How much does an anchor weigh? Psychophysical anchoring and the role of mental representation in weight judgments

Senior Project in Cognitive Science

Ben McCoubrey
Yale University
Advised by Shane Frederick

ABSTRACT

In the literature on judgment and decision-making, evidence abounds for the intrusive effects of peripheral information when making simple evaluations and estimations. In particular, the "anchoring effect" indicates a robust and widespread phenomenon in which the initial presentation of quantitative information tends to bias judgments of subsequent targets in the direction of the previously presented "anchor"– for example, your offhand estimation of the chance of rain in London tomorrow might be significantly lower if you were just told that the Phillies only have a 2% chance of winning the World Series in 2017 than if you'd made the guess alone. While such effects have been demonstrated across an array of domains, the mechanisms of anchoring remain the subject of scrutiny. Different models find support from different experiments, but the field has yet to produce decisive evidence for the precise nature of the anchoring effects: in particular, whether anchors are capable of distorting actual mental representations of target stimuli, or if they merely disturb the mapping of those representations on to the response scales demanded by the tasks. Our study supports the latter model by introducing a psychophysical anchoring paradigm in which anchors influence judgments about an object but not the underlying mental representation of it that they form. Across two studies, we use two different types of weight anchors and measure expectations about the weight of a novel, ambiguous object to produce evidence in favor of a scale-distortion model of anchoring, with an acknowledgement of the potential for conceptual priming in numerical anchoring paradigms.

INTRODUCTION

How much does an anchor weigh? Not the psychological phenomenon–an anchor, as in an anchor dropped by the Titanic. You might guess 8,000 pounds, 15,000 pounds, or anything remotely in the neighborhood. You've probably never been told the weight of an anchor aboard the Titanic, but you might have access to some relevant information: the anchor had to prevent about a thousand feet's worth of metal, cargo, and passengers from drifting away. You might also have access to some irrelevant cues: James Cameron's film *Titanic* cost about $200,000,000 to produce. While you might filter such extraneous information out of your conscious reasoning processes, four decades of literature on judgment and decision-making suggests that your estimation process might not be so impervious to its influence. The "anchoring effect" suggests that individuals assimilate or otherwise adjust their judgments to peripheral information in their environment, meaning that you might give a much higher estimate of the anchor's weight if I first told you that the film Titanic cost $200,000,000 to produce than if I told you that it took 160 days to shoot.

The example here seems contrived, but every decision you make in your day-to-day life is informed by simple judgments about your choices: how much time it might take to finish a project, how likely it is to rain, how many calories you might burn doing an exercise, etc. The anchoring effect suggests that many of those judgments may be influenced by incidental information that has no informative value to your decisions whatsoever. By some of the most pessimistic accounts, these influences are pervasive and inescapable, but the general direction of research on the topic has been to delineate the boundaries and conditions under which the effects take hold, in effort to build a more thorough model of the anchoring phenomenon. I begin by reviewing the extant literature on the topic, and then introduce a novel approach to resolving between some of the competing models of the anchoring effect.

ANCHORING

In their seminal treatment of the topic, Tversky and Kahneman (1974) showcased the broad applicability of anchoring when they asked participants to estimate the percentage of African nations that were members of the United Nations. Before answering, participants spun a "wheel of fortune" to produce a random integer between 0 and 100 (the wheel was rigged to produce either 10 or 65), and then were asked whether the target percentage was greater or less than the number they spun. The "anchoring effect," as coined in the paper, referred to the strikingly assimilation effect to the ostensibly irrelevant numbers: a spin of 10 produced estimates around 25%, whereas 65 produced estimates around 45%. Similar effects were soon obtained in the context of temperature estimates (Quattrone et al., 1984), pricing decisions (Northcraft & Neale, 1987), recollection of historical facts (Russo and Shoemaker, 1989), among various other domains.

Despite the common elicitation of assimilation-based effects in most studies, the failure to observe anchoring under certain experimental conditions has led researchers to a host of explanatory frameworks for their contradictory results. Some models have been proposed in effort to narrow or constrain the theories advanced before them, but none have decidedly replaced others in the literature, as results in support of each model continue to appear in publications. The models have generally been categorized as:

Anchoring and Adjustment: In their landmark paper, Tversky and Kahneman (1974) offered a potential mechanism for their effects, which suggest that people fixate on the anchor and then incrementally adjust until reaching a value that appears plausible, thereby driving the target estimate to its upper or lower bound, depending on whether the anchor is high or low.

Numeric Priming: The anchoring and adjustment model was challenged on two accounts. First, it did not account for the observation of anchoring effects even when the number provided by the anchor was an entirely implausible response for the target judgment and therefore unlikely to be considered as a starting point for the estimation (Strack and Mussweiler, 1997). Furthermore, factors that should have encouraged further adjustment, like more time for deliberation, were ineffective in drawing anchored estimates towards baseline, suggesting that another mechanism drove the effect (Chapman & Johnson, 2002). Numeric priming broadened the definition of anchoring in the context of numerical cues, suggesting that the salience of the numbers could produce anchoring effects without any explicit incorporation into the judgment process (Wong & Kwong, 2000). By this account, implicit consideration of the primed number is sufficient to drive the effect, suggesting a much more undiscerning mechanism than the explicit adjustment heuristic offered by Tversky and Kahneman.

Selective Accessibility: To caveat the pure priming account of numerical anchoring, Strack and Mussweiler (1997) demonstrated that the way that the anchor is presented in relation to the target judgment holds significance. Their account implicates the relevance of the anchor to the target as a prerequisite for comparison of the two, and suggests that such a comparison elicits a tentative hypothesis in the mind of the estimator that the target judgment matches the anchor. For example, the anchor of an alarm clock's price would be pertinent enough to the estimation of a TV's price to produce the tentative hypothesis that the prices of the two electronic devices match (whereas the price of a three-course meal might not). In order to test such a hypothesis, the individual conjures evidence consistent with a match between the two (e.g. the TV is made of cheap plastic, is relatively small, produced by a lower-tier brand). Even though the hypothesis is ultimately rejected (the TV must cost more than the alarm clock), the biased feature evaluation produced by the anchor effectively pulls the estimate of the target towards the value of the anchor.

Scale Distortion: The selective accessibility account explicitly implicates the process of representation formation, which suggests that the effect of the anchor is mediated by the distortions it produces in the mental construction of the target. This stands in contrast to the anchoring and adjustment and numeric priming accounts, which only require distortions at the level of the numerical responses to which the individual translates their representation of the target. Recognizing the distinction between the two levels at which anchoring theories operated, Frederick and Mochon (2012) produced evidence that scale distortion descriptions were sufficient to capture many of the findings that had been advanced in favor of selective accessibility. They challenged the complexity of an account at the representational level by demonstrating that anchoring effects disappeared whenever the link was broken between the scale of the anchor and the response scale for the target judgment. For example, if participants estimated a raccoon's weight in pounds, their responses would be diminished from control on the subsequent estimation of a giraffe's weight; but when the raccoon's weight was first estimated on a Likert scale from "not at all heavy" to "very heavy", the giraffe was estimated to weigh the same number of pounds as if they hadn't been asked about the raccoon at all. According to the authors, the mental representation of the giraffe must have remained constant in the face of the anchor if the difference observed between the conditions depended entirely on the consistency of the scale used to produce the anchor and elicit the judgment.

Conceptual Priming: Whereas the majority of anchoring research has concerned numerical primes, Oppenheimer et al. (2008) suggested forms of anchoring that were untethered to numbers. Their studies showed that non-numerical primes like drawing short or long lines on a piece of paper could influence subsequent numerical estimations like the length of a river or the temperature in Honolulu. Their findings don't fit neatly into the parsimonious scale distortion theory, as they directly echo the selective accessibility accounts in their mechanism for the cross-modal effects observed. When participants were instructed to draw long or short lines, as they did in the anchoring tasks, they revealed selective activation of magnitude-consistent concepts– for example, those who drew longer lines more frequently filled in unfinished words like _ALL and

B_G to produce TALL and BIG than did those who drew shorter lines. Furthermore, the effects were found to be bidirectional: physical anchors could influence numerical estimates just as numerical anchors could influence physical estimates. Given that the effects don't rely on a numerical scale, this form of anchoring may lie outside of the domain elucidated by a scale-distortion account of anchoring.

While many of the anchoring theories offer competing accounts, evidence abounds for the merits of each. The failure of any single theory to dominate the field suggests that the domains and paradigms used in different experiments may require more theoretical consideration if a unified theory of anchoring is to be advanced. The present study seeks to provide evidence in favor of either the selective accessibility or scale-distortion theories by measuring more directly the representations that are formed in the context of anchoring information, by means of physical interactions with objects.

PSYCHOPHYSICAL TECHNIQUES

Interactions with physical objects have been used to reveal psychophysical representations – mental representations of the properties of the physical world – at least since the 19th century. Charpentier's size-weight illusion (1891) provides early evidence that perceptions of heaviness are remarkably subjective. Participants who lift two objects of equal weight but unequal size consistently judge the larger object to be lighter. The illusion is persistent and cannot be attributed to size-dependent sensorimotor feedback (Buckingham & Goodale, 2010), meaning that the expectations informed by visual perception must play an important role.

Buckingham et al. (2011) developed and operationalized a measure of weight expectation by installing pressure sensors on a handgrip used to lift objects in a study of weight illusions. They confirmed the translation of mental weight representation into participants' initial grip forces in the context of another visually driven illusion in which different materials drive different expectations of weight. The grip force data replicated previous measures of weight expectation in the material-weight illusion such as vertical force and height of lift.

The studies previously cited on anchoring have exclusively relied on survey-based questionnaires, with little direct inquiry into the cognitive structures that may mediate the relevant effects. The anchoring literature suggests that anchors act across modes and the psychophysics literature suggests that distortions in the mental representations of objects will reveal themselves in the context of actual interactions with those objects. Using the methods developed in the psychophysics literature, I seek to determine the conditions under which anchors can or cannot distort mental representations of object attributes – weight, in particular – for the ultimate purpose of providing evidence that might strengthen evidence for the models that have been advanced in the anchoring literature.

STUDY 1: Sequential Anchoring and Physical Interaction

To begin our exploration of the role of mental representation in the anchoring effect, we carried out a study in which participants gave a series of judgments and then lifted an object with an ostensible "performance" goal. The manipulation of interest was a question designed to elicit an anchor that was either relatively high or relatively low, and the measure of interest was grip force applied when lifting an object of ambiguous weight. In contrast to the original anchoring questions developed by Kahneman and Tversky (1974), our question was designed in accordance with the paradigm used by Mochon and Frederick (2013). Rather than providing an anchor through a comparative question ("Is a giraffe taller or shorter than 10 feet?"), we elicited anchors by simply asking participants to estimate the weight of objects ("In feet, how tall is an average adult giraffe?"). According to Mochon and Frederick (2013), responses to such questions serve as anchors for estimates on subsequent questions as long as the responses share a scale, but not otherwise, suggesting that the mental representation formed about the object in the second question is not fundamentally altered by exposure to an anchor in the first– merely that its translation to the response scale is distorted. The current study essentially replaces the second question with a more direct measure of the anchoring question's effect on subsequent formations of mental representation: an interaction with the second object rather than a judgment about it. According to the scale-distortion theory, a judgment should be influenced by the anchoring question but a mental representation should not. Thus, we hypothesized that the magnitude of a weight-based anchoring cue should have no discernible impact on expectations of the object's weight.

APPARATUS

In order to measure mental representation in an interaction with a physical object, we borrowed a method used in psychophysical experiments by Flanagan & Beltzner (2000). An apparatus (see Figure 1) was constructed in conjunction with Yale's engineering department to measure the force applied to a pinch-grip handle (thumb and forefinger).

The handle was attached to a 16-oz full cornstarch container, which was selected based on a pretest in which passersby in the Yale Center for Engineering, Innovation, and Design were asked to lift opaque containers and report whether they were heavier or lighter than anticipated. The pretest yielded 13 underexpectations and 13 overexpectations across the 26 pretesters, making it substantively ambiguous in its perceived weight for the purposes of the apparatus. For both the pretest and the experiment, the container was wrapped in a layer of duct tape to mask any associations with its original identity or any implications of its surface material, in light of material-weight illusions reported by Buckingham et al. (2011). The object and its handle were connected by a thin wire to a circuit board housing on the table, where an Arduino microcontroller recorded grip-force data at 10ms increments. Next to the object stood an upright ruler with a green line marking a vertical height 5 inches above the table's surface. Digital readings from the pressure sensor were transformed to force (in Newtons) using a calibration formula derived by matching readouts from the sensor to those on a digital lab scale.

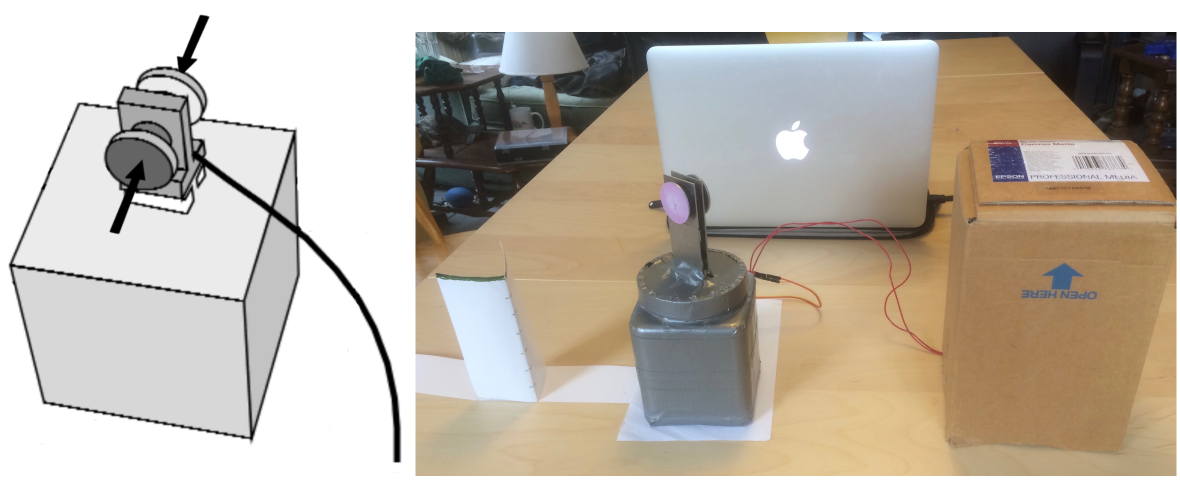

Figure 1: Left, a schematic for the object and pinch grip (adapted from Flanagan and Beltzner, 2000); right, the experimental apparatus used in Studies 1 and 2

METHOD

We recruited 35 participants from outside the Davenport dining hall at Yale University, with 18 randomly assigned to the "heavy anchor" condition and 17 to the "light anchor" condition. Each participant was instructed to take a seat at a table in front of the concealed apparatus, and fill out a brief questionnaire asking to estimate various quantities. For participants in the "heavy anchor" condition, the key question asked for an estimate of the weight of a bowling ball. In the "light anchor" condition, the target object was a tissue box. The manipulation was masked by including several non weight-related judgments before it (e.g. "How long does it take to walk from Silliman College to Pierson College?"). Upon completion, the physical object was revealed, and participants were introduced to an ostensibly performance-based portion of study. Each participant was instructed to grasp the handle by the thumb and forefinger (dominant hand), and lift it as quickly as possible such that the bottom of the object coincided with the green line marked on the vertical ruler, without overshooting it. They were informed that the time would be recorded from the precise moment of contact with the grip, and to grasp and lift the object in a single fluid motion. Once they had lifted the object, they were asked to report whether it was heavier or lighter than they had anticipated, and then to give an estimate of the weight of the object.

RESULTS AND DISCUSSION

As expected, the bowling ball was estimated to weigh more (M = 9.81 lbs) than the full box of tissues (M = 0.93 lbs). To gauge the effect of anchor magnitude on expectations of object weight, we analyzed the grip force profiles over time for each trial (the data for one participant was excluded due to technical malfunction). Following established psychophysics methodologies (Hermsdörfer et al. 2011), we obtained time derivatives of grip force as a proxy for anticipated weight. This was done by processing the raw output from the force sensor (measured every 10 milliseconds) through a median filter, and measuring the average slope of the grip force profile between the first nonzero value and the first local maximum. The particulars of this data processing are particularly adept at distinguishing underexpectations of weight from overexpectations because the typical form of the grip force profile depends on whether the object is heavier or lighter than the weight anticipated before lifting it. Lighter-than-expected objects tend to produce a sharp peak followed by a trough, as the force necessary to hold the object is initially overapplied, and then adjusted downwards as necessary. Heavier-than-expected objects tend to produce a gradual rise in the grip force profile, as additional pressure is required until the object finally lifts off from its surface (Figure 2).

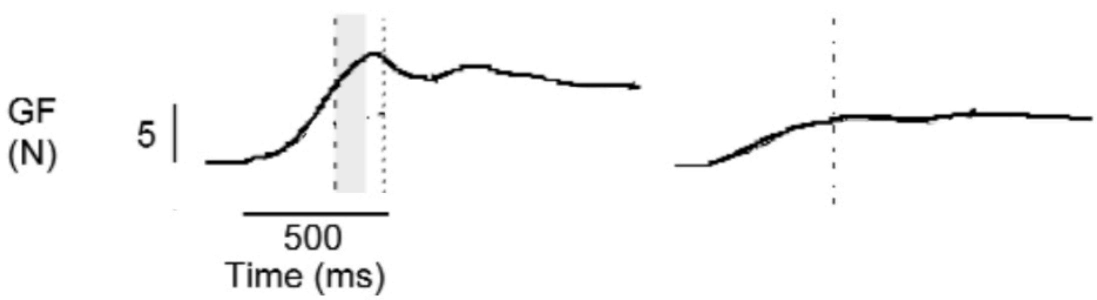

Figure 2: Left, typical grip force profile over time for lifting an object lighter than expected; right, for lifting an object heavier than expected (from Flanagan and Beltzner, 2000)

Contrary to our scale-distortion hypothesis, we found that initial grip force rates were moderately higher for those who received the bowling ball anchor (M = 0.123 N/ms) than for those who received the tissue box anchor (M = 0.090 N/ms), suggesting that the ambiguous object was expected to weigh more after reporting a larger weight estimate ($t(30) = 2.26$, $p = .03$) (see Figure 3). The effect of the anchor on expectations was further supported by the direction of the difference between expected and actual weight reported by participants. Whereas the object had elicited a 50/50 split of over- and under-expectations in the pretest, its effects in the study were different depending on the experimental conditions. In the “heavy anchor” condition, 10 participants were surprised at the lightness of the object as opposed to 6 who found it heavier than expected (1 participant reported that it was the same weight as they had expected). The reverse effect was observed in the “light anchor” condition, where 12 participants were surprised at the heaviness of the object while 6 found it lighter than expected.

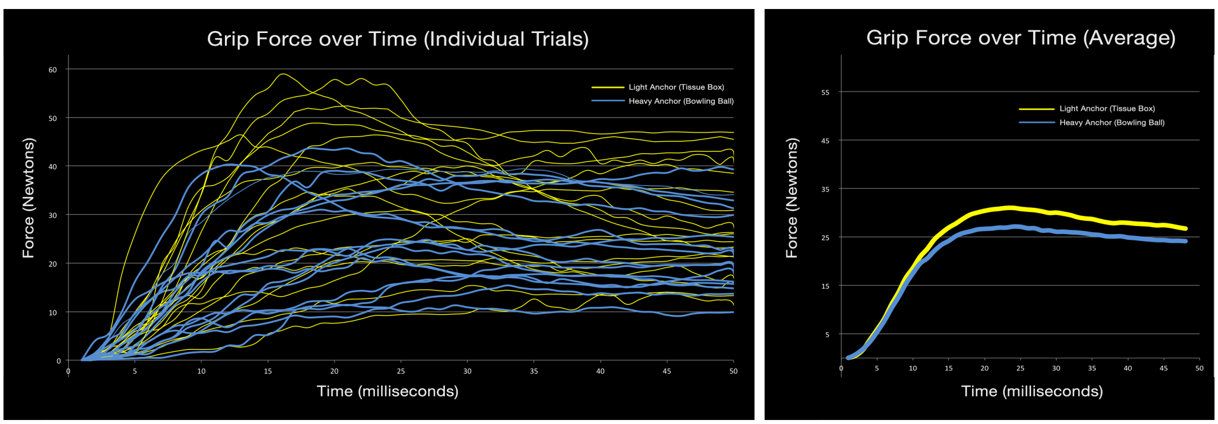

Figure 2: Left, raw force grip data from individual participant trials, color-coded by anchor condition; right, the averaged grip force trials for each (see Appendix for larger versions)

In terms of the estimate made after lifting the object, we didn’t enter with a strong hypothesis about the effect of the anchoring question. In this case, the psychophysics and anchoring literature predict opposite effects: Mochon and Frederick’s sequential anchoring paradigm uses two similarly worded estimation questions (albeit without a task to interrupt between them) to produce assimilation effects: the second judgment will tend to be closer to the value given for the first question than if it were made in isolation. The actual interaction with the object, however, should produce contrast effects based on the expectations produced by the initial anchoring question, thereby driving the ultimate estimation in the opposite direction of the anchor. The two groups did not demonstrate any significant differences on their ultimate assessments of the object's weight, suggesting that neither effect strictly dominated the other; however, the question of the interaction of anchored expectation and expectation violation ought to be considered more thoroughly in future research.

While these results offer preliminary evidence for a representation-based account of anchoring, there are facets of the study's design that prevent us from making strong claims against a scale-based theory. The primary issue with using this paradigm to distinguish between selective accessibility and scale distortion is that the method of eliciting the anchor may have produced an effect that was not derived from the magnitude of the number itself. Although the self-generated nature of the anchor alleviated concerns of experimenter demands, the different mental images conjured of heavy or light objects across conditions (bowling balls or tissue boxes) may have primed participants in a manner divorced from the number produced as an anchor. Evidence from neuromotor research suggests that mental imagery may be sufficient to modulate sensorimotor activity in the cerebellum and influence motor behavior (Lacourse et al., 2004). Given that the heavy and light anchors may have produced strong mental images of heavy and light objects, the effects in this study may have better been categorized as conceptual priming effects. As mentioned before, conceptual priming does not rely on numeric anchors, so its effects may confound the attempt to distinguish between scale-distortion and selective accessibility models of anchoring. These methodological issues were addressed in the design of our second study.

STUDY 2: Arbitrary Anchors and Physical Interaction

The purpose of our second study was to test the influence of anchors on weight perception in the absence of potential conceptual priming. We returned to a version of the standard anchoring paradigm, in which the anchor is introduced through a comparative question: "*Is the object heavier or lighter than ____ pounds*?" The method has the advantage of introducing the anchor without an object of reference, but runs the risk of reintroducing the experimenter demands that the sequential anchoring paradigm prevented. To resolve this, we had participants roll a six-sided die to produce the anchor, ensuring that the anchor was not interpreted as an insinuation about the true weight of the object. While the natural range of the die certainly implies something about the range of the object's potential weight, we found the die to be a suitable source of the anchor. The vast majority of the pretest estimates of the object's weight fell between one and six pounds, so we were not concerned about floor effects stemming from the natural estimate falling outside of the anchor's range. We split the participant pool into one condition in which they simply made an estimate of the object's weight after they rolled the die and answered the comparative question, and another in which they instead carried out the object-lifting task from Study 1 after the roll and comparative question. If the effect of the anchor on weight expectations in Study 1 depended entirely on the description of another physical object (a conceptual prime), then a randomly generated numeric anchor should influence the numeric response given to estimate the object's weight but should *not* influence the mental representation of its weight– in other words, the anchor should not influence their expectations about its weight or, consequently, the trajectory of force that they apply to grip it.

METHODS

We recruited 55 participants in the Berkeley and Davenport dining halls, with 25 assigned to the "judgment" condition (2 excluded for technical failures) and 20 assigned to the "interaction" condition. Each participant was seated at a table with the object apparatus on the surface, and was asked to roll a six-sided die. After reporting the outcome to the experimenter, the experimenter asked, "Just by looking at this object, would you estimate that it weighs more or less than *X* pounds?" (with *X* filled in emphatically as the outcome of the die roll). Participants in the "interaction" condition then performed the object-lifting task from Study 1. Participants in the "judgment" condition were simply asked to then estimate the weight of the object.

RESULTS AND DISCUSSION

As anticipated, the outcome of the die had a significant effect on estimates of the object's weight, such that participants in the judgment condition tended to guess higher weights after higher rolls ($r(21) = .58$, $p = .004$). This confirms that the standard anchoring paradigm influenced judgments in the predicted direction, and that the range of the die was sufficient to incorporate plausible weight estimates for the object. This result is consistent with both scale-distortion and selective accessibility theories of anchoring, but the "interaction" condition ought to distinguish between them by directly mobilizing the mental representation of the object. For these participants, the roll of the die did not significantly predict the averaged time derivatives (measured just as in Study 1) of their grip force profiles ($r(18) = .08$, $p = .734$). This result offers evidence for the notion that numerical anchors do not fundamentally influence mental representations of objects. Taken together with the evidence that numerical anchors *do* influence numerical estimates about the same object, we might infer that the standard paradigm removes conceptual priming from the anchoring equation, and further, that the anchoring effect only influences judgments insofar as the anchor distorts the scale upon which those judgments are made. A selective accessibility account would suggest that the mental representation of the object would be formed in such a way as to bias information supporting the hypothesis that the object was equal to the outcome of the die (ie. filled with candy for a roll of one, filled with quarters for a roll of six). Given that participants did not engage with the object in any systematically different ways after different die rolls, we find no evidence of such an effect.

Worth noting, however, is a slight but insignificant effect found in an auxiliary portion of this study. After rolling the die, answering the comparative question, and giving an estimate of the object's weight, participants in the "judgment" condition were also presented with the object-lifting task. The main comparison of interest in Study 2 was between judgments and interactions with an object, but by including an object interaction in both conditions, we could compare weight expectations across conditions to see if the act of making an explicit weight estimation (which occurs in the "judgment" condition but not the "interaction" condition) influences weight expectations (measured through grip force in both conditions) even if the anchor that produced the estimation is incapable of directly modifying such mental representations. Although it fell short of the threshold of significance, we found a slightly positive correlation between weight estimates and grip force time derivatives for these participants who estimated the weight of the object and subsequently lifted it ($r(21) = .348$, $p = .10$) suggesting that even if a numeric anchor is incapable of *directly* influencing mental representations of physical properties, it may be capable of *indirectly* distorting expectations of those properties if an explicit estimation is demanded by the situation.

If such an effect were to bear out with a larger sample, it would require a more nuanced explanation of the relationship between estimation and representation. If the estimation made about an object's weight influences its representation in a manner not mutually attributable to the anchor that preceded both measures, then perhaps the demand for an explicit articulation of object judgments serves to reify or solidify the representation of the object in a systematic way that is not provoked by the simple "more than / less than" question. Perhaps the answer would lie in the conceptual priming logic of the outcome in Study 1: even if the weight estimates are distorted by the scale effects of the anchor, the explicit report itself might conceptually anchor the representation mobilized in the interaction with the object. Such a characterization is underdetermined in its assignment of antecedents and consequences when it comes to mental representations and the numeric values associated with them, and the near-significant correlation might disappear entirely with a more powerful sample, but in any case, the questions it raises could provide fodder for future investigation. Research has already explored the role of representations in forming numeric judgments (Siegler & Opfer, 2013), but the potential for numeric judgments to bidirectionally influence the solidification of object representations is less clear– and potentially consequential for any sequential anchoring study design.

Beyond increasing the sample size, a concrete improvement to the study could be to scale the entire apparatus up in size such that participants could make more granular estimates of the object's weight without straying from integers. A 20-sided die could encourage a broader range of guesses than the six-sided die, and potentially tease out some effects that were washed out by the narrowness of the range in our study.

GENERAL DISCUSSION

No existing research has approached the anchoring effect using psychophysical methods, so the two studies included in this project ought to shed light on some of the questions that remain unanswered using paradigms already common to the literature. In these two studies, we provide evidence that an anchor can serve as a conceptual prime for a weight-based interaction with an object, but that the phenomenon may not reveal anything about the capacity for numeric anchors to directly influence the formation of mental representations. The implications of the present study are best illuminated by revisiting the various models of anchoring introduced at the outset. Most anchoring and adjustment accounts require that the anchor be consciously processed as a relevant benchmark for the judgment at hand (Mochon & Frederick, 2013). In Study 1, we used a sequential anchoring paradigm in which the anchoring cue was masked amidst other judgments, and presented in a disjoint manner from the dependent measure, suggesting that the anchoring and adjustment model may not be particularly pertinent to the effect found in our study. Indeed, anchoring and adjustment may be an unnecessarily strict model of anchoring to encapsulate the range of the effect, as we found that ostensibly irrelevant numeric anchors could influence judgments in Study 2. Comparing the findings in Study 1 – in which a self-generated anchor influenced subsequent expectations about the object's weight – with those in Study 2, where a randomly generated anchor failed to distort those expectations, we might infer that the effect in Study 1 is better characterized as an example of conceptual priming rather than selective accessibility. Study 1 confounded the magnitude of the anchor with the mental image of a relatively heavy or light object, meaning that it did not serve as an adequate test case for the model of anchoring in which the anchor biases the formation of subsequent mental representations. The selective accessibility model is challenged more directly by comparing the conditions within Study 2, in which the randomly generated anchor only influenced responses made on the same scale as the anchoring question. Estimates of the object's weight were reliably predicted by the outcome of the six-sided die, but mental representations did not appear to be influenced by it after analyzing the grip force data. We consider this evidence for the descriptive value of a scale-distortion model of anchoring as opposed to selective accessibility, and propose that anchors' effects may be more limited in their consequences for behavior than the earlier literature in the field may have suggested.

Further, the weaknesses of Study 1's design highlight a methodological consideration that all anchoring researchers should take into account. Any study involving a numeric anchor that conjures mental images of a physical object must take into account the potential for conceptual priming, which may operate separately from the numerically-based anchoring theories that much of the literature seeks to distinguish.

The strongest implication of our study is that anchoring has fewer behavioral consequences than may have been previously inferred from the strength and robustness of judgment effects in the extant literature. Considering effects on judgment and effects on behavior separately is critical for those seeking to mobilize the effect– for example, if someone were instructed to choose the 20-oz gold bar from an array of differently-weighted bars, a low-price anchor shouldn't cause them to choose a more massive bar but it might lead them to put in a lower bid for the bar if it were up for auction. Behavioral effects must derive from scale-consistency if numeric anchors are to impact anything more than judgments and estimations. While the latter portions of our study offered some proposals about the nature of the cause and effect relationship between numeric and behavioral effects, future research should more carefully investigate the connection. Such findings could have broad implications for any research on anchoring effects when they occur in series, and might even offer novel explanations for existing research. And since people often form judgments about objects with the intent of interacting with them in some capacity, future research should also investigate the aggregate effect of judgments and interactions with objects. We were unable to discern the aggregate effects of the anchor (which predicted assimilation) and the object interaction (which predicted contrast) when it came to making a weight judgment after experiencing both. Future research could vary features of the experimental paradigm that we held fixed, in order to determine the conditions under which each effect might dominate.

The question of conceptual priming vs numerical priming is an important one considering the number of anchoring studies that use estimates about objects to elicit their anchor. We propose a few concrete directions for further exploring the role of conceptual priming in the context of anchoring studies. First, it's unclear what the bounds are for conceptual primes manipulating mental representations. In our study, the thought of a bowling ball influenced the way that an object was lifted. Would the effect persist if the anchor and the target object don't both involve lifting? Future studies might prime participants with objects that are *pushed*, such as heavy doors, and measure whether it influences the strength with which a target object is then *pulled* in order to determine whether the heaviness primes conjure a generalized preparedness for interacting with heavy objects, or whether the effects are constricted to the same muscle groups and motor plans as those implicated by the anchor. Other forms of operationalizing the mental representation might also be used besides object lifting, such as pouring liquids with a certain volume goal or measuring qualitative impressions, such as willingness to carry an object around in one's backpack for an entire day. And if neuromotor scientists were to contribute to the investigation, they might be able to provide more direct measurements of motor plan activation and behavioral preparedness to determine their susceptibility to anchors and primes.

Even if it raises more questions than it answers, our study provides a novel paradigm through which to test the effects of anchors given various competing models of anchoring, and offers preliminary evidence for a scale-based account of numerical anchors as advanced by previous research, which only used judgments to illustrate the model. In light of recent research efforts to deconstruct previously accepted psychological phenomena (see Firestone & Scholl, 2014), this might serve to attenuate the fervor surrounding the anchoring effect that pervades pop-psych articles and books.

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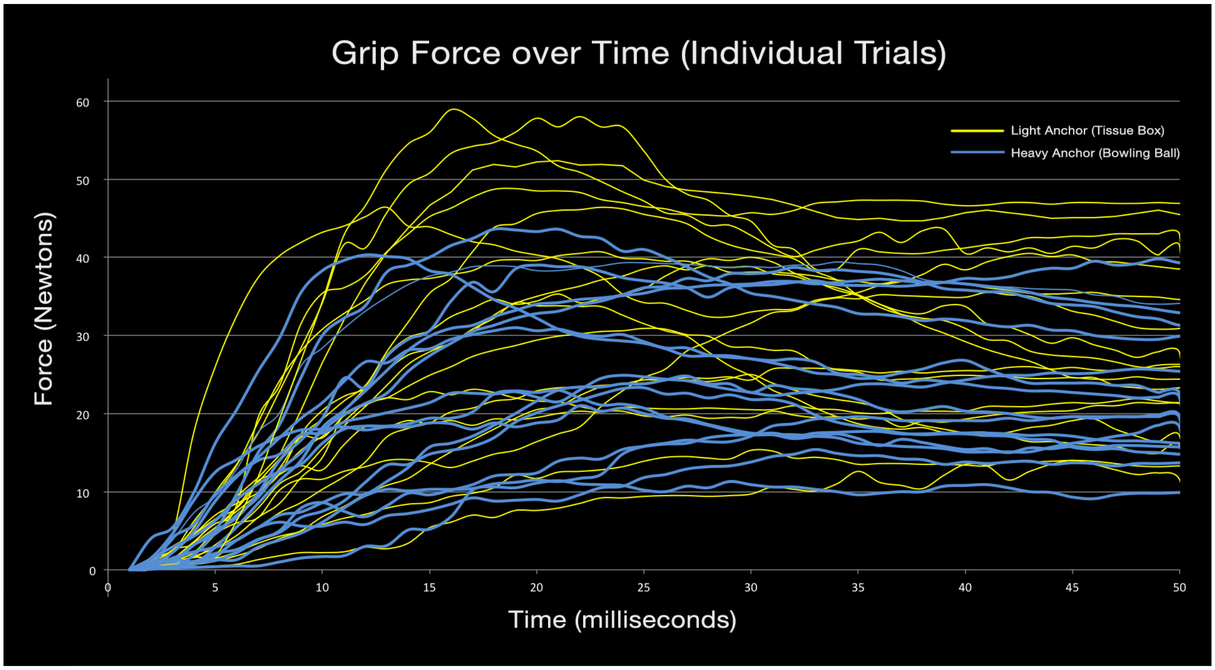
APPENDIX

From Figure 3: Grip force profiles from individual trials in Study 1



From Figure 3: Average grip force profiles from Study 1 by anchor condition