Known Unknowns: A Critical Determinant of Confidence and Calibration

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Abstract

We propose that an important determinant of judged confidence is the evaluation of evidence that is unknown or missing, and overconfidence is often driven by the neglect of unknowns. We contrast this account with prior research suggesting that overconfidence is due to biased processing of known evidence in favor of a focal hypothesis. In Study 1, we asked participants to list their thoughts as they answered two-alternative-forced choice trivia questions and judge the probability that their answers were correct. Participants who thought more about unknowns were less overconfident. In Studies 2 and 3 we asked participants to list unknowns before assessing their confidence. "Considering the unknowns" reduced overconfidence substantially, and was more effective than the classic "consider the alternative" debiasing technique. Moreover, considering the unknowns selectively reduced confidence in domains where participants were overconfident, but did not affect confidence in domains where participants were well-calibrated or underconfident.

In the run-up to the Iraq war of 2003 many leaders in the United States expressed great confidence that the Iraqi President, Saddam Hussein was developing weapons of mass destruction (WMDs). In a letter sent to President George W. Bush in 2001, ten of the most influential congressman, both Democrats and Republicans, wrote "There is no doubt that … Saddam Hussein has reinvigorated his weapons program. Reports indicate that biological, chemical and nuclear programs continue apace and may be back to pre-Gulf War status."[1] Senator Jay Rockefeller expressed the same sentiment in a 2002 speech: "There is unmistakable evidence that Saddam Hussein is working aggressively to develop nuclear weapons and will likely have nuclear weapons within the next five years."[2] As we now know, there were no WMDs, so these statements expressing "no doubt" and "unmistakable evidence" apparently reflected overconfidence that had major geopolitical consequences. While this example may be extreme it is not unusual. Overconfidence has been implicated in a wide range of decision errors, from going to war (Johnson, 2004) to treatment of medical conditions (Baumann, Deber, & Thompson, 1991; Oskamp, 1965) to corporate investments (Malmendier & Tate, 2005) to market entry (Camerer & Lovallo, 1999; Mahajan, 1992).

A great deal of research has attempted to understand the sources of error in judging confidence with an eye to developing debiasing techniques. Much of this research has attributed overconfidence to a systematic tendency to seek or overweight known evidence for a favored hypothesis over its alternatives. In the case of the Iraq war, overconfidence may have been driven in part by the Bush administration promoting the hypothesis that Iraq was developing WMDs and the bias among observers to seek and overweight evidence confirming this hypothesis. An abundance of research has found that people tend to focus disproportionately on evidence for a focal hypothesis relative to alternatives (Koriat, Lichtenstein, & Fischhoff, 1980; Hoch, 1985; Klayman, 1995), and they tend to seek evidence consistent with the focal hypothesis as part of a positive test strategy (Mynatt, Doherty & Tweney, 1977; Klayman & Ha, 1987; Nickerson, 1998), wishful thinking (Babad, 1987), motivated reasoning (Kunda, 1990), or to protect their self-image from failure and regret (Larrick, 1993). One reason this approach to understanding

[1] Letter to President Bush, Signed by Senator Bob Graham and others, December 5, 2001
[2] Senator Jay Rockefeller, October 10, 2002

overconfidence has been so influential is because it has led to successful debiasing techniques that tend to improve judgment calibration. Overconfidence can be reduced by prompting people to "consider the alternative" (Koriat, Lichtenstein & Fischhoff, 1980) or by designating a member of a decision-making team to advocate for the alternative ("devil's advocate technique"; Schwenk & Cosier, 1980).

A second class of theories of confidence represents the mapping between balance of known evidence and judged probabilities. Griffin and Tversky (1992) distinguish strength of evidence (i.e., balance) from weight of evidence (i.e., reliability or diagnosticity). They argue that when judging probabilities people tend focus on strength of evidence and give insufficient regard to weight of evidence. This can contribute to both overconfidence (when strength of evidence is high and weight of evidence is low) and underconfidence (when strength of evidence is low and weight of evidence is high). People focus on strength of evidence while neglecting weight of evidence because they overestimate the predictive validity of evidence that is representative (Kahneman and Tversky, 1979), internally consistent (Kahneman & Tversky, 1973), and based on small samples (Tversky & Kahneman, 1971). Similarly, in Support Theory (Rottenstreich & Tversky, 1997; Tversky & Koehler, 1994), probability is determined by the perceived balance of evidence for a hypothesis relative to its alternative. Overconfidence can occur due to scaling the perceived balance of evidence to overly extreme judged probabilities (see Fox, 1999), for instance when perceived evidence is seen as especially predictive of outcomes (Tannenbaum, Fox & Ülkümen, In Press), or when the environment does not provide particularly diagnostic cues (Brenner, Griffin & Koehler, 2005). In evidence accumulation models confidence is determined by weighting evidence based on feeling (Ferrell & McGoey, 1980) or self-consistency (Koriat, 2012), and overconfidence can occur when these cues are overestimated.

We propose that when assessing confidence people may also look directly to specific pieces of ***unknown evidence*** to determine how to weight or scale the balance of known evidence. By unknown evidence, we mean a variable whose value is unknown, but if it were known should change one's level of confidence. For instance, prior to the invasion of Iraq, Saddam Hussein's motivation for not cooperating with weapons inspectors was unknown to most American observers. Mr. Hussein may have wanted the world to believe that he ***did possess WMDs*** (to increase the perceived strength of the Iraqi military) or that he ***did not possess WMDs*** (to reduce the likelihood of a US-led invasion). Becoming aware of this important unknown factor would not change the information available to a judge. However, awareness of the unknown is likely to decrease confidence by making the judge aware that he or she is missing critical information. Unknown evidence can potentially support the focal or an alternative hypothesis once the unknown is resolved. So being aware of more unknown evidence should generally lead to less extreme confidence in both outcomes.

Biased evaluation of known evidence clearly plays a role in overconfidence, but failure to adequately consider unknowns may be equally important. A growing body of literature shows that people tend to think the world is simpler and more predictable than it is because they focus on what they know and tend to neglect what they do not know. For instance, people tend to think they understand various types of causal systems, from machines to public policies, in much greater detail than they actually do (Alter, Oppenheimer & Zemla, 2010; Fernbach et al., 2013; Rozenblit & Keil, 2002). People also tend to neglect unknown causes of system failure when diagnosing problems such as why a car won't start (Fischhoff, Slovic & Lichtenstein, 1978), and they underestimate the possibility of unknown or unexpected delays in the planning fallacy (Buehler, Griffin & Ross, 1994). People also exhibit a 'censorship bias' in which they fail to account for missing sample information when forming beliefs about an underlying population (Feiler, Tong & Larrick, 2013). Similarly, consumers tend to neglect unknown or unmentioned attributes when evaluating products (Sanbonmatsu, Kardes, & Sansone, 1991; Sanbonmatsu, Kardes, & Herr, 1992). More generally, Kahneman (2011) uses the focus on known relative to unknown information as an organizing principle for many phenomena in judgment and decision-making, that he refers to as the 'What You See is All There Is' (WYSIATI) principle.

We have proposed that judged confidence depends in part on the judge's assessment of how much evidence is missing or unknown. In particular, we predict that greater appreciation of unknowns will be associated with judged probabilities that tend more towards the "ignorance prior" probability of $1/n$ in an n-alternative forced choice paradigm (e.g., ½ when there are two alternatives) whereas less appreciation of unknowns will be associated with more extreme confidence judgments that depart more from the ignorance prior. Consistent with this hypothesis, previous studies suggest that when people are less knowledgeable they provide less extreme probability judgments. Fox and Clemen (2005) report that judged probabilities of *n* exclusive and exhaustive events—for example, the branches from a chance node in a decision tree—were biased more strongly toward probabilities of 1/*n* for events about which participants had less knowledge or expertise. Likewise, See, Fox and Rottenstreich (2006) found that judged probabilities were biased more strongly toward 1/*n* when participants had less opportunity to learn the frequencies of observed events or when they reported feeling less confident in what they had learned.

In Study 1 we use a correlational, thought listing paradigm to test whether differences in consideration of unknowns predict differences in confidence and overconfidence, controlling for the balance of known evidence. We also examine whether under-appreciation of unknowns is associated with overconfidence. In particular, we predict that prompting people to consider unknowns will reduce overconfidence. In Studies 2 and 3 we introduce a novel debiasing technique, "consider the unknowns," in which participants are asked to reflect on what they do not know before reporting their confidence, and we compare the efficacy of this technique to the classic "consider the alternative" intervention (Koriat, Lichtenstein, & Fischhoff, 1980).

Study 1

We asked participants to judge the probability of making a correct choice in a two-alternative forced choice (2AFC) task involving general knowledge questions. The 2AFC paradigm is a well-studied context in which people often exhibit overconfidence (for reviews see McClelland & Bolger, 1994; Koehler, Brenner & Griffin, 2002; Griffin & Brenner, 2004). As participants completed the task we also asked them to provide reasons for their judgments using a thought listing procedure (Johnson, Haubl & Keinan, 2007). We then asked participants to self-code each of their reason on the extent to which it referred to known versus unknown evidence. In addition, we asked two hypothesis-blind judges to code the extent to which each reason supported the chosen or alternative option. We predicted that respondents would exhibit lower confidence to the extent that they thought about more unknown evidence and that this relationship would hold after controlling for the balance of known evidence.

Methods

We recruited 134 students at the University of Colorado Boulder to participate in a laboratory experiment in exchange for a $3 payment (49% female; mean age = 20.0). We first asked them to answer ten 2AFC questions, each with two possible answers adapted from Klayman et al. (1999); a complete set of questions is provided in Appendix A. After answering each question, we asked participants to report their confidence by estimating the probability that they correctly answered the question, on a scale from 50% to 100%.

For the first 3 of 10 questions (questions 1-3 in Appendix A) we asked participants to list the reasons for their confidence:

> As you answer the question, please think of all the reasons that make you {more/less} confident you know the answer and all the reasons that make you {less/more} confident. We will ask you to enter your reasons one at a time. Type your first complete reason in the box below and, as soon as you are done, hit the "enter" key to submit it. You may enter your reasons in any order."

The order of the words 'more' and 'less' was randomly determined for each participant and had no effect on confidence or answer choice. Participants could list as many or as few reasons as came to mind. The entered reasons then appeared and participants had an opportunity to enter more reasons. Participants listed reasons while viewing the 2AFC question and they could change both their answer and confidence while listing reasons.

After completing all ten questions, we reminded participants of each of the reasons they provided for the first three questions. We then asked them to rate each reason as being about known or unknown evidence on a 1-7 scale (1=completely known; 7=completely unknown). We explicitly asked participants to rate how known versus unknown the reason was rather than how much each reason improved the participant's estimate in order to make sure we were measuring the content of the reason, rather than the effect of the reason on confidence. A sample of the rating instructions can be found in Appendix B. Finally, we collected demographic data and debriefed participants.

Results

Unknown Rating and Reasons Generated. For the three question for which participants provided and rated reasons for their confidence estimates, participants provided an average of 2.36 reasons per question with an interquartile range of (2.35, 2.56). We calculated participants' average rating of reasons for how much they involved unknown evidence (1 = completely known; 7 = completely unknown). The mean rating was 3.45 with an interquartile range of (2.56, 5.33), and 63% of participants had an average rating below the scale midpoint, suggesting that most participants reported more known than unknown evidence. Reasons rated as known tended to be statements of facts whereas reasons rated as unknown tended to be statements about missing information or lack of relevant knowledge. Appendix C provides examples of representative known and unknown reasons generated by participants.

Confidence, Percent Correct, and Overconfidence. Across the three questions where reasons were provided mean confidence ratings were 67.4% while on average participants answered 62.2% of questions correctly. For each participant, we calculated overconfidence following conventional methods (see McClelland & Bolger, 1994; Koehler, Brenner & Griffin, 2002; Griffin & Brenner, 2004) by subtracting the percentage of all items answered correctly from average confidence, resulting in mean overconfidence of 5.2%, significantly more than 0%, $t(133) = 2.36$, $p < .05$, replicating previous work (e.g. Brenner & Griffin, 2002). Confidence, percent correct and overconfidence did not vary significantly for the seven questions where no reasons were provided compared to the three where reasons were provided.

We next examined the relationship between unknown ratings, confidence, percent correct and overconfidence across the three questions for which participants provided reasons. We first calculated the average confidence and percent correct on these question. We regressed the average confidence judgment on the average unknown rating. As we predicted, participants who provided reasons that they rated as more unknown were less confident, $b = -3.11$, 95% CI [-4.63, -1.59], $p < .001$. We also regressed percent correct on the known vs. unknown rating and found no significant relationship, $b = 0.66$, 95% CI [-2.79, 4.11], $p > .5$. We then regressed overconfidence on unknown ratings. Participants who generated reasons that they rated as more unknown exhibited less overconfidence $b = -3.77$, 95% CI [-7.38, -0.16], $p < .05$. To assess the level of unknown rating at which overconfidence becomes significant we conducted a floodlight analysis (Spiller et al., 2013). The Johnson Neyman point occurred at an unknown rating of 3.1, meaning that at this level of average unknown rating and above it, overconfidence did not significantly differ from 0. Below this average unknown rating, participants were significantly overconfident. At no level of average unknown rating were participants underconfident.

Balance of Known Evidence. We asked two hypothesis-blind coders to code participants' reasons according to the extent to which they appear to support the chosen vs. alternative option, using a 1 to 7 scale (1 = strong support of alternative option; 7 = strong support of the chosen option). Coders were not provided with the unknown rating or any other data besides the study questions and participant reasons. Nine participants did not provide reasons on at least one of the questions and were not scored by coders. Inter-rater reliability of these scores was high (Cronbach's $\alpha = .80$). Not surprisingly, mean balance of known evidence was 5.33 in favor of the chosen option, with an interquartile range of (4.81, 5.58). Appendix C provides examples of representative reasons coded as supporting the chosen and the alternative options. Rated support was not significantly correlated with unknown rating, ($r=-.12$, $p = .201$). Focusing only on the questions where participants provided and self-coded reasons, we ran three separate regressions with balance of known evidence as the independent variable and either confidence, percent correct or overconfidence as the dependent variable. Participants who provided reasons that were rated as more supportive of the focal compared to alternative hypothesis were marginally more confident in their choices $b = 2.85$, 95% CI [-0.53, 6.24], $p = .098$. Balance of known evidence did not significantly predict percent correct, $p > .1$, or overconfidence, $p > .5$.

We next conducted hierarchical regressions with average confidence across the three questions for which participants provided reasons as the dependent variable, and known versus unknown rating and balance of known evidence as the predictors. The model R-squared increased from .02 to .15 when adding known vs. unknown rating to balance of known evidence, $F(1,122) = 18.15$ $p < .0001$. When adding balance of known evidence to known versus unknown rating, the R-squared marginally increased, from .11 to .15, $F(1,122) = 3.68$, $p = .057$. This is consistent with our hypothesis that known unknowns contribute to confidence in addition to the balance of known evidence for the chosen versus alternative option.

Within-participants analysis. Because each participant rated multiple items, we were also able to perform a within-participant analysis to examine if an individual's confidence, percent correct and/or overconfidence varied as he or she listed reasons that were more unknown across different questions. For each participant, we examined the relationship between question-level known versus unknown rating and confidence, accuracy, and overconfidence. For each of the three questions we recorded judged confidence and unknown rating. We scored accuracy as a 1 if correct and a 0 if incorrect, and scored overconfidence as confidence minus accuracy. To analyze the data we used a linear regression with unknown rating for a particular question as the independent variable and confidence as the dependent variable while clustering standard errors by participant. Replicating the between-participant analysis, participants were less confident when they provided more unknown reasons, $b = -3.73$, 95% CI [-4.45, -3.00], $p < .001$. Next, we ran the same regression with overconfidence as the dependent variable. Again replicating the between-participant analysis, higher unknown ratings were related to less overconfidence $b = -6.97$, 95% CI [-9.62, -4.32], $p < .001$. Finally, we ran the same regression with percent correct as the dependent variable. Interestingly, higher unknown ratings significantly predicted percent correct, $b = 3.25$, 95% CI [0.59, 5.90], $p < .05$, a result that we did not predict *ex ante*.

Discussion

This study showed that appreciation of unknowns is related to both confidence and overconfidence. Focusing on more known evidence was associated with greater overconfidence whereas generating reasons that were rated as entailing more unknown evidence was associated with less overconfidence. Previous research has attributed confidence primarily to the processing of the balance of known evidence. Unknown ratings significantly predicted confidence after controlling for the balance of known evidence, suggesting that consideration of unknowns also contributes to judged confidence.

While the results of Study 1 support our hypothesis concerning the role of known unknowns, we acknowledge that the evidence is correlational and thus open to alternative interpretations. For instance, it is possible that those who felt less confident were more likely to reference unknowns rather than the other way around. In Studies 2 and 3 we experimentally manipulate consideration of unknowns to provide causal evidence of the determinants of overconfidence.

Study 2

In Study 2 we manipulate thinking about unknowns by explicitly asking some participants to "consider the unknowns" (CTU) and we compared the effectiveness of this intervention to the classic "consider the alternative" (CTA) debiasing intervention, in which people are asked to consider known evidence for the alternative hypothesis (Koriat, Lichtenstein & Fischhoff, 1980). Considering the alternative has been shown to reduce overconfidence, in part by increasing the percent correct. For example, Koriat, Lichtenstein & Fischhoff found that percent correct in the control condition was 62.9% compared to 69.7% when people were asked to consider the alternative in the 2AFC paradigm. We believe that as people consider the alternative they sometimes correctly realize that there is more evidence in favor of the alternative and switch their choice. Thus, considering the alternative can increase percent correct and decrease confidence. In contrast, considering the unknowns should reduce overconfidence only by reducing misplaced confidence, and should not cause people to switch their choice.

Methods

We recruited 254 participants at the University of California, Los Angeles from an online university subject pool to participate in a laboratory experiment in exchange for $3 dollars plus a performance incentive (75.7% female; mean age= 21.0). The performance incentive could range up to $212 (see Appendix D for details).

Participants assessed their confidence that they provided the correct answer to each of eight general knowledge questions in a four-alternative forced choice (4AFC) format. A complete list of questions is displayed in Appendix E. We randomly assigned participants to one of three conditions: no treatment, consider the alternative, and consider the unknowns. In the no treatment condition participants answered the questions and estimated their confidence without providing any additional information. In the consider the alternative (CTA) condition we adapted the procedure from Koriat, Lichtenstein, & Fischhoff (1980) in which participants in a 2AFC paradigm were prompted to list reasons supporting the non-chosen option (the alternative hypothesis) before making a confidence judgment. In our study, we asked participants to generate reasons supporting one of three possible non-chosen options:

> "Write down in the spaces provided two reasons that support one of the alternative choices (non-chosen options). Please write the best reasons you can think of that provides evidence for the options you have rejected. For example, in answering the question: "Which of these cars has a larger engine by volume: Mitsubishi Lancer, Nissan Altima, Mazda CX-5, or Subaru Impreza?" If you chose 'Nissan Altima' you would then list reasons that the correct answer might be the Lancer, the CX-5 or the Impreza."

In the consider the unknowns (CTU) condition we asked participants to:

> "Write down in the space provided two pieces of missing information or two unknown factors that would help you determine the correct choice, if known. For example, in answering the question: "Which of these cars has a larger engine by volume: Mitsubishi Lancer, Nissan Altima, Mazda CX-5, or Subaru Impreza?" An unknown might be: 'I don't know what a CX-5 is,' or 'I don't know if a Lancer is a sedan or an SUV'. What's important is that you write down two factors that are unknown to you."

Appendix C shows examples of representative reasons generated by participants in the CTU and CTA conditions.

Results

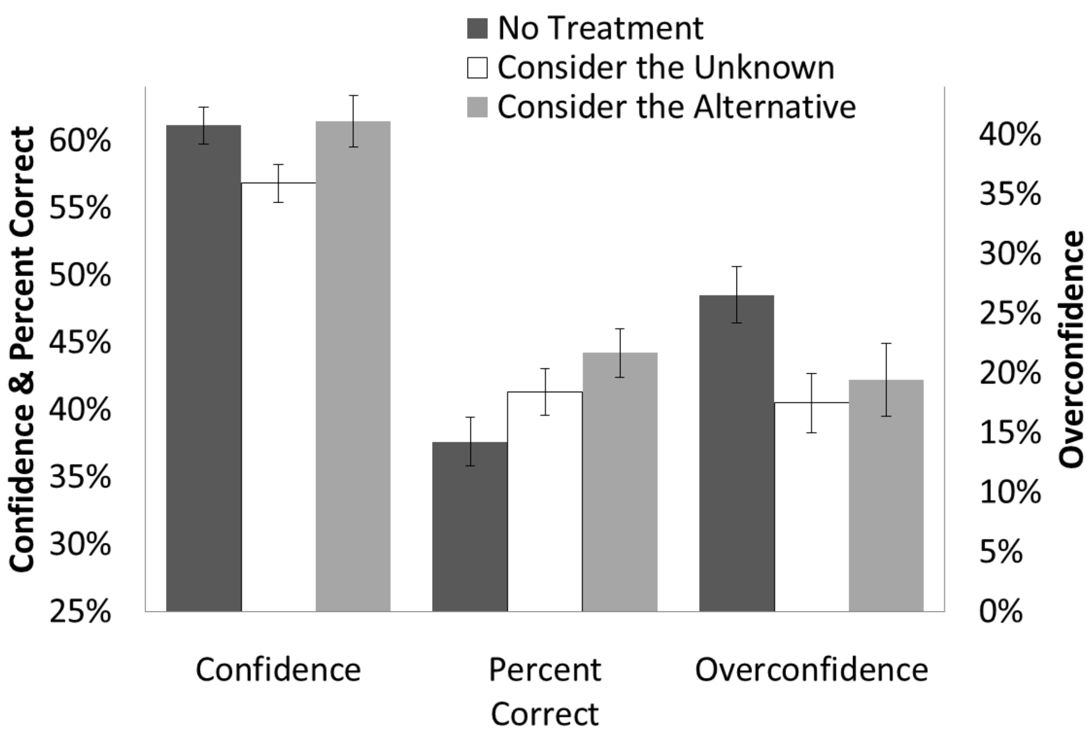
Figure 1 displays the mean level of confidence, percent correct and overconfidence across the three conditions. Confidence was calculated as the average level of confidence across all eight questions for each participant, percent correct was calculated as the percent correct across all eight questions, and overconfidence was calculated as the difference between the two.

We first analyzed the two treatment conditions against the no treatment condition and against each other. Participants in the CTU condition exhibited lower confidence than those in the no treatment condition, 56.8% vs. 61.1%, $t(170) = 2.14$ $p < .05$ and marginally lower confidence than those in the CTA condition, 61.4%, $t(166) = 1.96$, $p = .052$. Confidence in the consider the alternative condition did not differ significantly from the no treatment condition, $t(166) < 1$, *ns*.

Percent correct in the CTU condition was not significantly different than in the no treatment condition, 41.3% vs. 37.6%, $t(170) = 1.46$, $p > .1$ or the CTA condition, 44.2%, $t(166) = 1.18$, $p > .1$. Percent correct in the CTA condition was significantly higher than the no treatment condition, $t(166) = 2.59$, $p = .01$.

Overconfidence in the CTU condition was significantly lower than in the no treatment condition, 15.5% vs. 23.5%, $t(170) = 2.60$, $p = .01$ and was no different than in the CTA condition, 17.2%, $t(166) < 1$, *ns*. Overconfidence in the CTA condition was marginally lower than in the no treatment condition, $t(166) = 1.82$, $p = .070$.

Figure 1. Confidence, percent correct, and overconfidence in the no treatment, consider the unknowns, and consider the alternative conditions. Confidence and percent correct are shown on the left vertical axis and overconfidence is shown on the right vertical axis. Standard errors displayed.



Discussion

Considering the unknowns reduced confidence, resulting in decreased overconfidence relative to the no treatment condition. In contrast, considering the alternative did not reduce confidence but did improve percent correct, resulting in marginally less overconfidence than the no treatment condition. Thus, both debiasing techniques showed some efficacy, but considering the unknowns was more effective at reducing confidence.

One limitation of Studies 1 and 2 is they do not distinguish whether considering the unknowns generally improves calibration (i.e., meta-knowledge concerning one's accuracy) or whether it merely reduces confidence on questions where people are already overconfident. The downside of a general reduction in confidence is that when people are ordinarily well-calibrated it would lead to underconfidence, and where people are ordinarily underconfident it would exacerbate this bias. Study 3 allows us to examine the extent to which improvements in calibration following the consider the unknowns (CTU) intervention reflect a nonspecific reduction in confidence versus selective adjustment when confidence is misplaced.

Study 3

We designed Study 3 to replicate and extend the results of Study 2 by enhancing the design in three respects. First, to address the possible concern that the questions in Study 2 may have been especially difficult, which can lead to overconfidence through unbiased judgment error (Erev, Wallsten, & Budescu, 1994; Gigerenzer, Hoffrage, & Kleinbölting, 1991; Soll, 1996), we randomly generated the questions from a database of 778,169 questions across 9 domains provided to us by Jack Soll (personal communication, November, 2013). Second, in Study 3 we used a within-participant comparison between control and treatment to generalize the results beyond the between-participant design of Study 2. Finally, to establish the generality of the effects, Study 3 relies on a 2AFC paradigm whereas Study 2 used 4AFC.

Random stimulus sampling and the 2AFC format provide an additional benefit. Because we expect baseline overconfidence to vary across domains (see Klayman et al., 1999), Study 3 allows us to examine the extent to which improvements in calibration due to the consider the unknowns (CTU) prompt are driven by a general reduction in confidence or selective adjustments that depend on the degree of misplaced confidence. If CTU instead has a selective effect, it can provide a more useful and informative method for reducing confidence. To test this we compare changes in overconfidence in domains where participants are normally overconfident versus those where they are normally well-calibrated or underconfident.

Methods

Participants. We recruited 270 participants through a Qualtrics panel in exchange for $4 (66.3% female; mean age= 49.2). One participant did not finish the study and nineteen participants (7%)

requested that their data not be used in an opt-out option in the study debrief, leaving a sample size of 250.

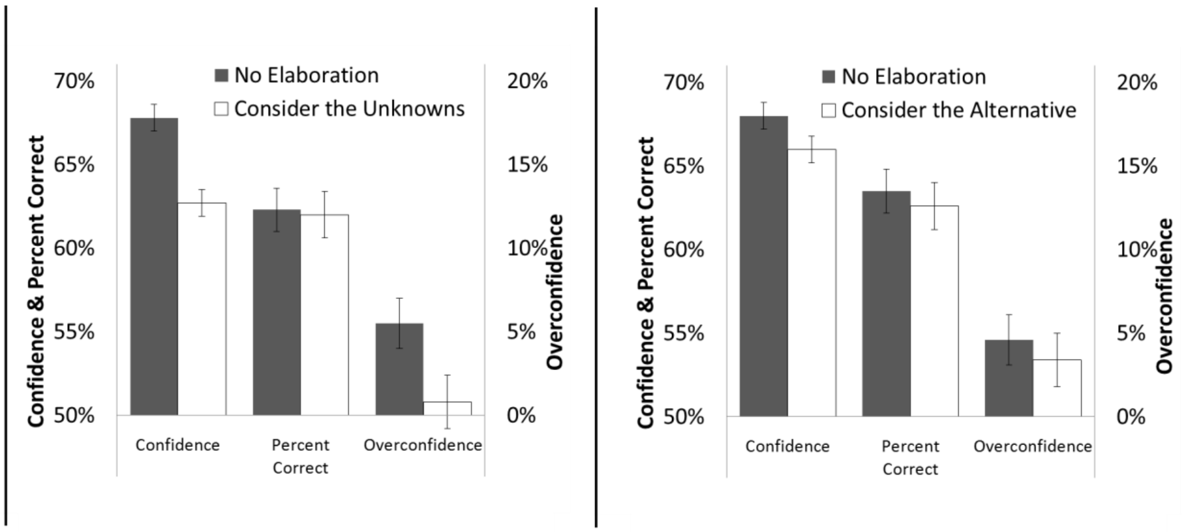
Stimuli and Procedure. Participants answered twenty general knowledge questions in a 2AFC format and assessed their confidence that they provided the correct answer. For each question, we asked participants to pick the correct answer and assess their confidence on a 50% to 100% scale. The twenty questions were grouped into two blocks of ten questions each: the first block was the no treatment block and the second block was the treatment block. Before the first block, participants read a brief set of instructions, completed a practice problem and then completed the ten questions with each question presented on a separate screen. Next, participants were randomly assigned to either the consider the alternative (CTA) or consider the unknowns (CTU) treatment condition. Depending on condition, participants read instructions similar to CTA or CTU conditions used in Study 2, and completed the second block of questions, this time elaborating on either the alternative or unknowns for each question, following the procedure of Study 2. Appendix C shows examples of representative reasons generated by participants in the CTU and CTA conditions.

Each participant received a randomly selected sample of questions drawn from a population of 778,169 question combinations developed by Jack Soll and colleagues. A complete list of question domains is displayed in Appendix F. Prior to the study, we created all possible question combinations then we randomly selected five questions per domain, for a total of forty-five questions. Each participant received twenty of these questions, sampled at random without replacement, following a method similar to Klayman et al. (1999)

Results

Figure 2 displays mean confidence, percent correct and overconfidence in the CTU and CTA conditions for the first ten questions (where there was no treatment) and the last ten questions, where participants considered the unknowns or the alternative. Replicating Study 2, considering the unknowns reduced confidence and overconfidence, and in this case, clearly had no effect on percent correct. In line with Study 2, considering the unknowns was more effective at reducing confidence than considering the alternative. For participants in the CTU condition, confidence was lower after generating unknowns than when answering the questions with no treatment, 62.8% vs. 67.8%, $t(120) = 6.14$ $p < .001$. For participants in the CTA condition, confidence was also slightly lower after generating alternatives than when answering the questions with no treatment, 66.0% vs. 68.0%, $t(128) = 2.37$, $p < .05$. However, the effect of considering the unknowns on confidence was larger than considering the alternative, $t(248) = 2.55$, $p = .01$. Considering the unknowns also reduced overconfidence relative to no treatment, from 5.5% to 0.8%, $t(120) = 2.70$, $p < .01$, whereas considering the alternative did not significantly reduce overconfidence, from 4.5% to 3.4%, $t(128) < 1$, $p > .5$. While the reduction in overconfidence in the CTU condition (4.7%) was greater than in the CTA condition (1.1%), this difference did not reach statistical significance, $t(248) = 1.38$, $p = .16$. However, overconfidence was not statistically different from 0 after considering unknowns, $t(134) < 1$, $p > .5$, whereas after considering the alternative overconfidence persisted, $t(128) = 2.30$, $p < .05$. Unlike in Study 2 neither manipulation significantly affected percent correct (means for CTU versus no treatment = 62.0% vs. 62.3%, p > .5; means for CTA versus no treatment = 62.6% vs. 63.5%, p > .5).

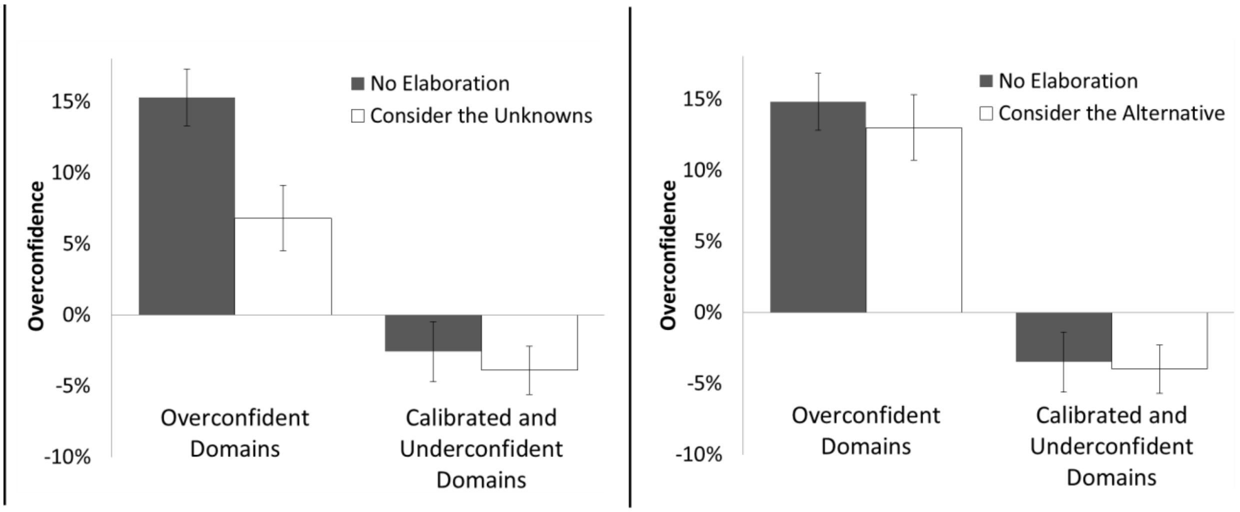
Figure 2. Confidence, percent correct, and overconfidence for questions with and without treatment. Confidence and percent correct are shown on the left vertical axis and overconfidence is shown on the right vertical axis. Left Panel: Consider the Unknowns; Right Panel: Consider the Alternative. Standard errors displayed.



We next examined whether considering the unknowns had a larger effect on answers where participants are normally more overconfident. We first identified domains for which participants exhibited statistically significant overconfidence, and domains for which they exhibited calibrated or underconfident judgment. We identified domains using a split-sample method similar to Klayman et al (1999) so that we could rule out regression to the mean as a trivial mechanism driving improvement (see Appendix G for additional details). Participants were overconfident in four domains (president elected first, food calories, beverage calories, and atomic weight) and calibrated or underconfident in five domains (country life expectancy, distance from Kansas City, state populations, movie box office revenue, and car miles per gallon). For each participant we computed four overconfidence scores: (1) overconfident domains with a treatment, (2) overconfident domains without a treatment, (3) calibrated/underconfident domains with a treatment, and (4) calibrated/underconfident domains without a treatment (see Figure 3).

We analyzed the CTU and CTA conditions separately using within-participant regression models, with overconfidence as the dependent variable. The independent variables were domain type (overconfident vs. calibrated/underconfident), treatment (treatment vs. no treatment), and their interaction. In overconfident domains, overconfidence was lower after considering the unknowns than when answering the questions with no treatment, 6.8% vs. 15.3%, $b = 8.5$, 95% CI [3.2, 13.9], $p < .01$. In contrast, in calibrated/underconfident domains, considering the unknowns had no significant effect, -3.9% vs. -2.6% $b = 1.3$, 95% CI [-4.0, 6.2], $p > .5$. The interaction between domain type and treatment was marginally significant, indicating that the effect of considering the unknowns was larger in overconfident domains, with a 8.5% reduction in confidence after considering unknowns in overconfident domains compared to a 1.3% reduction in calibrated/underconfident domains, $b = 7.2$, 95% CI [-0.4, 14.8], $p = .063$. In the CTA condition, neither of the simple effects was significant and there was no significant interaction, all p-values > .5.

Figure 3. Overconfidence on questions with and without treatment in overconfident domains and calibrated/underconfident domains. Left Panel: Consider the Unknowns; Right Panel: Consider the Alternative. Standard errors displayed.



Discussion

As in Study 2, considering the unknowns reduced confidence and overconfidence, but did not affect percent correct. The robustness of these effects to 2AFC vs. 4AFC, within- vs. between-participants and with randomly vs. non-randomly sampled questions suggests that considering the unknowns is an effective debiasing technique under a variety of conditions. Importantly, considering the unknowns selectively reduced confidence in domains where participants were overconfident. We found some evidence that considering the alternative has some efficacy at reducing overconfidence (consistent with Koriat et al., 1980), but the effect of this manipulation was not consistent across our studies. We found some increase in percent correct in Study 2 but no effect on confidence and a small effect on confidence in Study 3 but no effect on percent correct. Across the two studies, considering the unknowns was more effective than considering the alternative at reducing confidence and equal to or better at reducing overconfidence.

General Discussion

Our studies show that the evaluation of what evidence is unknown or missing is an important determinant of judged confidence. However, people tend to underappreciate what they don't know. Thus, overconfidence is driven in part by insufficient consideration of unknown evidence.

We conceptualize known unknowns as evidence relevant to a probability assessment that a judge is aware that he or she is missing while making the assessment. We distinguish this from unknown unknowns, evidence that a judge is not aware he or she is missing. It is useful at this point to further distinguish two varieties of unknown unknowns. In some cases a judge may be unaware that he or she is missing evidence but could potentially recognize that this evidence is missing if prompted. We refer to these as retrievable unknowns. In other cases, a judge is unaware that he or she is missing evidence and furthermore would need to be educated about the relevance of that evidence in order to recognize it as missing. We refer to these as unretrievable unknowns. To illustrate the importance of these distinctions, consider again the assessment of how likely it is that Iraq possesses nuclear weapons. In making this judgment, an intelligence analyst may explicitly ask herself whether Iraq possesses enriched uranium. The analyst may recall that enriched uranium is an important requirement for nuclear weapons, and that this factor is unknown. In this case, the question of whether or not Iraq has enriched uranium would be a known unknown. Alternatively, it may be that the analyst understands the relevance of uranium enrichment but does not consider this factor when judging the possibility of nuclear weapons. In this case the presence of enriched uranium is a retrievable unknown. Studies 2 and 3 demonstrate the effectiveness of using a prompt to direct attention to retrievable unknowns that people may not otherwise consider, as a means of reducing misplaced confidence and improving calibration. However, consider further a non–expert who does not know that enriched uranium is an important ingredient in nuclear weapons. In this case the presence of enriched uranium is an unretrievable unknown that a "consider the unknowns" prompt could never elicit, though presumably the novice could be educated. This analysis predicts that a "consider the unknowns" prompt will only be effective in reducing misplaced confidence to the extent that the judge has sufficient expertise to recognize unknowns when prompted to do so.[3]

Our results suggest a potent new method that could be disseminated to practitioners for reducing overconfidence. First, 'considering the unknowns' could be a self-administered treatment before making important judgments in situations where overconfidence is prevalent, such as when a CEO is making an acquisition (Malmendier & Tate, 2005), when a CFO is budgeting for an upcoming year (Ben-David, Graham & Harvey, 2007), or when a head of state is considering a military action (Johnson, 2005).

Considering the unknown may also be a more effective debiasing technique than considering the alternative in some situations. In Studies 2 and 3 we compared 'consider the unknowns' to 'consider the alternative' and found that considering the unknowns was more successful in reducing overconfidence. Further, we have provided some evidence that considering the unknowns selectively reduces confidence only when people are overconfident, whereas there is no evidence to suggest that correction is selective when considering the alternative. Considering the unknowns may also be more effective than considering the alternative in judgment tasks where no obvious alternative exists. For instance, when estimating quantities in confidence intervals, such as 'the cost of an advertising campaign' an instruction to "consider the alternative(s)" does not make sense (Alpert & Raiffa, 1982). However, it may be possible reduce interval overconfidence in such cases by prompting judges to consider the unknowns. This may be a fruitful area of future study because overconfidence is pervasive in confidence intervals estimation, with few techniques available to fully eliminate overconfidence biases (Klayman et al., 1999; Moore & Healy, 2008; Soll & Klayman, 2004).

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[3] Evidence that is recognized to be unknown may also vary in terms of its specificity. For example, when predicting the outcome of a football game a judge might consider that the health of the starting quarterback for the home team has been in question and so it is unknown whether or not the backup will have to carry the offense—a specific known unknown. Alternatively, a judge might consider that the variables that determine how the respective offenses and defenses of the teams match up is beyond his or her knowledge—a general known unknown. When debiasing using our "considering the unknowns" prompt, it is not clear to us which class of unknowns, the specific or the general, will tend to have a stronger effect on confidence and calibration.

Although we tout the potential of implementing a "consider the unknowns" strategy for debiasing, we do not claim that it will always outperform considering the alternative. One reason is that "consider the alternative" can sometimes not only lead to reductions in confidence but also improvements in the proportion of items answered correctly (as we saw in Study 2). Additionally, considering the alternative may be a more viable approach when trying to debias others since it may be more compelling to argue for a concrete alternative option (playing "devil's advocate") than to argue that the other person is missing information (given that another person's retrievable unknowns are not necessarily retrievable to the persuader). Of course these strategies are not mutually exclusive, and a hybrid strategy of considering both the *unknowns* and the *alternative* may be more effective than either strategy alone.

Donald Rumsfeld, secretary of defense during the invasion of Iraq in 2003 is famous for distinguishing between known knowns, known unknowns, and unknown unknowns. Our research suggests that the administration's overconfidence that Saddam Hussein possessed weapons of mass destruction may have been due, in part, to focusing too much on the known knowns and neglecting the known unknowns. When Colin Powell made a speech to the UN Security Council in February of 2003 in which he presented a persuasive series of known facts supporting the existence of WMDs in Iraq he stated, "My colleagues, every statement I make today is backed up by sources, solid sources. These are not assertions. What we're giving you are facts and conclusions based on solid intelligence." If Colin Powell wanted his audience to have a more balanced view, he should have also articulated what was unknown to the Bush administration. Known unknowns could have ultimately strengthened or weakened the case for WMDs once they were resolved. For example, US officials might have explicitly acknowledged how little they understood about Mr. Hussein's possible motivations for remaining coy about his nuclear program, and moderated their confidence. Recently it has come to light that Mr. Hussein was far more concerned about an internal coup or a Shiite rebellion than he was about a U.S. invasion, and so he encouraged everyone—from opponents in Iran to his own generals—to believe that he might have WMDs (Gordon & Trainor, 2006). Our studies suggest there would have been little downside to US officials considering what is unknown, at least from a judgment perspective. If unknowns are high, considering the unknown just might reduce overconfidence and if unknowns are low, considering unknown evidence will not impact calibration.

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Appendix A: Two Alternative Forced Choice Questions from Study 1

Question	***Choice 1***	***Choice 2***
Q1: Which of these U.S. presidents held office first?	Andrew Jackson	Franklin Pierce
Q2: Which of these fast food items has more calories?	Subway meatball marinara foot-long sandwich	McDonald's double quarter pounder with cheese
Q3: Which of these states had a higher population in 2010?	Connecticut	Nevada
Q4: Which of these attractions had more visitors in 2007?	Great Wall of China	Empire State Building
Q5: Which of these 2011-model cars gets more miles per-gallon in real driving (mix of highway and city)?	Volkswagen Jetta	Audi A3 Quattro
Q6: Which of these "tourist cities" has a warmer daily high temperature in July, on average?	Rome, Italy	Sydney, Australia
Q7: Which of these U.S. universities charged higher tuition in 2010?	University of Chicago	Harvard University
Q8: Of these two "principal mountains of the world," which is taller?	Muztagh Ata, China	Mt. Elbrus, Russia
Q9: Which of these states had a higher percentage of its population with incomes below the federal poverty line in 2010?	Missouri	Delaware
Q10: Which of these cities is farther from Los Angeles, in air miles?	St. Louis	Denver

Appendix B. Known unknown rating instructions in Study 1

Instructions: Please read the following information carefully

To what degree were each of your reasons about **something that is unknown to you** versus **something that is known to you**?

Please use this as a guide to carefully rate each of your reasons. We will use the estimate *'Who is older Madonna or Celine Dion?'* as an example:

If your reason was about something that you are **sure you know**, such as "*Celine Dion released more records over her career than Madonna*," then you might rate this a 6 or 7, since you are stating something **known to you**.

If your reason was about something that you **vaguely know**, such as *"I think Madonna has more children than Celine Dion,"* then you might rate this a 3 to 5 since you are stating something that is somewhere between **known and unknown to you**.

If your reason was about something **that you have no idea**, such as "*I have no idea if Madonna released her debut album before Celine Dion*," then you might rate this a 1 or 2, since you are stating something **unknown to you**.

If your reason was **not very specific or useful**, but still communicated a fact about which you are certain, such as *"I know that Madonna is older than Britney Spears*" you will still rate this as a 7, since it is still something **known to you**.

This is scale is **not** meant to measure how much each reason improved your estimate, or how relevant each reason was to your estimate. It is only meant to measure if the reason was about **something that is unknown to you** or **something that is known to you**.

As a reminder, You listed out reasons that you were certain or uncertain in your answer to:

Appendix C. Typical Text Responses across Studies 1, 2, and 3

Study 1 reasons listed by participants for *"Which of these U.S. presidents held office first? A. Andrew Jackson B. Franklin Pierce"*

Statement rated as unknown	*"I do not know much about andrew jackson so i do not know how old of a president he is"*
Statement rated as known	*"Jackson is known as one of the best presidents, and the best ones came first in America's history."*
Statement coded in support of chosen answer for when choice is "B. Franklin Pierce"	*"Franklin Pierce seems like an old-fashioned name."*
Study 1 Statement in support of alternative answer when choice is "B. Franklin Pierce"	*"Andrew Jackson is on the twenty dollar bill."*

Study 2 statements by participants

Question: "Which of these countries has the highest life expectancy? A. Greece B. Finland C. Singapore D. United Kingdom"

Consider the Unknowns (CTU) statement	*"what are the economic conditions in Greece"*
Consider the Alternative (CTA) statement when choice is "B. Finland"	*"The correct answer might be singapore because it has high average income"*

Question: "Which movie made the most money at the box office in real dollars? A. The Empire Strikes Back B. Ben-Hur C. 101 Dalmatians D. The Godfather"

Consider the Unknowns (CTU) statement:	*I don't know how popular the theaters were when the movies came out*
Consider the Alternative (CTA) statement when choice is "A. Emprie Strikes Back"	*"The Godfather is highly critically acclaimed, so it may have been seen in theaters more"*

Study 3 statements by participants

Question: ""Which of the following food items contains the least calories? A. Green beans (canned, drained, 1 cup) B. Chicken breast (boneless, skinless, roasted, 3 ounces)"

Consider the Unknowns (CTU) statement	*"What size can of green beans and is salt added?"*
Consider the Alternative (CTA) statement when choice is "A. Green beans"	*"Because the chicken breast is both boneless and skinless, the calorie count may be lower than the green beans."*

Question: "Which of these 2013 model cars gets the most miles per gallon in real driving (mix of highway and city)? A. Lexus IS 350 AWD B. Nissan Pathfinder 4WD

Consider the Unknowns (CTU) statement:	*"I don't know the size of the engines of these cars"*
Consider the Alternative (CTA) statement when choice is "A. Lexus IS 350 AWD"	*"It's possible the Nissan is a hybrid."*

Appendix D. Study 2 Performance Incentive

> Two participants will be randomly drawn to receive a bonus based on their performance in this task. If you are drawn you can receive a maximum total bonus of $212 depending on (1) the number of questions you correctly answer and (2) the accuracy of your probability estimates. For each question correctly answered you will receive $14. In addition, your assessed probability will be scored for accuracy by calculating a Brier Score. A Brier Score is a common scoring method for determining the accuracy or "calibration" of probabilistic predictions. More precisely, a Brier Score measures the mean squared difference between a person's probability judgments and the truth. Scores take on a value between zero and one, with lower Brier Scores reflecting greater accuracy and higher scores reflecting greater inaccuracy. The lower your Brier Score, the greater your bonus (A Brier Score of 0 will receive $100 on top of the bonus for questions correct, and a brier score of .5 will receive a bonus of $50, ect.). Thus, it is in your best interests to be as thoughtful and accurate as possible in all of your estimates. Please press 'enter' to begin the task.

Appendix E. Study 2 Questions

1. Which of these countries has the highest life expectancy? A. Greece B. Finland C. Singapore D. United Kingdom

2. Which movie made the most money at the box office in real dollars? A. The Empire Strikes Back B. Ben-Hur C. 101 Dalmatians D. The Godfather

3. Which state had the highest population as measured in July, 2012? A. Maryland B. Indiana C. Missouri D. Tennessee

4. Which element has the lowest atomic weight? A. Carbon B. Nitrogen C. Oxygen D. Fluorine

5. Which of the following food items contains the most calories? A. Ice cream (vanilla, 4 ounces) B. Chicken breast (boneless, skinless, roasted, 3 ounces) C. Ranch salad dressing (2 tablespoons) D. Hot dog (beef and pork)

6. Which city is the further from Kansas City, MO in air miles? A. Little Rock AR B. Denver, CO C. Cheyenne WY D. Minneapolis MN

7. Which of these beverages have the highest number of calories? A. Cranberry juice cocktail (12 ounces) B. Whole Milk (12 ounces) C. Beer (12 ounces) D. Hard liquor (vodka, rum, whiskey, gin; 80 proof) (1.5 ounces)

8. Which of these 2013 model cars gets the most miles per gallon in real driving (mix of highway and city)? A. Honda FIT B. Ford Taurus FWD C. Honda Accord D. Cadillac ATS

Appendix F: Study 3 question stems and number of questions.

Participants viewed 20 non repeated questions that were drawn from the following 9 databases of question domains. Participants answered an even proportion of questions from each domain on average.

1. Which of these countries has the highest life expectancy? (24,753 questions)
2. Which of the following food items contains the least calories? (44,253 questions)
3. Which city is the closest to Kansas City, MO in air miles? (1,711 questions)
4. Which President was elected first? (946 questions)
5. Which of these 2013 model cars gets the most miles per gallon in real driving (mix of highway and city)? (679,195 questions)
6. Which state had the highest population as measured in July, 2012? (1,225 questions)
7. Which of these beverages have the lowest number of calories? (300 questions)
8. Which movie made the most money at the box office in real dollars? (19,900 questions)
9. Which element has the lowest atomic weight? (5,886 questions)

Appendix G: Study 3 Procedure for identifying overconfident domains and calibrated/underconfident domains.

We used a split sample procedure to identify which domains people show overconfidence or calibrated/underconfident domains. The Study 3 sample can be split into 4 groups: (1) CTU condition, no treatment questions (2) CTU condition, treatment, (3) CTA condition, no treatment questions (4) CTA condition, treatment questions. We wished to test the difference in domain calibration between groups 1 and 2. Thus, we must establish a baseline level of domain calibration in a sample outside of these groups to avoid regression to the mean (Klayman et al., 1999). To accomplish this we used group 3 (CTA condition, no treatment questions) to identify for which domains participants exhibited overconfidence and for which domains participants exhibited underconfidence/calibration.