Communication of predictions: effects of anchors, frames, and expressions of uncertainty

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Summary

When you are reading the weather forecast, listening to experts on the radio predicting economical growth, or telling your friends that you think Barcelona will win the Champions League, you are involved in the communication of a prediction. This thesis investigates communicative influences on predictions, and the findings demonstrate that changes in the communicative situation (e.g., irrelevant numerical anchors, or the frame a prediction is presented in) can affect both the production and interpretation of predictions.

In Paper I, we explored potential communicative moderators of the anchoring effect, which occurs when an initial piece of information unduly influences subsequent judgments. Previous studies have found that the numerical preciseness of the anchoring value and the credibility of the source of the anchor can influence the anchoring effect. In three experiments with 381 software professionals as participants, we however found no evidence that numerical preciseness or source credibility affected the strength of the anchoring effect for predictions of software project effort. This might be due to the difference in domain from previous studies, which investigated domains where a correct answer exists. In such domains listeners may infer that speakers using precise numbers have knowledge about the correct value. Predictions of performance time, on the other hand, are fraught with uncertainty, and precise predictions may indicate overconfidence rather than expertise or knowledge. However, we found a strong anchoring effect, which demonstrates that unrealistic values introduced in communication can dramatically influence the prediction that is produced.

Paper II examined the context-dependency of performance time predictions and verbal probability expressions. Previous research has demonstrated that some verbal probability expressions (e.g., "possible") are associated with maximum outcomes, while other expressions (e.g., "certain") are associated with minimum outcomes. However, we found that the orientation of the time dimension can be influenced by using linguistic frames that focus on duration ("It is possible/certain that I will spend _____ hours on this task") or on speed ("It is possible/certain that I can do this task in _____ hours"). In the duration frame, a high number of hours indicates the maximum outcome (the highest duration), while in the speed frame, a high number may represent the minimum outcome (the lowest speed). Three experiments showed that *possible* was associated with high estimates and *certain* was associated with low estimates of performance time in the duration frame, while the speed frame led *possible* to be associated with low estimates and *certain* to be associated with high estimates.

The topic of Paper III was the uncertainty of predictions. Some theorists prefer to describe uncertainty as due to stochastic processes in the world (external uncertainty), while others define uncertainty as a subjective degree of knowledge or belief (internal uncertainty). This distinction is also found in natural language, with some expressions focusing on external uncertainty ("It is 70% certain", "There is a 70% probability") while other expressions are associated with internal uncertainty ("I am 70% certain"). Four experiments demonstrated that both speakers and listeners are sensitive to the external/internal distinction in communication of predictions. External expressions were seen as more informative and were thought to signal greater knowledge, while internal expressions were associated with personal interest and engagement. A lower numerical probability was deemed necessary to recommend an action when probability was framed as external rather than internal, perhaps due to the increased perceived "objectivity" of external expressions. Finally, while degree of internal certainty in predictions of real-world sports events was influenced by participants´ degree of interest in the events, there was no such association between interest and external certainty.

The findings of this thesis have important implications, both for speakers that want to ensure that their predictions are understood as intended, and for listeners that want to accurately understand predictions. The thesis draws on previous research on communicative influences on judgment and decision making to put the current findings into context. In particular, research on anchoring, framing, and communication of uncertainty are relevant, and some connections with research on psycholinguistics are also discussed.

List of Papers

I. Løhre, E., & Jørgensen, M. (submitted). The robustness of anchoring effects in project cost estimation.

II. Løhre, E., & Teigen, K. H. (2014). How fast can you (possibly) do it, or how long will it (certainly) take? Communicating uncertain estimates of performance time. *Acta Psychologica, 148*, 63-73. doi: 10.1016/j.actpsy.2014.01.005

III. Løhre, E., & Teigen, K. H. (submitted). There is a 60% probability, but I am 70% certain: Communicative consequences of external and internal expressions of uncertainty.

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Introduction

Predicting the future is a notoriously hard task, but nevertheless people make bold predictions on a regular basis. In fact, some researchers argue that our brains are continuously generating predictions and simulating possible futures to help guide our actions, so that we can approach situations that will be beneficial and avoid situations that will be negative (Bar, 2007; Gilbert & Wilson, 2007). Predictions are frequent both in professional settings (e.g., when a doctor tries to predict whether a particular treatment will be helpful for a patient, or when a software engineer estimates how long it will take to develop a software project) and in everyday life (e.g., when one tries to predict how a friend will react to a gift, or how much money one will spend on a vacation).

Although we sometimes predict privately and do not communicate our predictions to others, many predictions are made in a social, conversational context: you make a prediction of how long it will take you to get to work when your boss calls you to ask whether you will be there for the meeting, and you ask a real estate broker to predict how much your flat will sell for. In such cases, the communication of predictions is of importance. The receiver of a prediction wants to understand what the prediction means, and the producer of the prediction presumably wants to produce a prediction that agrees with the request the receiver made. Previous research on communication of predictions has mostly focused on the communication of risks associated with everything from nuclear power to climate change and medication use (e.g., Berry, Raynor, Knapp, & Bersellini, 2003; Budescu, Por, Broomell, & Smithson, 2014; Slovic, 1987), but there are also studies on the communication of positive or at least non-negative predictions, such as financial forecasts and predictions of benefits associated with different products in consumer contexts (e.g., Du, Budescu, Shelly, & Omer, 2011; Teigen & Filkuková, 2013). In this thesis, three papers that investigate different topics in communication of predictions are described. The current research shows how changes in the communicative situation can influence the prediction that is made (Paper I), and how subtle linguistic manipulations can change the way that speakers express and listeners understand both predictions and expressions of uncertainty in predictions (Paper II and Paper III).

In Paper I, we investigated the anchoring effect in predictions of performance time, and explored whether this effect is moderated by the numerical preciseness of the anchor and by the credibility of the source of the anchor. Although we found that introducing an irrelevant number in the communication context strongly influenced performance time predictions, neither of the proposed mediators strengthened or weakened this effect. Paper II showed that the meaning of a performance time prediction is highly context-dependent. The same numerical estimate (e.g., 8 hours) can be seen as a maximum or a minimum estimate, depending on whether the prediction is given a *duration* frame ("It is possible that the task takes 8 hours" = maximum estimate) or a *speed* frame ("It is possible that the task is done in 8 hours" = minimum estimate), and on the chosen verbal probability expression, e.g., *certain* vs. *possible*. Paper III focused on expressions of uncertainty, and found that people distinguish between uncertainty expressions implying external uncertainty due to stochastic processes that can be assessed in a frequentistic way (e.g. "There is a 60% probability) and expressions that imply internal uncertainty due to incomplete knowledge that are assessed in a subjective way (e.g., "I am 60% certain"). External expressions were seen as more objective and trustworthy, while internal expressions were seen as more valid indicators of characteristics of the speaker.

In the following, I will first briefly discuss some central issues in the psychological research on predictions. Next, some relevant theoretical perspectives for this thesis will be introduced. Here, I will first discuss communication generally and communication of predictions more specifically, before I review empirical findings and relevant theoretical background for three specific topics that are investigated in the three papers, namely anchoring, framing, and expressions of uncertainty. After some methodological considerations and a summary of the papers, I will proceed to the general discussion. In the discussion I attempt to put the current studies in a broader context, to review theoretical insights and applied implications of the findings, and to discuss some potential directions for future research.

Predictions

A prediction (sometimes called a forecast, or an estimate) can be defined as a belief about the probability of some future event (Fischhoff, 1994). A prediction can be more or less informed, and can be based on previous experience, statistical models, expert advice, inferences from perceived causal relationships, or just be a simple guess. One can distinguish between two types of predictions: categorical and numerical predictions (Kahneman & Tversky, 1973). Categorical predictions concern events on the nominal level, for instance, whether or not a presidential candidate will win the election, or whether or not a medical treatment will be successful. Numerical predictions involve numerical quantities, be it money ("I believe the trip to Moscow will cost me more than 1500 €"), time ("It will probably take us 2 to 4 hours to drive to your grandmother"), or number of attendees ("We expect about 200 people to show up for the concert"). Both categorical and numerical predictions are investigated in this thesis, but most attention is given to one kind of numerical predictions, namely predictions of task performance time (Halkjelsvik & Jørgensen, 2012).

Predictions have been extensively studied in psychology, and particular attention has been given to accuracy and bias in prediction. Dunning (2007) concludes that overall, people´s predictions tend to be inaccurate and overoptimistic (however, for examples of accurate predictions, see Griffiths & Tenenbaum, 2006), and that people in addition tend to be overconfident about the accuracy of their predictions. A well-known example of the overoptimism of predictions is the so-called planning fallacy (Buehler, Griffin, & Peetz, 2010; Buehler, Griffin, & Ross, 1994), which refers to the finding that people usually give too optimistic estimates of when they will finish a given task, even when they have experience with performing similar tasks and should know that their predictions are optimistic. Although a degree of optimism may be associated with positive outcomes such as greater motivation, more effective performance, and greater persistence at a task (Taylor & Brown, 1988), optimistic and overconfident predictions can of course also have negative effects both in business and in daily life, such as disappointment or regret when outcome expectations are not met (Carroll, Sweeny, & Shepperd, 2006). For example, if a software company is hired to develop a project, and their prediction of the time it will take to complete the project is too low, the result might be reductions in quality, budget overruns, delays, and customer dissatisfaction.

The optimism and overconfidence of predictions may stem from the way in which predictions are made. There is substantial support for the claim that people usually make predictions by constructing scenarios, that is, through building causal chains from the current conditions that would lead to a specific outcome (Dunning, 2007). In other words, people are too often taking an "inside view", where they base their predictions on one or a few scenarios for how a specific outcome might be caused, rather than taking an "outside view" where an event is seen as one example of a set of similar events, and a prediction is based on the outcomes of previous similar events (Kahneman & Lovallo, 1993; Lagnado & Sloman, 2004). Dunning (2007) concludes that scenario building is of limited utility because people build incomplete scenarios in which they focus on central outcomes and neglect alternatives, focus on optimistic and neglect pessimistic scenarios, and focus on the strength but neglect the weight of evidence.

For numerical predictions, the scenario building approach does not clearly explicate how a constructed scenario is translated to a specific numerical prediction. The metrics and mappings model (Brown, 2002; Brown & Siegler, 1993), developed in the context of real-world quantitative estimation under uncertainty (e.g., how people come up with numerical estimates of the populations of different countries), may give some insight into how people settle on a specific numerical prediction. In this model, it is assumed that estimates are based on knowledge of distributional properties (metrics) and knowledge of relations between different entities in the distribution (mappings). The specific numerical estimate is then produced through a retrieval-inference cycle. To exemplify, if you are asked what the population of Krakow is, you retrieve related information, and if the information seems relevant, you make a plausible inference based on the retrieved information. For instance, since you know that Poland is a quite large European country, and that Krakow is one of the most famous cities in Poland, you believe that it is not a very small city, and you may infer that it has at least 400.000 inhabitants. Through such inferences, you can establish an upper or lower limit, or restrict the range of possible responses, and this retrieval-inference cycle is repeated until a satisfactory answer has been reached. One could easily imagine a similar process for numerical predictions. This model of course does not exclude that scenario building is involved in numerical prediction (a plausible inference could be based on a scenario, or could be part of building a scenario), but goes a step further in specifying the different steps in the prediction process for numerical predictions.

As a final point in this section, it should be emphasized that the concept of *uncertainty* is an important part of the definition of a prediction. If a prediction is a belief about the probability of some future event, then the assigned probability represents the uncertainty of a prediction. Formally, uncertainty can thus be assigned a numerical value between 0 and 1, with 0 indicating (a belief) that an event definitely not will happen, while 1 indicates (a belief) that the event definitely will happen. Psychologically, however, the concept of uncertainty may be more complicated. Lipshitz and Strauss (1997) reviewed a variety of definitions of uncertainty in the judgment and decision making field, and suggested that uncertainty that influences decision making can broadly be defined as "a sense of doubt that blocks or delays action" (p. 150). Arguably, this "sense of doubt" can be said to stem from a lack of information (e.g., a lack of information because of the stochastic nature of an event, or a personal lack of knowledge about the object of prediction, for instance because the information is hard to obtain). Although recent research suggests that uncertainty can intensify both positive and negative affect (Bar-Anan, Wilson, & Gilbert, 2009), uncertainty is generally thought to be an aversive state that people are motivated to reduce in different ways (Neace, Deer, Michaud, & Bolling, 2011). With the fundamental uncertainty of the future in mind, it should be clear that the inaccuracy of predictions is not only due to incomplete scenario building. Even if we took an outside view and adopted all the currently recommended strategies, our predictions might still fail spectacularly due to their inherent uncertainty.

Theoretical background: Topics in communication of predictions

In many circumstances predictions may be expressed implicitly through the choice of a particular course of action. For instance, if I choose not to get car insurance for my rental car on a vacation, this may be seen as expressing my belief that it is highly unlikely that I will be involved in an accident, and when I choose to take an umbrella with me, it indicates that I predict that it will probably rain. In this thesis, however, the topic is explicit predictions, that is, statements that convey a belief about the probability of a future event. Such explicit predictions are stated through the use of words and/or numbers, and can easily be viewed from a communicative perspective.

In general, communication can be seen as a process in which a speaker uses some verbal symbols to convey what she means to a listener, and the listener then has to decode the symbols to understand the speaker´s intended meaning (Fiedler, 2008). Since a word (or a sentence) often can have multiple meanings, the process of comprehension in modern theories is often seen as a dynamical, context-driven process, in which multiple meanings of a word are simultaneously activated, but the context constrains the possible interpretations in a probabilistic fashion until the listener has arrived at an understanding (Altmann, 1998; Elman, Hare, & McRae, 2004). In addition to the complex "decoding" of ambiguous words or sentences, successful communication more often than not requires that the listener goes beyond the literal meaning of the speaker´s statement (Wänke, 2007). The listener makes pragmatic inferences based on the principles of conversational logic (Grice, 1975) to arrive at an understanding of the speaker´s *intended* meaning instead of simply relying on the literal meaning of a statement. As this very brief overview shows, communication is a complex process that has inspired a broad range of research from linguists, psychologists, philosophers, and anything in between. It is beyond the scope of this thesis to give a more complete description of the research on communication in general, but I will return to some of the topics mentioned in this paragraph in the general discussion to shed light on the findings of the three papers in this thesis.

Going from communication in general to communication of predictions, the task of communicating a prediction requires, according to Fischhoff (1994), that it is clearly stated what events are being predicted and how likely they are thought to be, and that the prediction addresses the recipient´s needs. This might seem like a straightforward task, but complexities and misunderstandings can arise at different stages in the communication process. For example, the recipient of a prediction might misunderstand which class of events the probability of a prediction is referring to, such as when the statement "There is a 30% chance of rain tomorrow" is misinterpreted to mean that it will rain 30% of the time or in 30% of the area (Gigerenzer, Hertwig, van den Broek, Fasolo, & Katsikopoulos, 2005). Similarly, listeners may misunderstand verbal expressions of probability. For instance, the Intergovernmental Panel on Climate Change (IPCC) has issued guidelines for communicating the uncertainty of climate change predictions using verbal probability expressions. However, in a large study including participants from 25 different countries, a "very likely" climate change was interpreted to have less than 70% probability of occurring by half of the participants, instead of a probability of more than 90%, as intended by the IPCC (Budescu et al., 2014). Such misinterpretations of the probability of climate change could possibly make people less willing to respond to initiatives to reduce carbon gas emission.

Communication effects can also be important for the production of a prediction. A prediction is often made because someone requests it, and as the literature on response format effects shows (e.g., Schwarz, 1999), the way a request is made might influence the answer that is given. For instance, for predictions of task performance time it has been shown that changing the question from the traditional "How many minutes will it take you to read X pages?" to the alternative formulation "How many pages can you read in X minutes?" strongly influences predictions (Halkjelsvik, Jørgensen, & Teigen, 2011). Participants gave higher productivity estimates (amount of work per unit of time) for larger than for smaller tasks with the traditional request format, but the pattern was reversed with the alternative request format.

Another problem in communication of predictions can occur when the speaker´s prediction does not address the listener´s needs. For instance, it has been shown that listeners who are uncertain about travelling distances and times prefer to receive upper limit estimates ("The hike will take less than 4 hours"), but uncertain speakers prefer to give their predictions about the same quantities using lower limit estimates ("The hike takes more than 3 hours") (Halberg, Teigen, & Fostervold, 2009). This discrepancy between listeners´ and speakers´ preferences probably occurs because speakers are not only concerned about providing the most informative statement; they are also concerned about not being wrong. A speaker saying that it will take “more than 3 hours” will be right if the hike takes 3, 4, 5, or 10 hours, while a speaker saying it will take “less than 4 hours” has a smaller chance of being right.

The three papers in this thesis investigate predictions in communication both from the speaker´s and from the listener´s point of view, and explore how the prediction that is produced can be influenced by communicative factors, and how, in turn, listeners´ interpretations of a prediction can change when the prediction is expressed in slightly different ways. In the following sections I will go more into detail in reviewing three topics that are addressed in the three papers that form the basis of this thesis: anchoring (Paper I), framing (Paper II and Paper III), and expressions of uncertainty (Paper II and Paper III).

Anchoring

Imagine that someone asks you whether you think that Gandhi was older or younger than 140 years old when he died. Undoubtedly, you would say that he was younger than 140 years, and you would probably think this was a stupid question. Nevertheless, research shows that if you are then asked how old Gandhi actually was when he died, your numerical estimate usually ends up being much higher than it would have been if you hadn´t been asked this “stupid question” first. This effect of initially encountered, irrelevant information on subsequent judgments is known as the anchoring effect (Tversky & Kahneman, 1974), and is one of the most robust research findings within the field of judgment and decision making, and indeed more generally in experimental psychology (Klein et al., 2014). In the traditional experimental paradigm, anchoring is investigated through asking participants to give answers to general knowledge questions (e.g., “What is the length of the Mississippi river?”, “How old was Gandhi when he died?”), after they have been exposed to irrelevant numerical anchors that are either higher or lower than the correct answer. Generally, participants give answers that are higher after exposure to and rejection of a high anchor than after exposure to and rejection of a low anchor.

The initial explanation of the anchoring effect focused on insufficient adjustment: people find the anchoring value to be too high or too low, but fail to adjust sufficiently when they are giving their answer (Tversky & Kahneman, 1974). This explanation has later been found to be relevant for self-generated anchors, but not for the experimenter-provided anchors that are more commonly used in the literature (Epley & Gilovich, 2001). Currently, perhaps the most generally acknowledged explanation of the anchoring effect is the selective accessibility model (Mussweiler & Strack, 2001), which posits that exposure to an anchor value makes participants consider this value as a possible answer to the question. A process of confirmatory hypothesis testing (Klayman & Ha, 1987) leads participants to retrieve knowledge consistent with the suggested value, and the increased accessibility of this knowledge at the time that the final judgment is made, makes the final judgment closer to the anchor value than it otherwise would have been.

In traditional studies on anchoring, researchers often do their best to minimize the communicative aspects of anchoring, for instance by introducing anchors as randomly selected numbers from a (rigged) wheel of fortune, or by using digits from the participants' social security number as anchors. In this way, researchers try to demonstrate the "irrationality" of the anchoring effect: if a judgment under uncertainty is influenced by a number that is totally irrelevant for the judgment in question, this is arguably more irrational than a judgment being influenced by a more relevant number. However, even though researchers do their best to convince participants that a numerical anchor is irrelevant, communicative influences may still come into play, since it would violate many principles of conversational logic to introduce a completely irrelevant number into a conversation (Kahneman & Tversky, 1982). Furthermore, in real-life settings, numerical anchors are arguably more often introduced as (more or less) relevant parts of a conversation, and in such cases, one could argue that anchoring could be viewed as a communication process.

An alternative theory, the attitude change approach (Wegener, Petty, Detweiler-Bedell, & Jarvis, 2001), agrees with this view, and focuses on communicative aspects of anchoring. The theory sees a parallel between research on attitude change and research on anchoring in that both of these research traditions are concerned with presenting someone with a message (an argument or a numerical value) that is somewhat different from their own opinion. Attitude change research has found a number of factors that moderate whether or not such a message will be successful in influencing the attitudes of the receiver, and consequently the same factors may moderate anchoring effects. In addition, attitude change theory stresses that the same message, or in this context, the same anchor, may be processed more or less thoughtfully, and that different types of processing can lead to different effects on judgment. For instance, anchors that are processed more thoughtfully may lead to longer lasting impacts on judgments.

There are a few studies that demonstrate the relevance of the anchoring effect for the communication of numerical predictions. For instance, predictions of task performance time can be strongly influenced by numerical anchors. In one study, when a group of software professionals and computer science students was told that a client believed that 50 hours would be a reasonable estimate for a software project, their predictions of how much time the task would actually take were much lower than the predictions of another group that was informed that the client believed that 1000 hours would be a reasonable estimate for the same project (Jørgensen & Sjøberg, 2004). Paper I also investigated the effect of numerical anchors on predictions of performance time, and explored whether the numerical preciseness of the anchor and the credibility of the source of the anchor can influence the strength of the anchoring effect.

It should also be mentioned that a prediction might function as an anchor in itself. For example, one study showed that participants' expectations of future weather conditions can be influenced by the numerical information they are given (Joslyn, Savelli, & Nadav-Greenberg, 2011). Presenting a "worst case"-scenario weather forecast (e.g., "a 10% chance that high wind speed will be greater than 27 knots") in addition to the most likely forecast led to biased understanding of future weather conditions, compared to presenting only the most likely forecast, or presenting both a "worst case"- and a "best case"-scenario. The participants´ expectations of future wind speed were (too strongly) anchored on the quite unlikely "worst case"-scenario, and the authors suggest that giving information about only one bound of an uncertainty interval can mislead the users of a forecast. Another illustration of how predictions may function as anchors is "Parkinson´s law", which states that work expands to fill the time available for its completion. In other words, if it a task performance time prediction is too high, workers may spend more time than necessary on perfecting the product, simply because the initial prediction is used as an anchor (Jørgensen, 2014).

Framing

The concept of framing is used in many different research areas, and is defined in a variety of ways. In the field of judgment and decision making, one broad definition describes framing as a situation "in which a speaker, often with a persuasive agenda, selects one among multiple possible ways of presenting 'the same information' to a listener" (Sher & McKenzie, 2011, p. 35). A framing effect occurs when the listener responds differently to this information depending on the way in which it is presented. For instance, in a classic study, Tversky and Kahneman (1981) found that people´s preferences between two options reversed when two different, but logically equivalent descriptions were used. When two treatments of a rare disease were described according to the number of people that would be saved, people were risk-averse and preferred the "safe" option in which 200 of 600 people would be saved (alternative frame: 400 of 600 people would die) over the "risky" option in which there was a

1/3 probability that 600 people would be saved, and a 2/3 probability that nobody would be saved (alternative frame: a 1/3 probability that nobody would die, and a 2/3 probability that 600 people would die). However, when the alternative, but logically equivalent frame was used, and the same two treatments were described according to the number of people that would die, people preferred the "risky" option (Tversky & Kahneman, 1981).

Levin, Schneider, and Gaeth (1998) distinguishes between three different kinds of framing: risky choice framing, as in Tversky and Kahneman´s (1981) example, attribute framing, and goal framing. Attribute framing, which is the most relevant type of framing for this thesis, occurs when two different descriptions of the same attribute influence evaluations of the object of judgment. For instance, a brand of yogurt that is described to contain "5% fat" is perceived as less healthy than a yogurt that is described as being "95% fat free", and even quite large quantities of fat are found to be acceptably healthy when they are presented in the "fat free"-frame (Sanford, Fay, Stewart, & Moxey, 2002).

Framing effects are often said to be in conflict with one of the key principles of normative theories of judgment and decision making, the so-called principle of invariance. This principle states that different but logically equivalent descriptions of the same information should lead to the same choice. Since framing studies show that people´s choices can be strongly influenced by changes in description, it is often concluded that such studies demonstrate that humans behave "irrationally", or at least not in accordance with normative theories (Tversky & Kahneman, 1986). However, Sher and McKenzie (2006; 2011) argue that listeners´ reactions to different frames can be seen as rational behavior. Even though two different framings of the same problem are logically equivalent (e.g., the glass is half full vs. the glass is half empty), the different framings may not be what these authors call "information equivalent". Speakers do not choose frames at random, but rather seem to choose descriptions that reveal something about the state of the world. For instance, speakers prefer to describe a previously empty glass that has been filled to the half mark as half full, while a previously full glass is described as half empty after half of the liquid has been poured out (McKenzie & Nelson, 2003). The choice of frame here "leaks" information about the reference point (the previous state of the glass), and in other cases, chosen frames reveal the speaker´s preference (Sher & McKenzie, 2006). In this way, when a treatment for a disease is described as having "a 20% mortality rate within 5 years" a rational listener might infer that this treatment has a higher mortality rate than normal, or that the speaker´s attitude towards the treatment is negative; when the treatment is described as having "an 80% survival rate within 5 years”, the listener may infer that this logically equivalent statement reveals the speaker´s implicit recommendation of the treatment.

Framing effects can naturally be of importance for the communication of predictions. A recent study found that predictions were evaluated as more accurate when they were framed in a way that was congruent with the outcome (Yeung, 2013). For instance, when University B won the college football game with University A, the prediction “University B has a 30% chance of winning” was deemed as more accurate than the logically interchangeable prediction “University A has a 70% chance of winning”. This finding is an example of how the framing of a prediction can influence how a listener interprets it. In addition, one can imagine that the way some information is framed could influence the prediction that a speaker makes. These potential framing effects in predictions were investigated in Paper II and Paper III.

Expressing uncertainty

The uncertainty of a prediction can be expressed in a number of different ways. One can express uncertainty as a numerical probability from 0 to 1 (or as a percentage from 0 to 100%), with 0 indicating that there is no chance that the outcome will occur, and 1 indicating that it definitely will occur. Such numerical probabilities are usually combined with some kind of linguistic expression, for instance, “There is a 60% probability that outcome A will occur”, or “I am 70% certain that outcome A will occur”. Alternatively, uncertainty may be expressed using verbal expressions such as “I am not certain that outcome A will occur” or “It is highly likely that outcome A will occur”. For numerical predictions, uncertainty can also be expressed through the precision of the prediction itself. One can choose to give a point estimate (“I think the task will take 5 hours”), an interval prediction (“There will probably be between 100 and 200 students attending the lecture”), or a one-sided interval prediction (“I am almost certain that we will spend more than 1000€ on our vacation”). As illustrated, point and interval predictions may be combined with numerical or verbal probability expressions, with so-called confidence intervals (“I am 80% certain that the task will take minimum 10 and maximum 20 work-days”) providing the most complete picture of the perceived uncertainty of a prediction, since uncertainty is expressed both through the width of the interval (wide intervals signal higher uncertainty than narrow intervals) and through the chosen level of probability.

People prefer to receive numerical probabilities when uncertainty is communicated to them (Erev & Cohen, 1990). Given the preciseness of numerical probabilities, one might believe that there is little room for (mis)interpretation of a numerical probability. However, research has shown that even numerical probability statements can be interpreted in different ways depending on the context. For instance, a 70% probability is perceived as more likely for expected than for unexpected outcomes (Windschitl & Weber, 1999), and the same numerical probability of a negative outcome (e.g., that the participant´s stock will go down in value) is deemed to communicate a greater risk when the speaker is polite than when the speaker is blunt (Sirota & Juanchich, 2012).

As another example of such a context effect, the same numerical probability may be interpreted differently depending on whether the expressed source of uncertainty is *external* or *internal*. When a weather forecaster predicts "There is a 70% probability of rain tomorrow", the statement indicates that statistics show that in 7 out of 10 cases, the current weather conditions will be followed by rain the next day. This type of uncertainty can be referred to as external uncertainty, stemming from random processes in the world. However, when a football expert claims "I am 70% certain that Team A will win tomorrow", it is probably not statistical records and frequentistic interpretations of probability he has in mind. Rather, he expresses his subjective assessment of the confidence he has in his prediction that Team A will win. This type of uncertainty can be called internal uncertainty, and reflects the subjective degree of knowledge or belief of the speaker. The distinction between external (aleatory) and internal (epistemic) uncertainty has been prominent in theoretical debates about probability since the first development of probability theory in the 17th century (Hacking, 1975), and more recently, Fox and colleagues (Fox & Irwin, 1998; Fox & Malle, 1997; Fox & Ülkümen, 2011; Fox, Ülkümen, & Malle, 2011) have investigated the same distinction in natural language. Their studies found, for instance, that more responsibility was attributed to a speaker using internal expressions of uncertainty. Participants were more willing to promote an economist who made a correct prediction using an internal expression ("I am 70% sure") than when an external expression ("I think there is a 70% chance") was used, and were more willing to fire an economist who made an incorrect prediction using an internal expression. Although the effect of the implied source of uncertainty has predominantly been studied for numerical probability expressions, it may also be found to be relevant for communication of predictions using verbal probability expressions. The distinction between external and internal uncertainty was further investigated in Paper III.

While listeners generally prefer to receive numerical probability statements, speakers prefer to use verbal probability statements when they are expressing the uncertainty of a prediction (Erev & Cohen, 1990). This might be because they feel verbal expressions are more natural, or because they do not feel they have enough information to give a precise numerical probability. But what do people mean when they say that something is “likely”, “improbable”, or “possible”? One way to approach this question is to ask people to provide numerical translations of such verbal probability expressions. This translation approach has been used in a number of studies (for reviews, see Clark, 1990; Theil, 2002), and the general finding is that although there is some stability at the group level in how different expressions are interpreted (e.g., “certain” is almost always given a higher numerical translation than “unlikely”), there is also a great deal of individual and between-studies variability in which numbers participants see as suitable for different expressions. This indicates that verbal probability expressions are probabilistically vague, a vagueness that opens the possibility for different interpretations.

However, even if they are probabilistically vague, verbal probability expressions may convey meaning in a way that numerical probabilities do not. For instance, verbal probability expressions have been found to have “directionality”: while some expressions (such as probable, likely, possible) are “positive” in that they point towards the probability of the occurrence of an event, other expressions (such as unlikely, improbable, not quite certain) are “negative” and point towards the probability of the non-occurrence of an event (Teigen & Brun, 1995). In a way not unlike the framing effects previously discussed, directionality has been found to influence decision making and reasoning. For instance, although the expressions “quite uncertain” and “some possibility” both indicate a probability of around 35%, people are more willing to recommend a treatment to a friend when it has “some possibility” of being helpful than when it is “quite uncertain” that it will be helpful (Teigen & Brun, 1999).

Furthermore, when people are asked *which outcomes* verbal probability expressions refer to, there seems to be much more agreement between individuals than when they are asked to translate from verbal to numerical probability. In several recent studies by Teigen and colleagues, participants were given a distribution of outcomes, for example a graph describing the battery life for a brand of laptop batteries which last from 1.5 to 3.5 hours, and were asked to indicate which outcome they associated with different verbal probability expressions by completing statements like “It is possible that the battery will last for _____ hours”. These studies demonstrated that verbal probability expressions are generally used by speakers and understood by listeners to refer to particular instances in a distribution of outcomes. For instance, while the expressions “unlikely” and “improbable” are translated to a numerical probability of 10-30%, participants use them to describe outcomes that have never occurred (Teigen, Juanchich, & Riege, 2013); possible, which is thought to describe approximately a 50% probability, is used to describe outcomes from top of the distribution (maximum outcomes), while certain (around 100% probability) is used to describe outcomes from the low end (minimum outcomes) (Juanchich, Teigen, & Gourdon, 2013; Teigen, Juanchich, & Filkuková, 2014).

This “which outcome”-approach demonstrates that the pragmatic meaning of verbal probability expressions differs from the probabilistic meaning, which may help to explain some of the variability found in the numerical translation studies. For instance, if I say “It is certain that the battery will last for 1.5 hours”, I might intend this as an “at least”-statement. Hence, even though I would agree that there is a 100% probability that the battery will last *at least* 1.5 hours, I might indicate a low numerical probability that this specific outcome will occur (e.g, a 10% probability that the battery will last around 1.5 hours), leading to a seemingly paradoxical numerical translation of “certain”. In Paper II, we continued the investigation of the “which outcome”-approach, and demonstrated how the pragmatic meaning of verbal probability expressions can depend on the linguistic framing of a prediction.

Methodological considerations

The participants in the three papers were recruited from different sources, according to the topic of the investigation, and according to convenience. In Paper I, the participants were software professionals from Romania, Ukraine, Argentina and Poland; while the participants in Paper II and III were students at different Norwegian universities (mostly the University of Oslo), US residents recruited online via MTurk (Goodman, Cryder, & Cheema, 2013), and, in one experiment, Norwegian citizens from the general population recruited via facebook (i.e., mostly friends and acquaintances of the experimenters). The software professionals and the MTurk participants received payment for their participation, while student participants (and facebook friends) volunteered to complete the surveys without compensation. Neither of these samples can be said to be representative of the general population and as such, it should be stated here that the current findings are not necessarily valid in all cultures, all contexts and with all participants. However, at least some of the effects studied in this thesis (such as anchoring and framing) have already been demonstrated in a large variety of contexts and with many different types of participants, so there are reasons to believe that the findings are relatively robust. Furthermore, in Paper II and III, some generality is granted since effects were replicated using participants from two different countries and stimuli in two different languages (Norwegian and English), and in addition the MTurk samples that were used included participants with more diverse backgrounds and a larger age range than typical student samples (Paolacci, Chandler, & Ipeirotis, 2010). As for Paper I, we chose to use software professionals as participants because it has practical relevance to study anchoring effects in predictions of software projects, and software professionals is the most relevant population to sample in this respect. The fact that the participants in Paper I was from four different countries should further ensure that the findings are relevant in different cultural contexts, and it can be argued that the sample here is more or less representative of the population of software professionals in these countries.

Participants either completed the questionnaires online, or gave their answers using paper and pencil during breaks in lectures. Both of these environments are less than optimal for data collection. It is hard to ensure that all participants are giving their full attention to the questionnaire, that there are no distractions, and that participants do not look at other participants´ responses. Although this might create "noise" in the data, it is doubtful whether such environmental factors could lead to systematic deviations, especially over a series of experiments. Thus, the current results may be seen as indicating that the effects are rather robust even in settings that are not optimal for their detection.

In all experiments, participants were either asked to make predictions or to interpret predictions, but in most cases, the predictions were hypothetical. Only in Paper III (Experiments 4A and 4B) did we ask participants to predict real-world events. It might be that hypothetical predictions differ in some way or the other from predictions of real outcomes that have significance for the individual. For instance, a person who predicts that he will spend maximum 10 hours on writing a 5 page summary of a book chapter might increase this estimate if he is told that he is actually going to do this task and has to consider whether such an estimate is actually feasible. In other words, participants may feel more *accountable* (Lerner & Tetlock, 1999) for their predictions when the prediction concerns a real event or outcome. Although including more data on non-hypothetical scenarios (e.g., data from field experiments, archival records, observational studies, or simply predictions of tasks or events that the participants are personally involved in) could have increased the external validity of the current findings, we chose to use scenario studies to have strict control over the stimuli. In spite of their artificiality, scenarios can ensure a higher degree of internal validity, since the only difference between two versions of a scenario should be the manipulation of the independent variable. Real life is often more chaotic, and there are usually multiple factors acting at once, which makes it harder to demonstrate causal effects of the kind of subtle communicative manipulations that are studied in this thesis.

Both Paper I and Paper II exclusively investigated predictions of task performance time. This means that for the first two papers, we cannot firmly state that our findings are relevant for other kinds of predictions, although we expect this to be the case, at least for other numerical predictions. In fact, there is already some evidence that the findings of Paper II are relevant for other numerical quantities (Teigen et al., 2014). In Paper III, however, we investigated predictions of real-world sports events and predictions of the outcomes of actions (whether a treatment will be successful and whether a student should read an extra-curricular book) in addition to predictions of task performance time. Hence, Paper III showed that different kinds of predictions were influenced by manipulations of the same independent variable (source of uncertainty), and thus some generalizability across different kinds of stimuli was demonstrated. As there are undoubtedly important differences between predictions of performance time and predictions of the outcome of a football match, one cannot expect the same experimental manipulations to always have similar effects on different kinds of predictions. The three papers can thus be seen as representing three attempts to address the same overarching topic of how predictions are communicated, and whether or not the current findings are relevant for all kinds of predictions, is a question for future studies.

The topics studied in these studies are not controversial, and do not require that participants reveal intimate details about their private lives. Still, to ensure ethical treatment of the participants, they were given information about the topic of the study so that they could give their informed consent to participate, they were told that they could withdraw from the study at any time, all responses were anonymous and individual participants were unidentifiable once data collection was over. Another topic in ethics that is quite relevant for this thesis, and that has been getting increasing (and deserved) attention recently, is ethics in the reporting and analyses of data. There are many so-called “questionable research practices” that could be a threat to the validity of research findings, such as not reporting the removal of outliers from studies, only reporting studies and/or dependent variables that “worked” (i.e., studies and variables that provided positive, statistically significant findings), applying the statistical technique that gives the “best” results (i.e., the results that look most convincing), checking the data while collecting and stopping data collection when significant results are obtained, and so forth (Simmons, Nelson, & Simonsohn, 2011).

The treatment of outliers was particularly relevant for this thesis. Performance time predictions, which are investigated in all papers, are known to be highly variable, and it is not always obvious when a performance time prediction should be called an outlier. For instance, in Paper I, Experiment I, participants in the control group gave a mean most likely estimate of 77 hours, but their responses ranged from 5 hours to 800 hours. Although 5 and 800 hours may seem unrealistically low and high, respectively, we do not know how the participants reasoned, since we did not ask participants to provide any explanation of their predictions. It could for instance be that a participant predicts that the task will take 800 hours because she knows she will have to learn a completely new technology in order to complete it, or that a participant knows that he can just slightly modify an old project in order to fulfill the task requirements, in which case 5 hours might be sufficient. In such cases, the predictions are justified. In other words, it is hard to know what represents a typing error, a misunderstanding, or a well justified, although deviant, response. Rather than setting an arbitrary cut-off point and calling all responses over or under this point outliers, I chose to use log-transformations to help normalize the distribution and to minimize the effect of potential outliers. When responses were removed from datasets, this was reported in the methods section. In this, and in other choices in analysis and reporting of data, I attempted to follow ethical guidelines to the best of my ability.

Summary of the papers

Paper I – The robustness of anchoring effects in project cost estimation

Previous studies of the anchoring effect have found that precise numbers (e.g., $21) lead to a stronger anchoring effect than round numbers (e.g., $20) of the same magnitude (Loschelder, Stuppi, & Trötschel, 2014; Mason, Lee, Wiley, & Ames, 2013; Zhang & Schwarz, 2013). In a study done in a price negotiation context, Mason et al. (2013) argue that listeners infer that speakers using precise numbers are more knowledgeable about the true value of the object in question, and that this inference leads to less adjustment from precise numbers. This explanation underscores that anchoring may be influenced by pragmatic inferences based on the principles of conversational logic (Grice, 1975). Seeing the effect of preciseness on anchoring as an effect of the inferred knowledge of the source, makes these findings in line with other studies that have shown stronger anchoring effects when the source of the anchor has high rather than low credibility (Wegener, Blankenship, Petty, & Detweiler-Bedell, 2009; cited in Wegener, Petty, Blankenship, & Detweiler-Bedell, 2010). While traditional studies of anchoring often go to great lengths to convince participants that anchors are irrelevant to the judgment in question, and attempt to minimize the effects of pragmatic inferences, these findings underscore that in more realistic, conversational settings, it is important to consider communicative aspects of anchoring.

In Paper I, we attempted to replicate the effect of anchor precision and source credibility on the anchoring effect for predictions of task performance time, using software professionals as participants. More specifically, we investigated whether task performance time predictions are more strongly influenced by numerically precise than by round anchors (e.g., 998 hours vs. 1000 hours), and whether anchors from sources with low credibility have less impact on predictions than anchors from high credibility sources. We also employed a new type of anchors that may be particularly relevant for performance time predictions, namely interval anchors (e.g., “How likely is it that Task A will take between 900 and 1100 hours?”). Interval anchors can be conceptualized as an alternative way of studying anchoring precision. Relatively wide intervals are less precise than relatively narrow intervals, and as previous studies have shown that listeners find narrow intervals to be more informative than wide intervals (Du et al., 2011; Yaniv & Foster, 1995), one might expect narrow intervals to lead to a stronger anchoring effect than wide intervals.

In Experiment 1, we found a strong anchoring effect on task performance time predictions, but no effect of anchor precision whether precision was operationalized as a precise vs. a round number (998 hours vs. 1000 hours) or as a narrow vs. a wide interval (900 – 1000 hours vs. 500 – 1500 hours). Experiment 2 similarly showed a strong anchoring effect, but a narrow interval anchor using precise numbers (19 – 21 hours) did not lead to a stronger effect than a wide interval anchor using round numbers (10 – 30 hours). In Experiment 3, we manipulated source credibility directly. The same low anchor (10 hours) was introduced to participants either as a question from a person in the administration with no software development background (low credibility source), as a question from a company manager with background in software development (high credibility source), or without specifying the source of the anchor (“neutral” source). In other words, credibility in this experiment was operationalized as expertise rather than as trustworthiness, which is another important component of credibility (Pornpitakpan, 2004). The same operationalization of credibility was used in the one previous study we know of that found an effect of credibility on anchoring (Wegener et al., 2009). Although we again found an anchoring effect in Experiment 3, the credibility of the source did not moderate the strength of this effect. Overall, the results indicated that performance time predictions can be strongly influenced by numerical anchors, and that numerical precision and source credibility does not seem to strengthen or weaken the anchoring effect in this context.

The findings of Paper I contradicts some previous studies. We speculate that one reason why no effect of precision was found in this study is that precise numbers may not indicate expertise for predictions of performance time. Previous studies that found an effect of numerical preciseness investigated domains where a correct answer exists, for example price negotiations (Loschelder et al., 2014; Mason et al., 2013), where one must assume that each object has a "true" value. In such domains, a precise number may indicate that a speaker has more knowledge about the correct value. Performance time predictions on the other hand, are fraught with uncertainty, and one can usually not claim to know in advance precisely how much time a task will take. Hence, precise numbers may be associated with overconfidence rather than with expertise or knowledge, and it cannot be expected that precise numbers will lead to a stronger anchoring effect.

We further discussed whether the expertise of our participants might have diminished potential effects of precision and source credibility. However, additional analyses dividing participants into a low experience (< 5 years) and high experience (≥ 5 years) group showed that precision and source credibility had no more moderating effect on anchoring for low than for high experience participants. Instead, the anchoring effect was found to be somewhat weaker, but still clearly present, for high-experience participants. We argue that the results are in line with the selective accessibility model (Mussweiler & Strack, 2001): simply considering a high number (or a high interval) makes participants retrieve evidence that suggests that the task might take a long time, and the increased accessibility of this information at the time the judgment is made, leads the prediction to be closer to the anchor value than it otherwise would have been.

Paper II – How fast can you (possibly) do it, or how long will it (certainly) take? Communicating uncertain estimates of performance time

The "which outcome"-approach to verbal probability expressions (Teigen et al., 2014) has found that some expressions (e.g., certain) are usually associated with outcomes in the low end of a distribution, while other expressions (e.g., possible) are associated with outcomes in the high end. However, some dimensions may be reversible, in that low numerical values sometimes can be seen as minimum outcomes, and sometimes as maximum outcomes. For instance, a low number of hours may be seen as the minimum time required to do a task, or alternatively as the maximum speed with which the task can be performed (i.e., the best, maximum outcome). Paper II studied this proposed "reframing" phenomenon in communications of task performance time predictions. To manipulate the orientation of the time dimension, we used statements that were focused either on the number of hours a task *will take* (duration frame) or on the number of hours in which a task *can be done* (speed frame), and we hypothesized that the speed frame would lead verbal probability expressions that are usually associated with low outcomes (e.g., certain) to be associated with outcomes from the high end of the distribution, while expressions that are usually associated with high outcomes (e.g., possible) would be associated with low outcomes.

In Experiment 1, we asked speakers to give performance time predictions for three academic tasks by completing sentences containing the verbal probability expressions *certain* and *possible*. In the duration frame, participants were asked to complete the statements "It is certain that I will spend _____ hours on this task" and "It is possible that I will spend _____ hours on this task", while in the speed frame the corresponding statements were "It is possible that I can do this task in _____ hours" and "It is certain that I can do this task in _____ hours". Participants were asked to fill in numbers they felt were appropriate in the context, and as hypothesized, *certain* was associated with low numbers in the duration frame and high numbers in the speed frame, while *possible* was associated with high numbers in the duration frame and low numbers in the speed frame. Thus, speakers used certain and possible to refer to opposite ends of a distribution, but which end an expression was thought to refer to, depended on the way the prediction was framed.

In Experiment 2, listeners were asked to interpret statements based on those produced by the speakers in Experiment 1. For instance, participants were given the statement "It is possible that I will spend 8 hours on this task", and were asked how probable the speaker thought it was that the task would take 8 hours, and to indicate what the speaker thought was the minimum and maximum duration of the task. The statements were presented either in a duration frame or in a speed frame, and listeners were found to be sensitive to the framing. In the duration frame, *possible* was thought to refer to outcomes closer to the maximum while *certain* was closer to the minimum, but in the speed frame, this pattern was reversed. However, this "reframing" effect was much weaker than for the speakers, which is also demonstrated by the finding that listeners indicated that a *possible* outcome had about a 2/3 probability of occurring. This numerical translation of *possible* is not in line with the use of this expression by speakers in Experiment 1 to refer to an extreme (and therefore low probability) outcome.

In Experiment 3, participants were again asked to act as listeners, and were told to imagine that they had had a water leak in the kitchen, and that they had gotten three estimates from three different plumbing companies that could fix the leak. In other words, the participants were presented with three performance time predictions of the same task, presented either in a speed frame or in a duration frame, and featuring different verbal probability expressions. For each prediction, the participants were simply asked whether they thought the speaker believed that the task might take less than, about, or more than the predicted time. For the expressions *certain* and *possible*, the previous findings were replicated and strengthened: listeners believed these expressions referred to opposite ends of the time dimension, and framing influenced which end each expression was thought to refer to. In addition, expressions with negative directionality were investigated, and were found to be influenced by speed or duration framing. In the speed frame, *not certain*, *improbable* and *not possible* were almost exclusively thought to refer to low numbers (i.e., "It is improbable that the task is done in 12 hours" means that the task will probably take more than 12 hours). In the duration frame, the pattern was more mixed, but a majority of participants indicated that *improbable* and *not possible* referred to high numbers (i.e., "It is improbable that the task takes 12 hours" means that the task will probably take less than 12 hours).

Overall, the experiments replicated previous findings in the "which outcome"-approach to verbal probabilities, and in addition gave some new insights into how such expressions are used in communication. Different verbal probability expressions were again found to be associated with high and low outcomes in a distribution, but framing the prediction can change which end of the distribution an expression refers to. This reframing effect arguably makes communication with verbal probability expressions even more complex than previously thought, and as illustrated by the findings in Experiment 2, there are plenty of opportunities for misunderstandings. The findings were interpreted as coherent with psycholinguistic theories that see comprehension of language as a dynamical and context-driven process. I will return to this point in the general discussion of this thesis.

Paper III – There is a 60% probability, but I am 70% certain: Communicative consequences of external and internal expressions of uncertainty

The distinction between external (frequentistic) and internal (subjective) conceptions of probability and uncertainty is well known among probability theorists (Hacking, 1975). Past research has demonstrated that this distinction is also found in natural language, and that the implied source of uncertainty in a speaker's statement has consequences for the attributions and inferences that listeners make (Fox & Ülkümen, 2011). However, the previous research by Fox and colleagues compared internal statements like "I am 60% sure" with external statements that could also be said to include an "internal" component, such as "I think there is a 60% chance". In Paper III, we investigated the distinction between internal and external expressions of uncertainty in communication of predictions. We compared internal statements ("I am 70% certain") with statements that in our opinion were more clearly external ("It is 70% certain" or "There is a 70% probability"). Our hypothesis was that the external expressions would be associated with external evidence, such as statistical records, and would therefore be interpreted as being more objective and valid. Internal expressions on the other hand, were hypothesized to be associated with subjective opinions, and could therefore be thought to reveal characteristics of the speaker rather than information about statistical records.

In Experiment 1, participants were given predictions of performance time for three tasks, with the speakers using internal ("I am 70% [90%] certain") or external ("It is 70% [90%] certain") expressions of uncertainty. Compared to predictions containing internal expressions, predictions containing external expressions of uncertainty were rated as more informative, and the speakers were thought to be more knowledgeable. After being informed that all the predictions were slight underestimates in comparison to the time the tasks actually took, there was a tendency for participants to rate external statements as more accurate, and for speakers using external statements to be trusted more to predict how long it would take to do similar tasks in the future.

Participants in Experiment 2 were asked to imagine an advisor (a medical expert or a university lecturer) who makes a statement of the degree of certainty needed to recommend a particular action, using either an internal or external expression. For instance, one of the scenarios described a friend suffering from migraine headaches who is considering a new treatment, and a physician who is asked for advice says: "To recommend this treatment, I should be at least _____ % certain [there should be at least a _____ % probability] that it will be helpful". If external expressions are thought to be more objective and valid than internal expressions, lower numerical probabilities may be seen as sufficient for recommending an action when an external expression is used. Participants were asked to complete the statements by entering a number between 0 and 100 that seemed natural in the context, and for two scenarios, a lower degree of external certainty (about 60%) than internal certainty (about 70%) was deemed necessary to recommend an action. However, a third scenario investigating how new evidence influences degree of certainty showed no effect of the source of uncertainty. If there is a 30% probability (or a profiler is 30% sure) that a suspect is guilty, and new evidence pointing in the same direction comes in, the profiler is thought to give a 60% probability (or to be 60% sure) that the suspect is guilty.

In Experiment 3, participants were given fictitious conversations about upcoming (real) football matches in the Norwegian premier league. The speakers in the conversations used external or internal expressions of uncertainty in predictions about the outcomes of these matches. As hypothesized, internal expressions were found to be more informative of characteristics of the speaker. Speakers using internal expressions ("I am 90% certain that Team A will win") were thought to be more supportive of the teams they predicted would win than speakers using external expressions ("There is a 90% probability that Team A will win"). Unlike Experiment 1, we however did not find that speakers using external expressions were rated as more knowledgeable. We speculate that this discrepancy may be due to the difference in the type of predictions, with football matches being viewed as more fundamentally unpredictable than task performance time. Hence, "objective" external expressions were not seen to indicate greater knowledge, since objective information was not necessarily thought to be obtainable.

In Experiment 4A and 4B participants were asked to report their own predictions for the outcomes of real-world sports events. In Experiment 4A, participants retrospectively indicated their degree of internal or external certainty in their outcome expectations for the World Chess Championship 2013. The participants reported to have had similar levels of certainty in predicting that the Norwegian chess player Magnus Carlsen (who actually won) would win the championship. However, the results showed that when participants were asked to report their internal certainty, their reported certainty correlated with their personal interest in the championship, while no such correlation was found for reported external certainty. Experiment 4B replicated this finding when participants prospectively predicted the outcomes of 20 different events in the 2014 Winter Olympic Games. Participants´ agreement with statements such as "I am [It is] certain that Petter Northug will get at least one individual gold medal in cross-country skiing" correlated with personal interest in the Olympics only when internal expressions of uncertainty was used. The results of Experiment 4A and 4B are in agreement with Experiment 3 in indicating that internal expressions convey degree of personal support and interest in a prediction, while external expressions do not reveal speaker characteristics in the same way.

The findings of Paper III indicate that the distinction between internal and external uncertainty found in probability theory is also important in communication of predictions. Whether the implied source of uncertainty was manipulated through use of voice (*I am* X% certain vs. *It is* X% certain) or through choice of terms (I am X% *certain* vs. There is a X% *probability*), we found influences on listeners' attributions about the predictions and about the speakers. The results demonstrated another way in which numerical as well as verbal probability expressions are influenced by context. Our findings can be said to be in line with the pragmatic inferences one might expect speakers and listeners to make if users of natural language are sensitive to the same distinction that is made between internal and external uncertainty in probability theory. The discussion points out how our studies partly contradict previous findings: while Fox and colleagues found that listeners had a preference for speakers using internal expressions, we found that speakers using external expressions were (at least sometimes) deemed to be more knowledgeable. This indicates that including the phrase "I think" before external expressions of uncertainty changes the way listeners perceive such statements, and we argue that the expressions used in Paper III can be more clearly thought of as internal vs. external.

General discussion

The three papers that form the basis of this thesis investigate a quite diverse set of topics in communication of predictions. As such, one aim for the discussion is to show how this collection of research findings can be said to address the same overarching theme, and how the different papers connect with each other. The following sections will describe how the current findings can be interpreted from (and potentially contribute to) different theoretical approaches, which practical implications the findings have for communication of predictions, and suggest some potential directions for future research.

Anchoring

In Paper I, we explored whether two communicative factors, numerical preciseness and source credibility, affected the strength of the anchoring effect in the context of performance time predictions. Despite previous studies showing that both factors can moderate the anchoring effect (e.g., Mason et al., 2013; Wegener et al., 2009), we found a similarly strong anchoring effect whether the numerical anchor was precise or round, and whether the source of the anchor had high or low credibility (i.e., expertise). One could thus argue that our results show that communicative factors do not have a strong effect on anchoring. However, such a conclusion is premature. The results of a single study are not enough to disconfirm several previous studies showing that such factors may influence anchoring. Rather, one may speculate that the discrepancy in results is due to differences in the populations and/or in the studied domain. As mentioned in the summary of Paper I, while previous studies finding an effect of numerical preciseness were done in a context where a correct answer is known to exist (e.g., in price negotiations where a "true" price of an object exists), our participants were asked to predict a future outcome that is highly uncertain. Given this uncertainty, a precise numerical value may seem downright ridiculous rather than suggestive of expertise.

Incidentally, this suggestion is similar to the proposed reason for the discrepancy between Experiment 1 and Experiment 3 in Paper III. While Experiment 1 showed that speakers using external expressions in predictions of performance time were rated as more knowledgeable than speakers using internal expressions, Experiment 3 did not find any such difference between speakers using external and internal expressions in predictions of football matches. We speculate that football matches are more fundamentally unpredictable than predictions of performance time. While it at least in principle is possible to base a task performance time prediction on prior experience with similar tasks, it might be harder to claim that predictions of the first football matches in a season are based on information from objective sources. Hence, both in Paper I and in Paper III we argue that the degree of uncertainty of a prediction (or more generally, the degree of uncertainty of a judgment) is an important factor to consider. A listener may make different conversational inferences in contexts where it is reasonable to believe that the speaker knows the quantity in question (i.e., in contexts where a correct value is known to exist) than in contexts where the speaker can only make more or less informed predictions about what the correct quantity might be (i.e., in contexts where a correct value will only be known in the future, and where there might not even be access to any reliable probability).

Returning to Paper I, the fact that the anchoring effect did not seem to be moderated by communicative factors may not only be explained by the proposed effect of degree of uncertainty. In addition, some methodological choices in Paper I perhaps did not create optimal conditions to expose communicative effects. Since we investigated communicative effects on anchoring, we should perhaps have taken a further step away from the traditional anchoring procedure and presented all anchors in a conversational context, and should maybe have made the anchors more clearly relevant for the predictions. For instance, the one study we know of that shows an effect of source credibility on anchoring (Wegener et al., 2009), gave participants anchors that were suggested as possible answers to general knowledge questions from sources that had high or low credibility. For example, a mountain climbing club (high credibility) or a group of migrant workers in Florida (low credibility) suggested what the height of the tallest mountain in North America might be, and people were more influenced by the suggestions from the mountain climbing club than from the group of migrant workers. If a similar procedure (e.g., an expert developer or a manager without development experience suggesting that the task *might take* 10 hours rather than asking *whether* the task will take less than 10 hours) was used in our Experiment 3, it is conceivable that we may have found a similar pattern. For Experiment 1 and 2, it might have helped to simply present anchors as customer requests, rather than ask participants to consider anchors from an unspecified source. These suggestions, admittedly, are speculative, but are included here as potential ideas for future studies of communicative effects on anchoring. For increased understanding of how anchoring functions in real life, it is necessary to do more studies where anchors are more relevant, and in such cases, pragmatic inferences may come into play to a greater degree than they perhaps did in Paper I.

In addition to being the main focus of Paper I, the anchoring effect may also be seen as relevant for some of the findings in the other papers. In Paper II, Experiment 2, participants acted as listeners and were asked to interpret statements such as "It is possible [quite certain] that I can do this task in 8 hours". While speakers in Paper II, Experiment 1, used *possible* and *certain* to refer to extreme (minimum or maximum) outcomes, listeners often indicated that 8 hours was a more central outcome in the distribution with a high probability of occurring, regardless of the verbal probability expression. This discrepancy could partly be explained by a difference in methodology: while speakers in Experiment 1 completed statements featuring the expressions *certain* and *possible* in close succession, each participant only encountered one of these expressions in Experiment 2. Joint presentation facilitates comparison and can sensitize participants to differences between expressions (Hsee, 1996), while separate presentation may obscure such differences. However, part of the difference between experiments may also be explained by anchoring. Participants in Experiment 2 may have used the predicted outcome (i.e., the stated number of hours) as an anchor, and failed to take into consideration the pragmatic implications of the verbal probability expressions. Hence, even though 8 hours is meant as an extreme value, the anchoring effect is so potent and robust that it could overshadow the potentially weaker effects of pragmatic inferences from framing and verbal probability expressions.

A general point mentioned in the background section that makes the anchoring effect relevant for all papers in this thesis, is that predictions can function as anchors. People anchor their expectations of future outcomes on the predictions they are given or on the predictions that they themselves make. An anchoring effect of this kind may be involved in Paper III, Experiment 1. In this experiment, participants were given performance time predictions qualified by a high (90%) or low (70%) degree of certainty, using either an internal (I am X%

certain) or external (It is X% certain) expression. Participants were informed that the predictions were somewhat off the mark (all tasks took a little bit longer than estimated), and were asked to rate how accurate the predictions were, and to what degree they would trust the speaker to make similar predictions in the future. One would perhaps expect that speakers indicating a lower degree of certainty would be deemed as more accurate, and as being more likely to be trusted in the future. After all, speakers indicating higher degrees of certainty were more clearly overconfident in their predictions, and it has been found that overconfident and inaccurate advisors are rated as less credible (Sah, Moore, & MacCoun, 2013). However, degree of certainty affected neither judgments of accuracy nor judgments of degree of future trustworthiness. In this case, the predicted outcome (e.g., that a task will take between 3 and 4 hours) may function as an anchor. Judgments of accuracy then rely on how close the predicted outcome was to the actual outcome, and additional information about expressed certainty is not incorporated. This can be seen as similar to the findings in Paper I, Experiment 3, which showed that anchors from low-credibility sources had an equally strong effect as anchors from high-credibility sources. Whether judgments of accuracy would be influenced by expressed degree of certainty in cases where there are larger differences in expressed certainty (e.g., 90% vs. 50%) or in cases where the predictions are farther from the actual outcome (e.g., a task predicted to take 3 to 4 hours actually took 10 hours rather than 4.5 hours) is an empirical question.

Framing

As discussed in the theoretical section of this thesis, framing is often defined as a situation in which the "same information" is presented in different ways to different people, and a framing effect is said to occur when people respond differently to the different descriptions (Sher & McKenzie, 2006). The methods applied in Paper III seem to agree with this definition: the statement "It is 70% certain that it will take between 3 and 4 hours to drive from City A to City B" contains the same core information as the statement "I am 70% certain that it will take between 3 and 4 hours to drive from City A to City B". The findings of Paper III can then be interpreted from the information leakage perspective: manipulating the "voice" (1^{st} vs. 3^{rd} person) of an uncertainty expression ("I am X% certain" vs. "It is X% certain") or the type of uncertainty expression ("I am X% certain" vs. "There is a X% probability") leaks information about a state in the world, in this case, the source of the uncertainty of the speaker. Hence, using Sher and McKenzie´s (2011) terms, one could argue that although "I am 70% certain" and "It is 70% certain" may be seen as logically equivalent statements, they are not information equivalent (for a discussion of different levels of information equivalence in framing, see Sher & McKenzie, 2011). As explained in the next section ("Psycholinguistic theories"), conversational pragmatics (Grice, 1975) may also be relevant for interpreting the findings in Paper III.

In Paper II, however, we cannot always say that we present the "same information". Although we ask speakers to give performance time predictions using the same verbal probability expressions (Experiment 1), or present the same performance time estimates (e.g., 10 hours) to listeners (Experiments 2 and 3), the linguistic context is not equivalent in the way equivalence is usually defined in attribute framing studies. While "a 25% mortality rate" logically implies "a 75% survival rate", a statement that "It is possible that I will spend 4 hours on this task" does not necessarily logically imply that "It is quite certain that I can do this task in 4 hours". With this in mind, it may be more appropriate to adopt a broader conception of framing to interpret the results of Paper II. One such broad definition was suggested by Entman: "To frame is to select some aspects of a perceived reality and make them more salient in a communicating text" (Entman, 1993, pg. 52). In Paper II, we use linguistic manipulations to make "speed" or "duration" in performance time predictions more salient. In a sense, the different frames may be said to evoke different implicit questions: the implicit question in the duration frame is "how *long* will it take", while the speed frame implicitly asks, "how *fast* can you do it".

Defining framing as selecting some aspects of reality and making them more salient also helps clarify that a parallel can be drawn between anchoring and framing when it comes to the proposed mechanism behind the effects. Anchoring, according to the selective accessibility model (Mussweiler & Strack, 2001), occurs because comparison with the anchor makes anchor-consistent information more accessible. Similarly, information that is made more salient through choosing one out of multiple possible frames should also be more accessible. Hence, although there are many important differences between these phenomena, they can both be said to agree with a general principle of information accessibility, or as Kahneman (2011) puts it, the WYSIATI-principle: what you see is all there is. In the same way that reading "the treatment has a 25% mortality rate" makes you think about the risks of the treatment rather than the high likelihood of survival that is also implied, receiving an irrelevant high anchor of 1000 hours makes you think about reasons why a project may be very challenging and may take a long time rather than reasons why the project may be simple and straightforward.

Psycholinguistic theories

In this section, I argue that it can be helpful to draw upon some psycholinguistic theories to put the findings in this thesis into a larger context. There are undoubtedly many other relevant theoretical perspectives that could be mentioned, with the vast literature on communication and psycholinguistics in mind, but for the purpose of this thesis, the current selection hopefully provides some interesting insights.

In Paper II, we interpret our findings from the perspective of psycholinguistic research on ambiguity in sentence processing (Altmann, 1998). Our results showed that a performance time prediction can have multiple meanings: a speaker may intend an estimate of 5 hours to be a low (minimum) estimate, a high (maximum) estimate, or a "most likely" (mean or median) estimate. We argue that the speaker´s choice of frame and verbal probability expression gives the listener cues to which interpretation is intended. According to dynamical, constraint-based approaches to language (e.g., Elman et al., 2004; McRae, Spivey-Knowlton, & Tanenhaus, 1998) such cues operate in parallel and in a probabilistic way to constrain the possible interpretations of an ambiguous statement or word. The different interpretations of an ambiguous statement are simultaneously activated, but contextual cues will help guide the listener so that he can settle on one interpretation. This perspective is very helpful in thinking about the findings in Paper II. Verbal probability expressions are found to be ambiguous, since they can refer to low or high numbers. However, the linguistic speed or duration framing functions as a cue to the intended meaning, and in this way, ambiguity is (at least to a certain extent) resolved.

Furthermore, we found in Paper II that the speed framing is a stronger cue for interpretation than the duration framing. For instance, while almost all listeners interpreted performance time predictions in the same way under the speed frame in Experiment 3, there was more variety in interpretations under the duration frame. This asymmetry between speed and duration framing has a parallel in psycholinguistic research on *markedness*. For instance, it has been found that answers to the question "How long was the movie?" were more variable than the answers to the question "How short was the movie?" (Harris, 1973). In short, *unmarked* words, such as "long", "heavy", or "many", are found to be more neutral than their *marked* counterparts "short", "light", and "few". If the speed frame, as suggested above, invokes the question "how fast can you do it" (or alternatively, "how short will it take"), one could argue that this is a marked statement as compared to the implicit question in the duration frame of "how long will it take". This difference between marked and unmarked words can also be interpreted using dynamical, constraint-based approaches to language.

Contextual cues (or constraints), according to such theories, differ in strength (Elman et al., 2004). Some cues are very strong, and are usually interpreted in the same way by most listeners (like marked words), while other cues are weaker, and may be interpreted in one way or the other, depending on other cues (like unmarked words).

As explained above, the information leakage perspective on framing is useful for interpreting the findings of Paper III. When a speaker says "I am 70% certain that Team A will win", this leaks information about his support for Team A, while the statement "There is a 70% probability that Team A will win" indicates that the speaker is more of a neutral spectator. The information leakage perspective assumes that listeners make some kind of (implicit) inference based on the speaker´s statement. Such inferences may be based on conversational rules (Grice, 1975). For instance, the maxim of quantity dictates that a statement should be as informative as is required, but not more; the maxim of quality dictates that you should not say what is false or what you lack evidence for; and the maxim of relation states simply that a statement should be relevant to the conversation. Hence, a listener might infer that the speaker who says "It is 70% certain that it will take between 3 and 4 hours to drive from City A to City B" has access to some objective, precise information. Otherwise, the speaker would have chosen an expression like "I am 70% certain" to indicate that this is a subjective opinion. Although Sher and McKenzie (2006) point out that their analysis "makes no assumptions about the existence of Gricean norms" (p. 470), which in other words means that they argue that information leakage can occur even without assuming that speakers and listeners act according to conversational norms, it seems natural to consider that conversational rules can guide both speakers in their choice of frame and listeners in their interpretation of frames.

As already hinted upon in the section on anchoring, conversational inferences are also probably relevant for anchoring effects in real-world settings. For example, it could be argued that when a numerical anchor is introduced in a conversation, a listener will infer that the speaker introduces this number because it is relevant to the judgment in question, as introducing irrelevant numbers would violate the maxim of quality, the maxim of relation, and the more general principle that a conversation is a cooperative effort (Kahneman & Tversky, 1982).

In summary, psycholinguistic theories are informative for the papers in this thesis, not only for the interpretation of the results, but also for placing the findings in a larger theoretical context. Much of the research on judgment and decision making concerns itself with the effects of manipulations that are arguably linguistic or communicative, but often, such theories are not receiving much attention in the interpretation of results. This can potentially slow down progress in theoretical development, or can lead to misinterpretations of research findings: for instance, what is actually a more or less rational conversational inference might be labeled as bias or irrationality (Hilton, 1995; Schwarz, 1994; Wänke, 2007).

Implications for communication of predictions

Communication of predictions is a broad topic that is relevant for a variety of fields, such as medicine, weather and climate research, scientific communication, public and private management, media, business and finance, and so forth. In this section I discuss some applied implications of the current findings for people involved in communication of predictions in these and other relevant fields.

The implications of Paper I seem very clear: introducing a numerical anchor before a prediction is made can strongly influence the prediction, even if the anchor is irrelevant, extreme in magnitude, and stemming from a source with low credibility. This finding, combined with research showing that it is extremely hard to remove the effect of an anchor once it has been introduced (e.g., Jørgensen & Løhre, 2012; Wilson, Houston, Etling, & Brekke, 1996), implies that all kinds of anchors should be kept away from the person producing a prediction. On the other hand, if you want to influence a prediction in a specific direction, you can of course use the anchoring effect strategically. However, strategic use of anchors may have other, unintended effects. Imagine, for example, that a customer introduces a very low anchor to a software developer in a conversation about the time it might take to develop a project. The software developer might then give a lower estimate of performance time, leading to an initial reduction in cost, but the customer may be seen as incompetent or highly demanding, and in addition, there might be delays, cost overruns, reduced quality, etc. Similarly, it has been argued that a main reason for the systematic underestimation of costs that is found for large transportation infrastructure projects is not that people are so bad at predicting costs, but rather that they are producing strategic estimates – or put more plainly, they lie (Flyvbjerg, Holm, & Buhl, 2002). In a sense, this view suggests that a low prediction is used strategically as an anchor in order to gather support for a project, with the expectation that once a project is initiated, cost overruns will be covered in one way or the other. Although it is not easy to provide hard evidence that underestimates are usually lies, there should be no doubt that strategic underestimation occurs, and that strategic communication of predictions is a potentially powerful tool.

It is well known that communication is a complex process, and that words can have many meanings. However, numbers seem straightforward: "8 hours" is "8 hours", right? Paper II demonstrates that even numerical predictions are ambiguous, with different verbal probability expressions and different framings influencing whether a numerical prediction is seen as a minimum, maximum, or most likely (mean) prediction. This indicates that there is a lot of potential for misunderstanding predictions, as illustrated by the findings of Paper II, Experiment 2. Here, listeners thought a "possible" prediction had a high likelihood, and represented a central outcome in the distribution, even though speakers in Experiment 1 used "possible" to refer to outcomes in the high or low end of the distribution, which presumably have a lower likelihood of occurring. Similarly, Paper II demonstrated that verbal probability expressions are even more complex than previous studies have shown. From before, we know that there is a large variability in people´s numeric translations of such expressions, and that verbal probability expressions have a pragmatic as well as a probabilistic meaning. With the findings from Paper II, we now know that the pragmatic meaning depends on the linguistic context, such that expressions that usually refer to the high end refer to the low end when they are uttered in another context. Communicators need to be aware of these effects in order to best convey the intended meaning of a statement (or to best obscure the meaning of a statement if they so wish).

The complexities of communicating uncertainty are similarly apparent in the findings of Paper III. Even numerical probabilities are context-dependent, with internal and external expressions of uncertainty influencing both how speakers express and how listeners interpret the statements. Since listeners seem to interpret external expressions of uncertainty as indicating that the speaker has access to some objective knowledge about the object of prediction, one might recommend speakers to use external expressions to appear more convincing. In some areas, such as scientific discourse, speakers already act accordingly: for instance, analysis of a report from the Intergovernmental Panel on Climate Change (IPCC) showed that external expressions such as "there is high confidence" were used instead of internal expressions like "we are highly confident" (Fløttum, 2010). On the other hand, Paper III also found that internal expressions signal interest and engagement, and choosing an internal expression may therefore make the speaker seem more personally engaged, which also might appear convincing in some contexts. Hence, Paper III does not show that one kind of expression is "better" than the other. Rather, it is demonstrated that choice of expression should be based on what the speaker wishes to convey.

Potential future directions

The present research answers a few questions about communication of predictions, but at the same time opens new questions and possibilities for further studies. Here, I will discuss some ideas for future work within this topic, building on the three papers in this thesis.

Although the anchoring effect has been investigated in a large variety of settings, there are not many studies that introduce anchors in a more naturalistic, conversational setting. Since this is arguably more common than the introduction of random, irrelevant anchors employed in traditional anchoring research, it would be interesting to see more studies of this kind. One possibility for future studies in this vein is to investigate how different kinds of anchors are influenced by verbal and/or numerical expressions of uncertainty. Although Paper I indicated that the anchoring effect is so robust that it is not moderated by source credibility, one previous study found that less credible anchors were given less weight than more credible anchors (Wegener et al., 2009). In their paper, Wegener et al. manipulate credibility through varying the expertise of the speaker, and one could argue that high expertise speakers should be more certain of their estimates than low expertise speakers. If this explanation holds, one could expect that relatively uncertain anchors might be given less weight than relatively certain anchors. Imagine, for instance, that software developers are asked to predict the number of work-hours necessary to develop a particular project. Before they give their predictions, they are informed that a colleague (an experienced developer) said either (a) "It is highly unlikely that we will need 500 hours", or (b) "It is quite probable that we will need 500 hours". If more uncertain anchors are given less weight, one would expect that developers exposed to statement (a) would give a prediction farther from the anchor than developers exposed to statement (b). Although the findings of Paper I indicate that the anchoring effect may overpower the more subtle effects of uncertainty expressions, doing some small changes in the design could give better chances to discover such a proposed communicative effect. In addition, one could argue that the potential practical value could make it worthwhile to do a study of this kind.

The findings of Paper II demonstrated the powerful effects of framing in communication of predictions, but like many other studies of framing, an important aspect was excluded from the investigation, namely when and why speakers choose different kinds of frames. It would be interesting to see whether choice of a speed or duration frame varies with, for instance, whether the speaker wishes to recommend or discourage a particular action. One might expect that a speed frame functions as an implicit recommendation: if I say "It is possible that this task can be done in 20 hours", this, from an information leakage perspective, might indicate that 20 hours is less than expected (the implicit reference point is higher than 20 hours), while when I say “It is possible that the task will take 20 hours”, it might indicate that 20 hours is above my expectation (the implicit reference point is lower than 20 hours). Therefore, it would be interesting to see whether a speaker who wants to convince someone to start a project might choose the speed frame, while a speaker who wants be discouraging might choose a duration frame.

Another idea that perhaps could be interesting is to combine the “reframing” effect from Paper II with an anchoring task. If reframing leads to a reversal of the quantitative dimension under study, will the direction of adjustment from an anchor also be influenced? Imagine for instance that a manager asks a worker either (a) “Is it possible that this project takes 200 hours?”, or (b) “Is it possible that this project is done in 200 hours?”, and that the worker next is asked to provide an estimate of how much time the project will actually take. If reframing influences the direction of adjustment, people may adjust downwards from 200 hours when it is seen as a maximum estimate, as with the duration framing in statement (a), while they may adjust upwards from 200 hours when it is seen as a minimum estimate as in the speed framing in statement (b).

Furthermore, we have started following up the reframing effect in the context of counterfactual thinking. People often think about how events in the past could have been different in one way or the other, and such counterfactual thoughts are found to have a variety of judgmental and emotional consequences (Roese & Olson, 1997). In an unpublished experiment, participants were asked to predict how much time a friend had spent on three academic tasks by completing statements like “I think my friend spent about _____ hours on this task”. One group of participants was then asked to complete a counterfactual statement focused on duration (“I think this task could have taken _____ hours, if…”) while the other group received a counterfactual statement focused on speed (“I think this task could have been done in _____ hours, if…”). Usually, studies of counterfactual thinking find upward counterfactuals (thoughts on how an outcome or event could have been better) to be more frequent than downward counterfactuals (thoughts on how things could have been worse) (Roese & Olson, 1997). We replicated this pattern, but also showed that the linguistic framing influences counterfactual thoughts: there was a higher frequency of downward counterfactuals (i.e., thoughts about how the task could have taken more time) under the duration frame than under the speed frame (Løhre & Teigen, unpublished data). These results establish that the reframing effect can be found even without verbal probability expressions as indicators of the orientation of the time dimension.

Paper III demonstrated that both listeners and speakers distinguish between internal and external expressions of uncertainty, and there are many ways the findings in this paper could be followed up. For instance, the fact that external expressions of uncertainty were seen as more informative and valid, while internal expressions were seen as more subjective, could have some interesting implications for interval estimation. There is a large body of research on so-called confidence intervals showing that when people are asked to provide intervals that they are 90% confident will contain the correct answer, they are usually severely miscalibrated, and much less than 90% of their intervals actually contain the correct answer (Soll & Klayman, 2004). This indicates that the intervals are too narrow for the assigned level of confidence, a specific kind of overconfidence that is referred to as overprecision (Moore & Healy, 2008). One could speculate that the type of uncertainty expression one chooses could influence the width of the intervals that participants provide. It might be that the subjectivity of internal uncertainty expressions allows participants to provide quite narrow intervals and still feel subjectively certain that they are right. If this were the case, people would provide wider intervals when an external uncertainty expression was used. We have some data, collected at the same time and with the same participants as in Paper I, indicating that this might be the case. In a pilot experiment, we asked software developers to predict the minimum and maximum number of work-hours needed to develop a software project. The type of uncertainty expression was varied, so that half of the participants were asked to give a minimum-maximum interval "so that you are 90% sure that your actual use of effort is between your estimated minimum and maximum effort" (internal expression) while the other group was instructed to provide an interval "so that it is 90% sure that the actual use of effort is between the minimum and the maximum" (external expression). The results showed a tendency for an effect in the expected direction: participants in the external group provided somewhat wider intervals than participants in the internal group (Løhre, Jørgensen, & Teigen, unpublished data). Although this difference was not statistically significant ($p = .17$ with a non-parametric test), it could be interesting to follow up this result in a study where participants are given several interval prediction tasks instead of just one, and perhaps also using different uncertainty terms ("I am 90% certain" vs. "It is 90% probable"). If this tendency for a difference is found to persist, it has potential applied value as well as theoretical interest.

Related to this finding, it could be interesting to do further studies on the communication of confidence interval predictions. Although there are many studies on confidence intervals, there are few studies that investigate how such interval predictions are influenced by for instance request format (such as whether an internal or external expression of uncertainty is used), and conversely, how intervals of different widths and with different expressed confidence levels are interpreted by listeners. In addition to the pilot experiment mentioned above, I have done one attempt to study the effect of request format on interval estimates in collaboration with Craig McKenzie. In one experiment, participants were given 10 questions about students at their own university (for example, "[In the fall 2012,] What percent of UCSD students were from San Diego?"), and were asked to give a low and a high estimate and to indicate either the probability that the correct answer was *inside* the interval or the probability that the correct answer was *outside* the interval. Previous studies have shown that focusing on exclusion (removing alternatives that are not correct rather than selecting those that are correct) can lead to wider choice sets (Yaniv & Schul, 1997), hence we hypothesized that asking about the probability that the correct answer is outside might reduce overconfidence. In fact, the results showed the opposite effect: the group who focused on exclusion (the probability that the correct answer was outside their interval) was actually more overconfident than the group who focused on inclusion (the probability that the correct answer was inside) (Løhre & McKenzie, 2014). Although a second experiment with some slight changes in procedure did not show any difference in overconfidence between exclusion and inclusion focus, the results of the first experiment are intriguing, and may be followed up at a later time.

Conclusion

The current thesis demonstrates how important it is to be aware of communicative effects when studying predictions. In much of the literature on prediction, it is an implicit assumption that a prediction represents the participant´s estimate of the most likely outcome. However, as should be clear from the findings described here, a prediction can be influenced by small changes in the wording of a request for a prediction, and on the other hand, the way a person expresses his prediction, for instance the verbal probability expression she chooses, may change the meaning of the prediction from a most likely to a minimum or maximum estimate. Such possible confusion about what a prediction is intended to mean, is in most cases undesirable both for producers and receivers of predictions.

Theories of how predictions are made could also benefit from incorporating communicative perspectives. Consider for instance the metrics and mappings model (Brown, 2002; Brown & Siegler, 1993), which suggests that people arrive at a numerical estimate through a process of plausible inferences based on the information they are able to retrieve about the object of judgment. It seems apparent that “plausible inferences” can be influenced by many different factors, with the framing and anchoring effects discussed in this thesis as good examples. Making one subset of all the potentially relevant information for a prediction more accessible through anchoring and framing could lead people to make other plausible inferences than they otherwise would have. Any theory of prediction ignoring communicative influences will provide an incomplete picture of how predictions are made.

For people involved in communication of predictions, the current findings show what a complex task this is. As a speaker, whether you want to ensure that your prediction is accurately understood, to encourage or discourage a particular option, or to motivate listeners to act, there are many ways in which you can make yourself both understood and misunderstood. And as a listener, it seems likely that it can be helpful to know how speakers may use predictions strategically, and how you can influence a prediction through the request that you make, so that you can be sure that you get the information that you actually need from the predictor, not only the information that the predictor happens to express. Although prediction in all likelihood will continue to be an extremely challenging task, and inaccurate prediction may still continue to be the norm rather than the exception, this thesis hopefully at least takes a small step on the way to ensuring that (inaccurate) predictions are communicated in the best possible way.

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