The Human Element of Decision Making in Systems Engineers: A Focus on Optimism

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Abstract. Biases continue to be an important aspect of human judgment and decision making because they can lead to unfavorable outcomes. Optimism bias is one type of bias that is often overlooked because of its association with good health and positive outcomes. However, the existence of optimism bias in human judgment can be very damaging especially when it distorts a person's view of future events.

In order to better understand optimism bias we explore the benefits and downsides of optimism as well as some empirically-based origins of both optimism and pessimism. This provides a backdrop for a methodology for quantifying optimism and pessimism using the Brier score developed for calibrating weather reporters and a discussion about how sports bookies make well-calibrated decisions. Results are explored from an optimism survey given to a cohort of eighty systems engineers, which ultimately portray the degree to which optimism bias influences decision making in large projects. Further exploration of the key differences in optimism across professions helps distinguish motivational factors and characteristics of well-calibrated professions. We also present results from a calibration exercise, designed to infer if such activities can be adopted to assist systems engineering estimation. Finally, we provide prescriptive advice on how individual decision makers can better manage their optimism and become more realistic.

Calibrating Optimism in Decision Makers

The motivation behind this work stems from the strong influence that human decision making has in the area of systems engineering, specifically cost estimation. Engineers often develop very sophisticated, well-calibrated, and accurate algorithmic cost models that are based on historical data of technical nature. These models provide estimates of cost and duration of projects based on well-understood technical parameters. However, the human element involved in estimating the inputs to these models as well as the use and interpretation of these models is poorly understood.

Equally important in the area of judgment and decision making are the limits of human performance. It is known that humans cannot run one mile (1.6 kilometers) faster that 3 minutes, and cannot jump over 9 feet (3 meters) because of the limitations of their physical abilities. There are equivalent limits of the mental abilities of humans in terms of our ability to remember a certain number of digits or able to perform certain mathematical computations. There are also

influences from our experiences and training that have a direct impact on the way we make judgments and decisions. In particular, these experience shape the way we see the world and determine whether we are optimistic or pessimistic in certain circumstances.

Judgment and Decision Making. It is important to distinguish between judgment and decision making since these terms are often used interchangeably. A judgment is when a quantitative assessment is made about a certain situation. A decision is how judgment is turned into action. In this paper, the focus will be on the judgments only because the decision making aspect involves an entirely different mechanism. It is important to consider how people make judgments about, in this case, the cost of a product they want to develop. The focus on optimism is because it represents a class of biases that is often ignored and can lead to unfavorable long-term outcomes despite its more visible short-term benefits.

Hypothesis. Engineers are sometimes too optimistic of their own abilities and claim that "one half of the glass is a hundred percent full." In order to correct optimism it must first be measured. An important concept presented in this paper is a methodology for quantifying a decision maker's optimism level based on the field of meteorology (Brier, 1950). This example provides a framework for measuring the potential effectiveness of training mechanisms to reduce optimism and supports the hypothesis that *optimism can be reduced through training*. This paper provides an overview of optimism, its advantages and disadvantages, its empirically-based origins, a method to quantify it, results of an optimism survey given to a group of systems engineers, and a discussion of optimism across professions. We conclude with a discussion of techniques that can help individuals better manage optimism, and an investigation regarding the feasibility of estimation calibration – by performing an exercise on a small group of estimators, to infer if similar practices and techniques can be used to calibrate systems engineers. One important implication of this work is that it demonstrates how experience can be substituted by training. The calibration process can accelerate the abilities of a decision maker to be less optimistic and more realistic.

The Double-Edged Sword of Optimism

This investigation into optimism is driven by the following question: *If being an optimist is good, then why can it sometimes be so bad?* In other words, why is something that is so good in life, potentially so problematic in the workplace?

Optimism is truly a double-edged sword with its range of advantages and disadvantages. We will first focus on comparing optimism and pessimism, and then focus on optimism itself and how it can be better controlled in certain professions.

Optimism Defined. An optimist is a person who is unrealistic about the short term but unrealistic about the long term, while a pessimist is a person that is realistic in both their short term and long term thinking (Seligman, 2006). Additionally, there are other aspects of being a pessimist. The most important one is that whenever a bad experience take place a pessimist considers the experience to be permanent and pervasive across other similar experiences. On the other hand, an optimist can have a bad experience and perceive it as temporal and specific that can end whenever one chooses.

Indirect Benefits of Optimism. Happiness is all around us. Aristotle (1974) refers to a "golden mean" where we can reach a balance of happiness. In Zen Buddhism, the goal is to be happy (Gaskins, 1999). The words "life, liberty, and the pursuit of happiness" are in the U.S. Declaration of Independence and the Japanese constitution. There is even an organization called Optimist International dedicated to help youth. The direct benefits of optimism are obvious; it helps people cope with negative events and carry a positive outlook on life which is very often transferred to others.

There are several indirect benefits of being an optimist, the most recognized of which is improved physical health (Bower, 2007). It has been shown scientifically that pessimistic people are more likely to have health problems later in life (Peterson, et al., 1998). One study focused on religious nuns found that those who wrote more positive things about their lives tended to live longer and the ones that wrote less positive things died earlier (Danner, et al., 2001). Optimistic people have also been found to be more creative and productive (Estrada, et al 1994), better at performing cognitive tasks (Isen, 1987), and less likely to get divorced (Harker & Keltner, 2001). More importantly, those who are optimistic believe that things can be accomplished – even if they are unrealistic – which results in being seen as competent and entrepreneurial in the workplace (Russo & Schoemaker 1992). These are the attractive aspects of being an optimistic person. Research also shows that being an optimist does not translate to being wealthier (Myers & Diener 1995), which complements the notion that being wealthier does not necessarily make you happier. The conclusion is that people across all socioeconomic levels can be happy for different reasons.

Downsides of Optimism in the Workplace. There are several disadvantages of being too optimistic in work-related situations. Some common examples are being too optimistic about the output of a particular factory and being unable to meet demand, estimating real estate prices without regard to market fluctuations, and deciding to drill for oil in a location that does not show promise from geological analysis. Each example has penalties in the billions of dollars because if the estimate is too narrow (i.e., with low variation) or too confident it can result in unrealistic business expectations and poor financial outcomes (Russo & Schoemaker 1992).

It is common for optimists to be seen as detached from reality (Ben-Shahar, 2008). This is where the "half of the glass is one hundred percent full" is commonly cited, also known as the Pollyanna principle (Matlin & Stang, 1978). Optimists are seen as Polyannish because they see the silver lining in every dark cloud. Being too optimistic often causes others to perceive you as naïve.

Empirically-Based Origins

The question that follows is: *why are certain people pessimistic or optimistic?* There are many studies that provide predictors of optimism; the most interesting of which is age (Charles, et al., 2001). The theory behind this is that the older you are the happier and more optimistic you tend to be. There are several explanations for this; one of them is that people learn how to optimize their life over time. Individuals learn what they like and dislike and do not bother with the useless tasks and instead focus on playing golf or playing with grandkids and – as a result – enjoy life more. But this is a selective data set because it is based on the people that are still

alive. Those nuns who were pessimistic tended to die earlier and may have affected the results of the study by biasing the sample analyzed.

One of the sources of pessimism is a person's *set point* which is defined by their genetic makeup (Braungart, et al., 2002). A person's default mood is often what defines them. Some people are generally pessimistic because the way they were raised influences the way they look at life. These are crucial perspectives to the question of why people are pessimistic or optimistic.

Presence of Optimism. There is ample evidence that individuals are optimistic most of the time as evidenced by their mis-estimation of the length of future tasks (Roy, et al., 2005), their personal abilities (Russo & Schoemaker, 1992), their knowledge about history (Hubbard, 2007), whether or not they will complete their academic thesis on time (Buehler, et al 1994), their favorite sports team (Babad, 1987), and their sense of humor (Matlin, 2006). The German author Johann Wolfgang von Goethe said "For a man to achieve all that is demanded of him he must regard himself as greater than he is." Society rewards those who are optimistic and frowns upon those who are pessimistic. If a person always underestimates themselves then it will be difficult for them to achieve the extraordinary. This demonstrates a contrast that involves the benefits and drawbacks of being optimistic. In the next section, we provide a methodology for quantifying optimism bias in order to measure its frequency among different professions.

Quantifying Optimism Bias

Considering the disadvantages of optimism in a variety of situations, it is important to understand when it is present so that it can be managed. To identify the presence of optimism, we provide two-dimensional scale that can be used to compare a person's confidence about a certain estimate versus the accuracy of an actual estimate. It was originally developed for assessing the accuracy of weather reporters in the 1950's (Brier, 1950) and is shown in Figure 1.
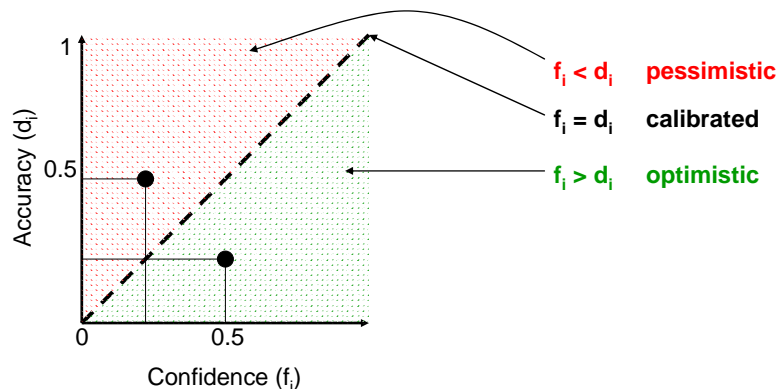

Figure 1. Confidence vs. Accuracy Dimensions

A perfectly calibrated person is someone that consistently falls along the diagonal ($f_i = d_i$). This means that if their confidence about a quantity is 50%, they are actually correct 50% of the time. Whenever their confidence (f_i) is greater that their accuracy (d_i), that person is considered to be optimistic. If the opposite is true, that person is considered to be pessimistic. A Brier score can be calculated for each individual as represented in Figure 2.

$$Brier\_score = \left(\frac{1}{N}\right)\sum_{i=1}^{N}(f_i - d_i)^2$$

f_i = respondent's probability that their judgment is correct
d_i = outcome of the respondent's accuracy
N = total number of judgments

Where
f_i is a subjective probability
d_i is an objective (empirical) probability

Figure 2. Brier Score

A higher Brier score indicates a greater distance from the diagonal, which may indicate optimism or pessimism. The judgments of a well-calibrated person would consistently fall along the diagonal, that is, their subjective probabilities would consistently match the empirical probabilities of events. The notion of being well-calibrated is not only an aspect of personality, it is also affected by a person's profession. We now explore how the phenomenon of optimism within systems engineers as well as other professions.

Optimism in Systems Engineers. In order to develop insight about optimism bias, a survey was administered to eighty systems engineers attending the 2008 INCOSE Symposium in Utrecht. A mixed group of both practitioners and academics made up the population, ranging in experience levels from relatively new in the community to well-informed experts. The goal of the survey was to gather a quantitative understanding about systems engineering estimation bias at the 90% confidence interval and at varied confidence levels – with the general hypothesis that systems engineers are inherently optimistic.

The survey (provided in Appendix A) consisted of two sections, each comprising of ten questions. Participants were informed that the survey was voluntary, and they were also made aware that understanding estimation habits – not testing intelligence – was the intent of the exercise. Participants were not allowed to consult other people or the internet for assistance, and they were advised that the survey should take approximately three minutes. The questions were not scientific in nature, but rather were common knowledge questions that all systems engineers at the conference should have had relatively the same exposure and ability to answer. For instance, participants were asked to estimate the population of China in the first section and asked whether or not Italy beat Brazil in the last World Cup Final in the second section. We now expand more on the goals and results of each respective section.

The first section of the survey asked participants to provide a 90% confidence interval of their certainty to the answers of ten different common knowledge questions. In short, they were to provide a "lower bound" and an "upper bound" in which they were to be 90% certain that their answer to the question would lie within that range. For example, one of the questions asked was "How many days does it actually take the Moon to orbit the Earth?" If one were to think the answer was 27 days, a typical confidence interval may have been 25 to 31 days, or some other range depending on the individual and their degree of certainty.

In order to depict the results from this set of questions, a histogram was created to show the scores of the eighty participants across the range of possible accuracy levels (0% to 100%). In the cases where participants failed to answer certain questions, those that went unanswered were not counted and their overall score was rounded up to the nearest 10%. By rounding up we ensured that the results were not slanted to show optimism. In theory, all eighty participants would have been in the 90% category or at least distributed around the 90% category. However, as shown in Figure 3, most systems engineers were around 30% correct when they should have demonstrated 90% accuracy in their estimates. This illustrates a significant degree of optimism to the extent that only one participant was actually met the 90% accuracy target.
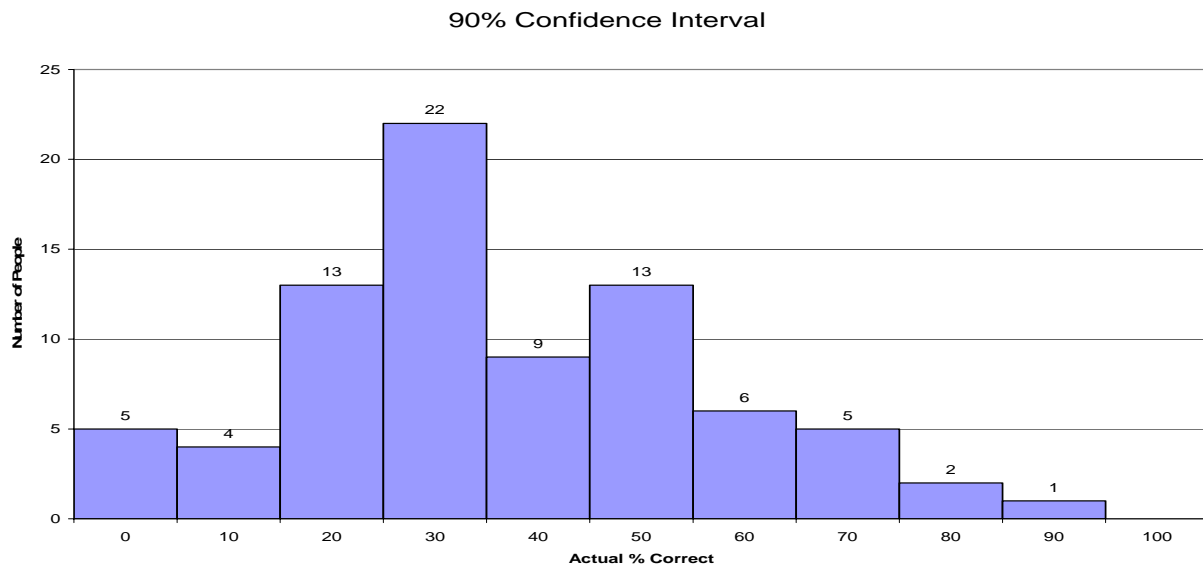
90% Confidence Interval

Figure 3. Results from 90% Confidence Interval Survey

Understanding the optimism bias of individual systems engineers with respect to a set accuracy target, we now visit the second section of the survey to examine the extent of estimation bias across a range of confidence levels.

The second section asked participants to provide a binary response, true or false, to ten common knowledge statements; and provide a confidence level between 50 and 100%. The lower bound to the confidence level is 50% because if one were less than 50% confident the answer was true, that would be equivalent to indicating they were more than 50% confident the answer was false. Thus, a truly unknown statement, such as "The coin will land on heads," should yield either 50% certainty of true or false from any rational decision maker.

The results of the second section can best be summarized in the form of the accuracy with respect to confidence diagram shown in Figure 4. In order to construct a similar diagram, the entire pool of answers from the eighty participants was segmented according to the confidence levels declared, and then grouped on the chart seen in Figure 4 with respect to their cumulative accuracy (i.e. point "(50, 49.4) n=176" reads – when 176 people asserted to be 50% confident in an answer, they were correct 49.4% of the time).
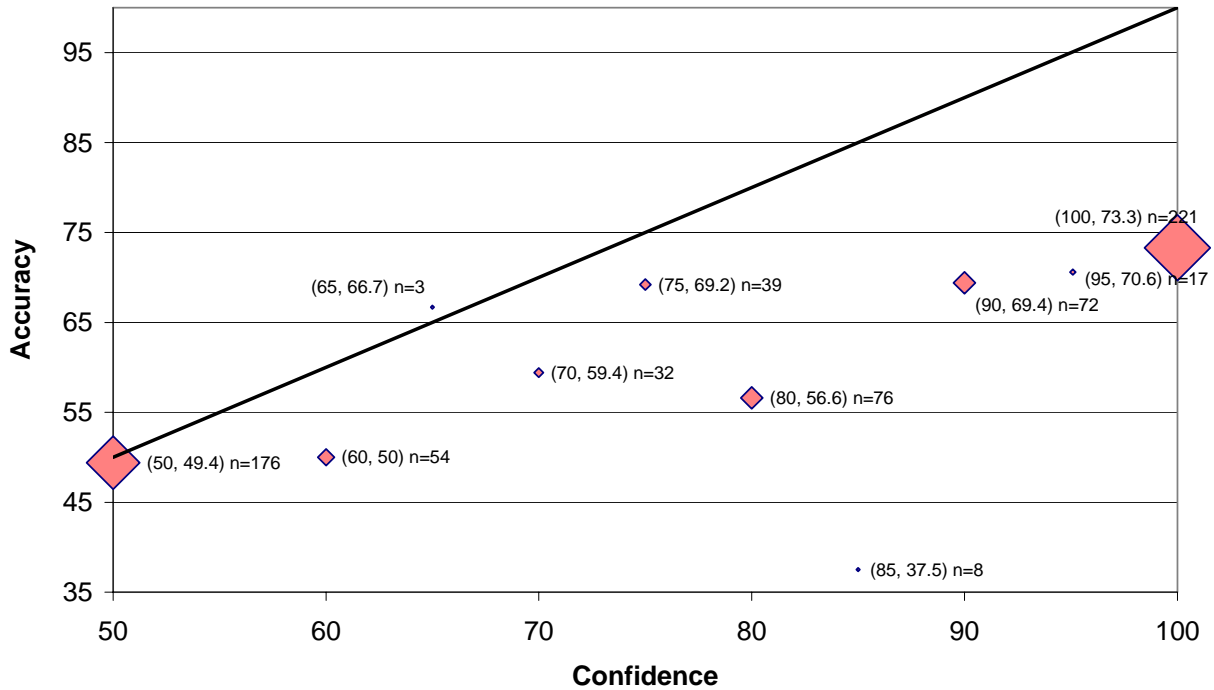
Accuracy vs. Confidence Estimates

Figure 4. Results from Accuracy vs. Confidence Survey

In general, this figure depicts that as confidence increases, accuracy diverges significantly from the perfectly calibrated diagonal where confidence equals actual. Note that the two clear outliers, (65, 66.7) and (85, 37.5), had too few samples, 3 and 8 respectively, to be statistically significant.

Results from these two sets of questions support our general hypothesis that systems engineers are inherently optimistic in estimation practice. With this understanding now accepted, we focus our attention on addressing the question – *how do systems engineers better manage optimism?* Since optimistic estimates about a program's cost, schedule, effort, or other attributes could lead to unattainable situations for decision makers, it is imperative that systems engineers are aware of this optimism phenomenon. As we can see from Figures 3 and 4, there are no general rules of thumb that can (or should) accurately be employed in attempts to discount the affect of optimism in an estimation. Rather, it is important that systems engineers take the time to engage in estimation exercises that move them closer to the calibration line discussed above. In fact, calibration seminars exist that use similar questions to those employed in our survey to help individuals learn a better understanding for connecting subjective probabilities and objective outcomes. A future paper will describe a specific calibration process that systems engineers can follow. Now that we have quantitatively demonstrated optimism in systems engineers, we will discuss trends in other notable professions.

Difference Across Professions. When one considers the calibration studies of doctors, accountants, IT professionals, strategists, analysts, and psychologists it is common to see optimistic bias. One of the corrections for this is to provide training on calibration, similar to that mentioned above, so that individuals can reduce their level of optimism. However, each of these professions has their own incentives for being calibrated judges of certain types of events. Accountants, IT professionals, strategists, and analysts may greatly benefit from being less optimistic, while doctors and psychologists may simply need to decide when to turn "on" or "off" their optimism depending on a particular patient's situation. Optimism of doctors has been shown to improve the psychological and physical health outcomes of their patients (Kubzansky, et al 2004). However, doctors are careful not to communicate a false sense of optimism in cases where expectations of eventual success are sufficiently unfavorable (Peterson & Bossio, 1991; Scheier & Carver, 1987). Optimism in health care presents a different environment for considering calibration because it has less to do with comparing confidence to accuracy and more to do with treating each case as unique given the scientific facts and knowing when it is reasonable to be optimistic based on experience with particular diseases.

There are other professions that can never afford to be optimistic because of the asymmetrical costs of the outcomes. We consider these to be well-calibrated professions: bookies and weather reporters. These professions are unique for three reasons. First, they receive immediate feedback on whether their predictions are correct or not based on the comparison between their confidence levels and the occurrence of actual events. Second, providing accurate predictions have career rewards. Bookies have financial incentives to be calibrated because they can earn more money when they are more realistic in the probabilities of sporting events. Weather reporters that are more accurate tend to earn respect in their field and may get promoted faster. Third, they do not overreact to extreme events since they understand that outcomes will eventually regress towards the mean. For example, bookies appreciate the fact that chance events make outcomes an imperfect measure of abilities (Lee & Smith, 2002). Weather reporters similarly understand that certain weather conditions are anomalies and damage can sometimes be concentrated on a small geographical area. This has created the need for specifically targeted weather alerts that do not affect large geographical regions.

Bookies do not want their profits to depend on the outcome of games. In American football, their objective is to set a point spread to equalize the number of dollars wagered on each team and to set the total line to equalize the number of dollars wagered "over and under" which relates not to which team wins and by how much, but to the total number of points scored by both teams. Bookies attempt to account for all of the factors that gamblers take into account: player strengths and weaknesses, injuries, home-field advantage, and historic rivalries. If bookies are aware of systematic bettor irrationalities, they will also take these into account (Bird & McCrae, 1987; Bruce & Johnson 2000). The ability to adjust their level of optimism based on what others think the outcome will be is certainly a learned skill that is perfected over time.

Conversely to bookies and weather reporters, some historically not well calibrated professions include those who are forced to bid on proposals. For example, in software project bidding, engineers and managers tend to have over-optimistic cost estimates. Jorgensen (2009) explains how the bidding process makes this profession especially susceptible to a variety of factors that breed optimism, two of which are referred to in economics as the "winners' curse" and "adverse

selection." Winners' curse occurs in bidding auctions when there are many bidders, wherein economic theory dictates that one is likely "to win only when being over-optimistic about the value of the bidding object (Jorgensen, 2009)" Thus, there is a great chance that the lowest bidder cannot actually deliver the promised low cost. With respect to adverse selection, the theory can be read that those with lower bids are more likely to be less competent. The more competent bidders that understand the problem better will have a higher bid – acknowledging the higher development cost which will ultimately yield lower lifecycle costs (Jorgensen, 2009). The prime take-away from understanding is that the bidding process needs a selection mechanism in place that accounts for these potential optimism induced phenomena and mitigates its effects.

The question becomes: *how can systems engineers be more like bookies or weather reporters and less like software project bidders in their judgments of probabilities?* By examining the performance of a field that relies more on scientific measurement – weather forecasting – we can gain an appreciation for the promise of calibration. The data for the weather reporters demonstrates that their predictions exactly match what actually happened for very large samples of predictions, as shown in Figure 5.
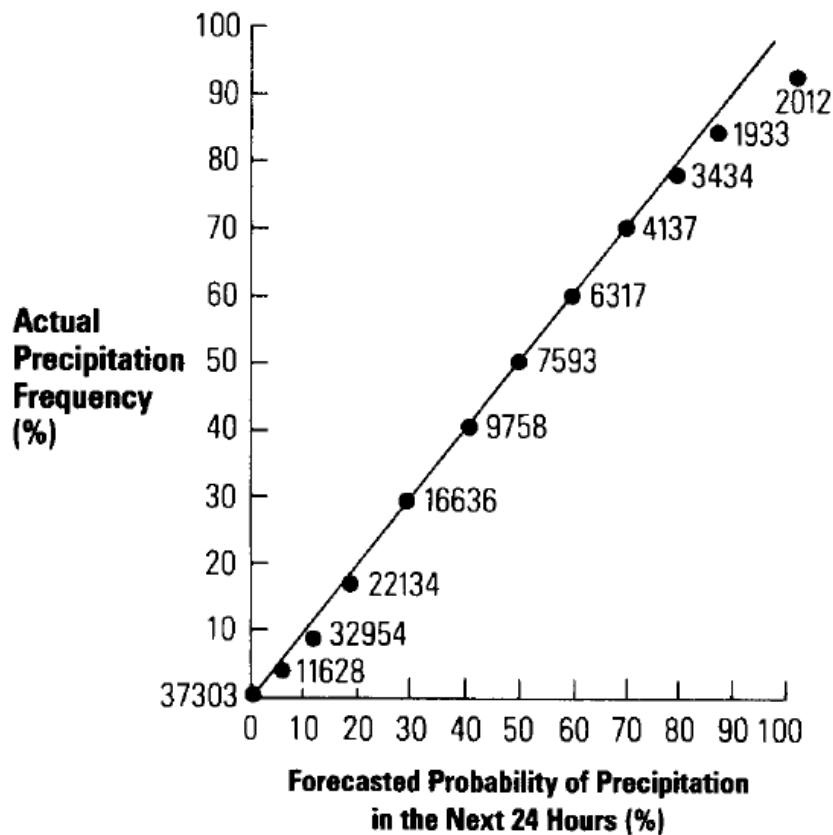

Figure 5. U.S. Weather Service Forecasting Accuracy (Murphy & Winkler, 1984)

It should be noted that the 100% prediction estimates resulted in 90% precipitation. This is reasonable considering most weather reporters are significantly accurate for all other confidence levels. But weather reporters are trained to do this deliberately because the penalties of

predicting that it is going to rain 90% of the time are asymmetrical. If people interpret this as a 10% probability of no rain then there is a chance that at least some of them will decide not to carry an umbrella when they go outside. To avoid this, weather reporters adjust their prediction to 100% chance of rain in order to encourage people to carry their umbrellas and prepare for at least some rain. In the event that the 10% chance of no rain actually takes place it becomes only a slight inconvenience for those carrying umbrellas.

Optimizing Optimism

Can we calibrate systems engineers to become less optimistic? The answer is yes, not only mathematically, but there are several strategies that can help people be less optimistic about the weather, the performance of their favorite sports team, etc. Some of these strategies are presented here but it is up to individuals to decide which are most appropriate for their circumstances. A method for combining some of these strategies is likely to work the best.

The simplest technique is betting money or pretending to bet money. One study showed that people do not necessarily have to bet money, as long as you pretend to bet money their accuracy automatically improves (Bukszar, 2003). Pretending that there is money involved tends to help individuals be more realistic judges of events because they associate their accuracy with a financial reward.

Another technique is to separate the observation from the task itself so that judgments can be made independent of outcome. One study found that separating "doing" from "observing" a task has an impact on optimism. Actually doing a task makes individuals more optimistic compared to those that simply observe it (Koehler & Harvey, 1997). Decision makers can reduce their optimism simply by removing themselves from tasks and position themselves as neutral observers.

There are many things to learn from people that are well calibrated and the underlying reasons for their accuracy. It is clear that personality plays a significant role, but professions – and associated rewards structures – also determine how well a person is calibrated. In some circumstances, optimism may lead to positive results in areas such as mental and physical health while in others it can lead to financial disaster. The medical profession has learned to manage optimism so that it is present when it is needed and absent when it may give a sense of false hope. With respect to the systems engineering community, one might relate implement best practices similar to those of more calibrated professions discussed above, such as: (1) constantly providing mechanisms of feedback about prior estimates, (2) creating an incentive structure that values accuracy in estimation, and (3) ensuring there is no over reaction to atypical events. In the next section, we further explore the notion of optimism calibration by performing a simple calibration exercise.

Optimism Calibration

In order to better understand the phenomenon of optimism calibration, we performed a trial calibration exercise on a group of systems engineering students in an MIT graduate class – Cost Estimation and Measurement Systems. The sample size consisted of five students, which although small, can still provide valuable insight. Moreover, this exercise was performed at the

end of the course, such that students were well educated with respect to estimation methods and principles. Next, we discuss the process we took to calibrate the students and the results from the exercise. The questions and answer forms used for this exercise can be made available upon request.

First, at the end of one class students were informed how to fill out the calibration answer form (similar to those given to the INCOSE population) for both 90% confidence interval and binary questions. Ten confidence interval and ten binary questions were asked to each students for the first round. Next, everyone was shown the results of the first round of the INCOSE exercise, wherein we facilitated a review of the optimism phenomenon that was seen, as is discussed above in this paper. Students were then shown the results from their original trial – in the same format as the results from the INCOSE population. After discussing optimism similarities to the INCOSE group, despite a smaller sample size, we reviewed some of the principles identified in this paper – pertaining to underlying reasons for optimism as well as some of the strategies for improvement.

Once this discussion concluded, the students were asked to complete twenty more confidence interval and twenty more binary questions. While they were shown their results relative to round 1, it was consensus opinion that there had been some improvement. In the ensuing discussion improvement strategies were again considered, such as pretending to bet money. Moreover, it was noted that the constant reinforcement of seeing scores immediately after testing improved the group's confidence in understanding their estimation capabilities and limitations.

Finally, a third round of questioning was performed, which similarly to round 2 consisted of twenty final confidence interval questions and twenty final binary questions. Following the expected trend, the group again came to the conclusion that noticeable improvements in calibration had been made. In the final discussion, we considered the variability across participants – who seemed to improve the most and why. In general, it was believed that the more cognizant one was of their estimation habits and improvement methods, the more they were able to improve. Those who saw minimal improvements believed they did so because they had an exceptional first round, either by good estimation or due to the smaller amount of questions. The group results are discussed below, and can be seen in Figure 6 and Figure 7.
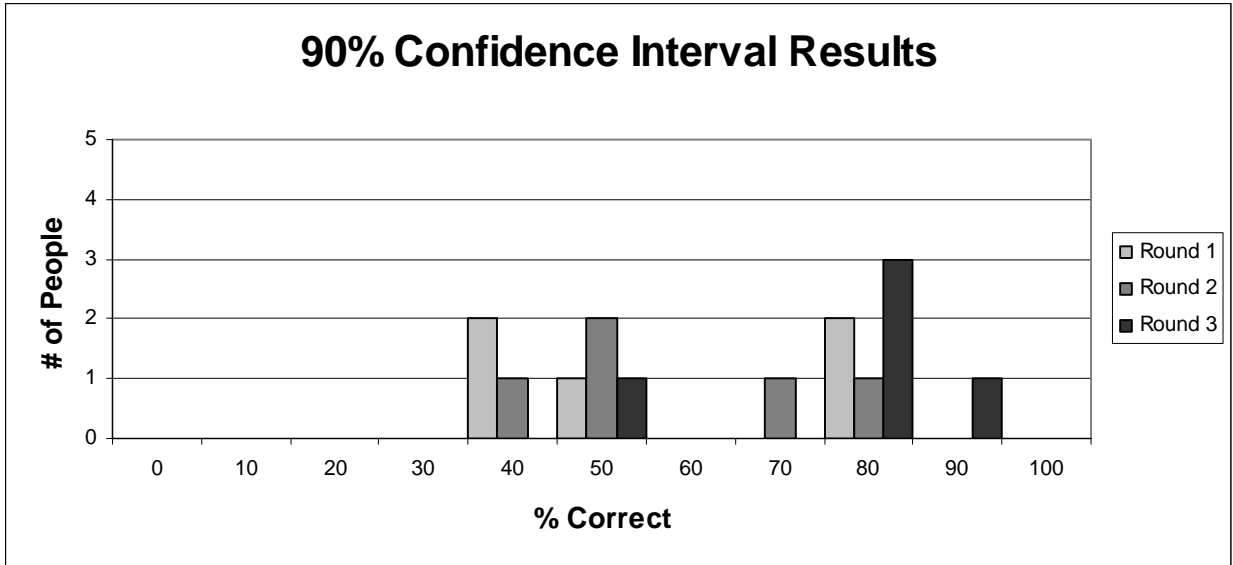
90% Confidence Interval Results

Figure 6. Class Calibration Exercise – 90% Confidence Intervals over Three Rounds

With respect to the calibration exercise, one can see a slight improvement from round one to two, and a more noticeable improvement from round two to three. In fact, we note that four of the five students achieved 80% or higher accuracy in the third round, whereas only two students were at 80% accuracy in round one. However, since only one student was at 90% accuracy by round three there are obviously improvements that can be made. At the end of the session, we discussed the concept of anchoring, which often throws off many confidence interval estimators. This phenomenon occurs when estimators think of the answer, and then add and subtract error accordingly. Although this strategy seems intuitively acceptable, it often yields tighter ranges than appropriate for 90% confidence. A more beneficial strategy for this exercise pertains to thinking about upper and lower bounds individually – by declaring you are 95% certain the answer lies below your upper bound and 95% certain the answer lies above your lower bound – as opposed to focusing on a central arbitrary number.
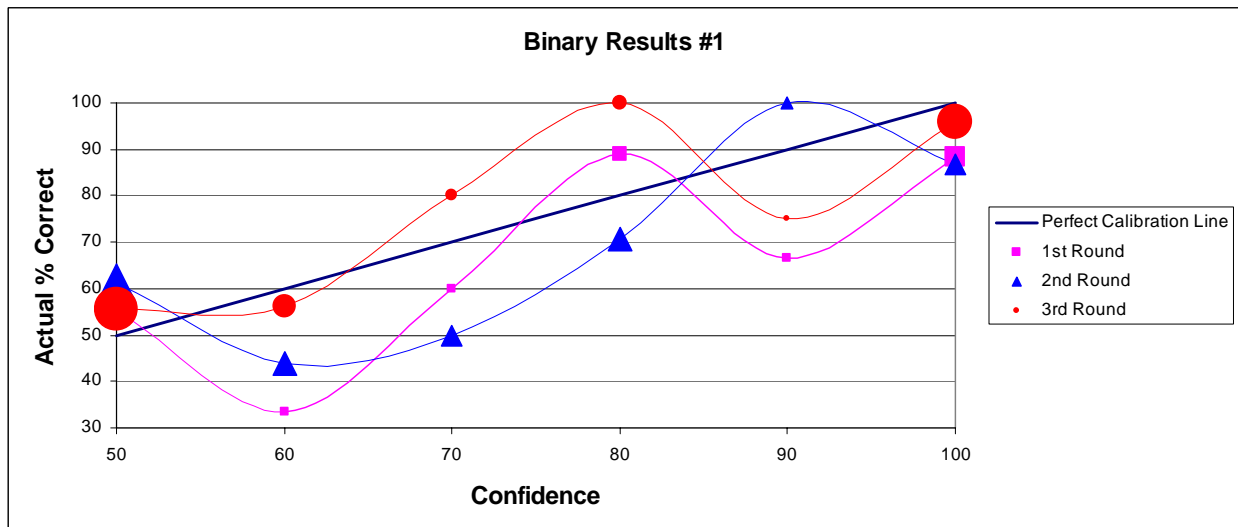
Figure 7. Class Calibration Exercise – Accuracy vs. Confidence over Three Rounds

Regarding the group binary results, there was also fair improvements. Most notably, the confidence levels that accumulated the most data points – 50% and 100% – saw improvements from round 1 to round 3. Additionally, the 60% confidence interval saw significant improvements from round 1 to 3, despite less data points than the 50% and 100% levels. In general, the 70%, 80% and 90% points were less clear – or failed to show improvements. Conversely, if one were to combine results from round two and three for a more statistically relevant depiction of estimation accuracy relative to round one, it appears the results would fall much closer to the perfectly calibrated line. Moreover, an interesting result of this exercise was the fluctuation between optimism and pessimism throughout the exercise, a result we hypothesize can be attributed to optimism bias over-compensation. However, with the exception of the 50% confidence interval, most all other pessimistic points (those lying above the calibration line) had less data points than their optimistic counterparts.

From the positive results of this exercise, we believe similar practices and techniques can be used to calibrate systems engineers. Although there could be some logistical concerns regarding data input and consolidation of larger groups, we believe this experiment can effectively be executed with a larger group. In short, even though the sample size was relatively small to yield definitive conclusions, insight from this exercise indicates that systems engineers can be calibrated for both better estimation accuracy and precision.

Conclusion

This paper involved organizing literature on happiness, judgment, decision making, meteorology, and gambling to explore the concept of optimism and consider a method to measure and calibrate it. A logical next step is the development of a formal methodology to train systems engineers in becoming better calibrated judges of future events.

One implication of this work is the ability to demonstrate that experience does not matter in terms of becoming a better judge. Common sense would suggest that more experienced professionals are better estimators but it can be shown that calibration exercises are an adequate substitute for experience. This understanding is important because it can save time, resources, and potential errors that may otherwise take decades to learn. Furthermore, this result would demonstrate that better calibrated people do not necessarily have better information or possess superior guessing skills, but that they are more in tune with their cognitive abilities and more realistic about their judgments – a skill that requires an understanding of the connection between subjective probabilities and objective outcomes.

Appendix A: Confidence Interval Survey

Estimation Survey
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INCOSE, June 2008

This is **not a test of intelligence**. Please answer each question below to the best of your knowledge. **Do not refer to a computer**, another person, or the internet for the answer. We are interested in your best estimate. This survey should take approximately **3 minutes** to complete.

Confidence Interval Questions

Please provide a "lower bound" and an "upper bound" answer for each question based on your 90% confidence level.

#	Question	Confidence Interval	
		Lower Bound	Upper Bound
1	In 1938 a British steam locomotive set a new speed record by going how fast (mph)?		
2	In what year did Sir Isaac Newton publish the universal laws of Gravitation?		
3	The Internet (then called the 'Arpanet') was established as a military communication system in what year?		
4	How many people attended the INCOSE 2007 Symposium in San Diego?		
5	As of mid 2007, what was the population of China?		
6	What is the distance between Amsterdam and Singapore (miles)?		
7	How many total members did INCOSE have as of December 2007?		
8	What percentage of a square could be covered by a circle of the same width?		
9	How many days does it actually take the Moon to orbit Earth?		
10	What year did NCOSE formally incorporate?		

Binary Questions

Please provide a "True" or "False" response to each question and your corresponding level of confidence in your answer on a range between 50% and 100%.

#	Statement	Confidence Interval	
		Answer (T/F)	Confidence (50-100%)
1	The ancient Romans were conquered by the ancient Greeks.		
2	"M" is one of the three most commonly used letters.		
3	A gallon of oil weighs less than a gallon of water.		
4	Mars is always further away from Earth than Venus.		
5	A kilogram is more than a pound.		
6	Two countries border the Netherlands.		
7	MIT & Harvard are both located in Cambridge, MA, USA		
8	In 2002 the price of the average new desktop computer purchased was under $1,500 (USD)		
9	The INCOSE Central Office is located in California, USA.		
10	Italy beat Brazil in the last World Cup.		

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