifications to Experiment 2 to alleviate some conceptual procedural issues that could have prevented participants from showing an ADE. Specifically, Experiment 3 removed the risk of any side biases and fully counterbalanced the comparison baseline measure by exposing participants to both orderings of AB and BA. Despite these procedural changes, we still observed no ADE in capuchins—participants showed no significant preference shifts for option A when decoys were present in any condition, and they did not violate regularity or the constant-ratio rule. Consistent with our earlier experiments, the homogeneity of choices in the forced choice familiarization trials, and the equivalent number and length of main trials resulted in a similar energetic intake across participants. Although participants avoided decoys across all three experiments, they failed to show any evidence of an ADE. Along with the results of Experiments 1 and 2, Experiment 3 provides evidence that capuchin monkeys do not show the sort of ADE reliably observed in humans.

General discussion

Our goal was to examine the ADE in a non-human primate species that has previously demonstrated other economic biases. We initially hypothesized that capuchins would likely show the ADE given that this effect has been observed in other non-human animals (Bateson et al. 2002, 2003; Edwards and Pratt 2009; Hurly and Oseen 1999; Latty and Beekman 2010; Morgan et al. 2012; Parrish et al. 2015; Scarpi 2011; Shafir 1994; Shafir et al. 2002; Waite 2001). In addition, we expected to find evidence of the ADE in capuchins in particular since this species shares a number of other human-like choice biases (e.g., Chen et al. 2006). In contrast to our initial hypothesis, however, we found no evidence of the ADE through violations of regularity or the constant-ratio rule in any of our studies, despite the similarity of our stimuli to other non-human and human experiments (e.g., Frederick et al. 2014). In Experiment 1, we tested for the ADE using a choice-based touchscreen method with food choices differentiated on two dimensions; we found no significant preference shifts between binary and ternary choice sets even though participants appeared to understand the touchscreen choice task enough to avoid decoy options. In Experiment 2, we used a free consumption method with juice reward stimuli and drinking time as our dependent variable to investigate the potential for contamination effects induced by perception-based attributes. We attempted to differentially prompt kind (i.e., categorical) and comparison judgments using choice dimensions known to elicit different processing modes in primates. Consistent with other non-human animal ADE studies, we also introduced a new value-based choice dimension of quality. Importantly, we confirmed that the familiarization trials did not lead to any differences in energetic intake. Although participants appeared to detect the dominance relationship and rarely selected the decoys, we found no evidence for the ADE. In Experiment 3, we used juice consumption volume as the dependent variable and adjusted the procedure to control for several theoretical confounds. Even with these improvements, we found no violations of regularity or the constant-ratio rule.

In light of the non-human animal literature, we were initially surprised that we failed to observe an ADE in capuchin monkeys. Our results imply that capuchin decision-making strategies might not exhibit the same ADE as humans, and suggest that the ADE might not be as robust as comparative researchers have previously thought. However, it is worth noting two key limitations to our studies. First, our experiments differed from other non-human animal studies in that we defined our choice dimensions in terms of quantity, quality, shape, or color, whereas previous animal studies tended to differentiate choices in terms of quantity, quality, or effort (e.g., Shafir et al. 2002). It is possible that we have discovered a boundary condition for the ADE in animals; value-based attributes such as quantity and quality and perception-based attributes such as color or shape might not reach a threshold level of salience to trigger an ADE (although see Santos et al. 2001 for hints that color should be a relevant dimension for primate food choices, and see Parrish et al. 2015 for evidence of the ADE in choices differentiated by perception-based attributes). A second limitation of the present experiments is that we used a relatively small number of trials compared to some animal studies (see Parrish et al. 2015, which used over 2000 trials per participant). It is possible that detecting an ADE requires a larger number of trials or a larger number of participants. On the other hand, other animal studies have detected ADEs using similar trial counts and participant sizes (Latty and Beekman 2010; Scarpi 2011; Shafir 1994; Shafir et al. 2002).

The limitations of our study may also give researchers some caution in interpreting findings that other non-human animals show the ADE. The fact that our stimuli lacked an effort attribute and that our methods involved a low trial count also make our experiments the *most similar to the methods used to test humans* of the other non-human animal studies to date. Indeed, there are several critical differences in the methods used with humans and animals. For example, while humans understand choices through numeric specification, animals typically require training on the choice stimuli prior to the decision task. As a result, animal research often pre-exposes participants to the choice stimuli during training for preference trials, which could cause participants to rationally adjust their preferences with new information or satiation. Moreover, while many human studies involve one-shot decisions about hypothetical choices, most of the published studies on animal ADEs involve repeated decisions with consumed rewards. In addition to potentially causing psychological fatigue, the repeated exposure and consumption of food rewards in animal studies could lead to state-dependent preferences during actual choice trials. As a result, the preference shifts that resemble the ADE may simply be a rational reaction to changes in energy intake prompted by the experiment (i.e., these preference shifts might not be present in the animals' spontaneous choices). In addition, changes in energetic states caused by training might not only influence preferences at the time of the experiment, but could also change a participant's nutritional needs in subsequent trials (Raubenheimer and Simpson 1997). For these reasons, some animal studies demonstrating a human-like ADE may be better described through alternative explanations that account for changes in energy states.

To explore the possibility of an energy state confound in the ADE, Schuck-Paim et al. (2004) systematically manipulated European starlings' (*Sturnus vulgaris*) food intake while exposing them to ADE trials. When participants were exposed to binary familiarization sessions that favored the option that would become dominated in the ternary decoy condition, they showed an ADE. However, when the experimenters controlled for energetic intake by holding the rate of reward delivery constant in the training sessions, participants entered the main trials with equal energetic rewards and did not display an ADE. Schuck-Paim and colleagues concluded that state-specific energy level differences could alternatively explain some of the previous ADE findings in animals. For example, Schuck-Paim and colleagues point to the results of Waite (2001), in which Gray jays who consumed fewer rewards in background contrast trials were more likely to select a riskier option in the subsequent preference trials. Instead of a violation of the IIA axiom, these results could be explained by a rational energy prediction strategy; it is unsurprising, and perhaps even evolutionarily advantageous, that birds at a significant energy deficit selected the high-effort, high reward option (Bateson and Kacelnik 1998; Cuthill et al. 2000). The same alternative explanation may account for preference reversals in hummingbirds (Bateson et al. 2002) and slime molds (Latty and Beekman 2010). Taken together, these results suggest that the internal state of an animal plays a key role in its decisions. Given that some studies on non-human ADEs have not controlled for differential energy states, they may have observed effects that resulted less from a human-like ADE than from unintended energetic factors.

Another difference between non-human and human ADE studies concerns stimuli selection: The comparative cognition literature on the ADE has almost exclusively involved food options (though see Parrish et al. 2015 for an example of the ADE in a visual perception discrimination task that did not involve food stimuli), while most of the human research has relied on non-food options, such as products defined by prices. However, humans make decisions differently for food than for monetary rewards or dimensions. For example, humans are more patient for money than for food (Rosati et al. 2007; Estle et al. 2007). In this way, human ADE studies that used money as a dimension may have been influenced by the multitude of ways in which money sways decision making (Heyman and Ariely 2004; Vohs et al. 2006; Lea and Webley 2006).

A third methodological distinction between the human and animal ADE research is that the former has predominately used choices defined by value-based dimensions represented numerically (e.g., a $10 pen with a rating of 4.5 out of 5), while the latter has almost exclusively used perception-based stimuli (e.g., a reward that requires more effort to obtain). It is possible that the strategies used to compare numerically defined options fail to extend to perceptually defined options. Indeed, Frederick et al. (2014) failed to detect an ADE in 27 human experiments involving non-numeric stimuli. Using an experimental design similar to Experiments 2 and 3 in this paper, Frederick and colleagues had over 250 human participants sample three Kool-Aid® beverages differentiated by flavor (cherry and grape) and sugar concentration (full and dilute) and found no ADE. Frederick et al. also conducted experiments in which a choice attribute was represented either numerically or perceptually, and only found the ADE when the attribute was described numerically or when participants were prompted to numerically rate the perceptual dimension. In these studies, participants chose between three televisions differentiated by price and picture quality in a choice set that included a decoy. In the numeric condition, options were depicted numerically by price and a picture quality score. In the perceptual condition, the numerical picture quality score was replaced with a photograph of a television screen representing the corresponding quality score. Frederick et al. found an ADE in the numeric condition, but found no effect in the perceptual condition. In a follow-up experiment that prompted participants in the perceptual condition to numerically rate the picture quality of each television before making a choice, the ADE re-emerged. In a separate set of experiments, Yang and Lynn (2014) failed to find an ADE in 52 of 54 human experiments with non-numeric attributes, despite their total sample size of over 2000 participants. Thus, recent research suggests that the comparative mechanism that causes the ADE in humans may require numerical representations that non-human animals would not comprehend.

The differences we have outlined between human and non-human studies of the ADE make it difficult to know whether similar mechanisms underlie the seemingly similar choice behavior observed across these populations. To better understand why the ADE might occur in humans and other animals, researchers would benefit from developing a standard experimental methodology with cross-species stimuli that carefully control for species-specific confounds. In addition, researchers must make an effort to replicate previous findings from different species using new methods for evaluating choice. Finally, researchers will need to test existing theories and attempt to build a more coherent explanation for the different categories of effects currently reported under the same operational definition.

Across three experiments using various preference elicitation techniques, value-based and perception-based dimensions, different dependent variables, and multiple methodological controls, we found no evidence for the ADE in capuchin monkeys. Although we had hypothesized a different result, we were able to account for the performance we observed by appealing to potential differences between our method and those used in other non-human animal studies. We then explored several alternative accounts of human-like ADE in other animals. To fully study the origins of the ADE, we argue that researchers should revisit the collection of phenomena that have been loosely termed the “asymmetric dominance effect” and develop standard experimental paradigms to explain one of the most pervasive cases of irrationality reported in the study of judgment and decision making.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This research was conducted in compliance with federal laws of the USA and with the regulations of Yale University. The protocol for non-human primates was approved by the Institutional Animal Care and Use Committee at Yale University (Protocol Number: #2008-10678).

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