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Adaptive Rationality in Strategic Interaction: Do Emotions Regulate Thinking About Others?

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Abstract. Forming beliefs or expectations about others' behavior is fundamental to strategy as it codetermines the outcomes of interactions in and across organizations. In the game-theoretic conception of rationality, agents reason iteratively about each other to form expectations about behavior. According to prior scholarship, actual strategists fall short of this ideal, and attempts to understand the underlying cognitive processes of forming expectations about others are in their infancy. We propose that emotions help regulate iterative reasoning, that is, their tendency to not only reflect on what others think, but also on what others think about their thinking. Drawing on a controlled experiment, we find that a negative emotion (fear) deepens the tendency to engage in iterative reasoning compared with a positive emotion (amusement). Moreover, neutral emotions yield even deeper levels of iterative reasoning. We tentatively interpret these early findings and speculate about the broader link of emotions and expectations in the context of strategic management. Extending the view of emotional regulation as a capability, emotions may be building blocks of rational heuristics for strategic interaction and enable interactive decision making when strategists have little experience with the environment.

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Keywords: emotions • adaptive rationality • game theory • levels of reasoning • feedback

1. Introduction

At least since Cyert et al. (1958), "The role of expectations in business decision making" management scholarship has considered alternatives to the concept of expectations as the first moments of the relevant probability distributions. Yet replacing this construct with behaviorally plausible alternatives (Gavetti 2012) presents several challenges regarding beliefs about the beliefs of others (henceforth their *higher order beliefs*).[1]

Consider an example: a set of firms (car producers) is jointly aware that a transition to an emerging technology (self-driving cars) may eventually occur, but the timing of the transition depends on their competitors' behavior. If competitors hesitate to invest, a leading car producer that is also working on other innovations (e.g., electric cars) may also hesitate in prioritizing its investment in electric cars. If, on the other hand, this producer expects that a critical mass of competitors will push ahead with investments in self-driving cars, it, too, may be better off immediately investing in self-driving technology. The car producer's beliefs about the actions of its competitors are likely based on its beliefs about the latter's beliefs regarding the timing of the transition.

How are such higher order expectations formed? In the extreme case of unbounded rationality in the sense of game theory (Bernheim 1984), we can model an agent A's own (i.e., first order) belief as a probability distribution. However, we can also model an agent A's belief of another agent B's belief as a probability distribution over probability distributions, which can be referred to as the second order belief. Similarly, we can also model agent A's belief of another agent B's belief of agent A's belief as a probability distribution over probability distributions over probability distributions as third order beliefs and so on. Beyond the first one or two orders, such modeling becomes behaviorally implausible[2] because most people cannot think their way through the resulting explosion of multiple layers of possibilities. Assuming common knowledge of rationality in game theory implies that beliefs contain not just first and second order beliefs, but reasoning about reasoning continues to higher and higher orders ad infinitum. There is ample evidence that people differ in their *levels* of reasoning when they form beliefs in interactions (Nagel 1995). The level of reasoning simply denotes the maximal order of beliefs formed and employed in the process.[3]

If confined to only the first order, the reasoning is shallower relative to formation and analysis at higher orders. The level of reasoning may be related to strategic performance (Levine et al. 2017).

However, given the level of reasoning (denoted by k) being unconstrained in theory, it is not obvious that an agent's performance in strategic tasks is monotonically increasing in k; an unbounded level of reasoning can create problems of its own. For instance, in the well-known two-generals problem (Gmytrasiewicz and Durfee 1992), general A sends a message to general B proposing a time to attack their common enemy, and general A cannot be sure that general B receives this first message. General A can wait for General B's reply (message 2) to be sure that the first message was received and that the attack time is agreed upon between the two generals. That would mean to choose $k = 2$, with which general A reasons about general B's reasoning. Yet, then, general B could worry if his confirming message 2 has indeed been received by general A and so on. In practice, a mechanism for keeping the value of k bounded is necessary if the generals are ever going to launch a coordinated assault on their common enemy.[4]

Strategists who work in teams continually face a similar problem (Barsade 2002). When does one know that the team agrees on something, for example, to focus on an existing product line instead of developing new product lines? The culture of the team may allow it to coordinate implicitly on a given level k of reasoning about others without formally documenting the expectation. For instance, all team members assume agreement by all once they get confirmation from all team members (so they choose $k = 2$); that may work well in practice without waiting to learn that all other team members also have the confirmation of all other team members (so $k = 3$ may already be too high). To emphasize, it is socially and collectively advantageous if the team members use the same k.

In interactions with competitors, Menon (2018) argues that more sophisticated, deeper reasoning (which may correspond to choosing a higher k) can help to outsmart competitors and establish competitive advantage. Levine et al. (2017), who explicitly study the level k of reasoning, find that slightly higher k indeed yields advantages in competitive trading interactions. However, outsmarting others requires one to have an accurate estimate of how "smart" the others are; errors of estimation are self-defeating.

Taken together, strategy research emphasizes the importance of higher order expectations and the advantage of slightly deeper reasoning (Muth 1961, Amershi and Sunder 1987, Geanakoplos 1992, Sunder 2002, Golub and Morris 2017). But the team agreement and the two-generals example point to just two of many contexts in which (slightly) deeper reasoning does not necessarily yield more effective responses to the behavior of others.[5] More broadly, the examples suggest that agents need to employ heuristics to cope with strategic interaction. Unbounded reasoning (k being infinite) can often place intractable computational demands on individuals and organizations (Bettis 2017). And, even if interaction situations could be handled by equilibrium analysis of a well-defined game, real-world strategic interactions almost always occur in ill-defined environments (Ehrig et al. 2021). If games are not clearly defined, equilibria are not defined. It is unclear what the meaning of rationality is or should be in such ill-defined, open-ended situations (Simon 1973).

Following Bettis (2017), we understand heuristics to be decision strategies that economize on information, time, and managerial attention. The use of heuristics in strategic interaction contexts is a necessity if situations are ill-defined and/or game-theoretical equilibria are not computable (Bettis 2017). Choosing a level of reasoning is a way to decide when to stop thinking; it simplifies computation and, thus, qualifies as a heuristic (Spiliopoulos and Hertwig 2019).

Heuristics are argued to be "rational," especially in adaptive contexts when knowledge of strategists is incomplete (Grandori 2010, Ehrig and Schmidt 2019). Simon (1967) suggests that effective thinking must be regulated to react to novel environments. For instance, urgent needs may require a strategist to interrupt a thinking process, and Simon (1967) argues that emotions may serve the role of functional interrupters of thinking.

The choice of a level of reasoning corresponds to a point at which thinking is disrupted. Our argument rests on the assumption that the effectiveness of a given level of reasoning or the degree of intensity of thinking is context dependent. The examples suggest that functional levels of reasoning (a choice of k that leads to the best outcomes) differ. How the choice of a level of reasoning is mediated is a relevant question. We explore a possible contextual factor—the emotional state of the strategist—that may affect the reasoning level, and then, we conduct and report the results of a controlled experiment to examine the role of emotions.

In the extant organization literature, the link between expectations and emotions is explored, but not in the context of higher order expectations and levels of reasoning. Herbert Simon (1945), early on, linked emotions to decisions via attention. In the 1960s, Chris Argyris and Herbert Simon had a lively debate about the role of emotions in rational organizational decision making. Whereas Simon initially resisted a prominent role for emotions in organizations and rationality,[6] Argyris convinced him, and Simon (1967) later proposes that emotions may regulate reasoning. More recently, emotions are argued to play a role in search behavior, and their positive role is emphasized (e.g., Hodgkinson and Healey 2011). Emotional regulation has long been seen to be a positive managerial capability that enhances team performance (Barsade 2002, Reus and Liu 2004). More broadly, neuroscience research suggests that emotions may facilitate rather than disrupt rational thinking (Camille et al. 2004, Brusoni et al. 2020)—an argument that is also acknowledged (Turner 2009) in sociology. Emotions may regulate when thinking processes start and stop to assist boundedly rational behavior as unbounded rationality by itself may be cognitively wasteful. Finally, the literature on workplace emotions (e.g., Ashkanasy and Daus 2002) acknowledges the positive function of emotions in an organizational context (e.g., with reference to the concept of "emotional intelligence"). However, none of the cited literature links emotions to the formation of higher order expectations or more broadly to heuristics used in strategic interactions.

Our results indicate that levels of reasoning are indeed mediated by emotions and altered emotions affect expectations of and among individuals. The level of reasoning tends to increase with experience under negative emotions and even more so under neutral emotions. Under positive emotions, experience does not lead to an increase in levels of reasoning on average.

After discussing the problem of higher order expectation formation from a theoretical viewpoint, we outline an experiment to measure both the level of reasoning of strategists and the possible influence of emotions on this level. We then report our results. Finally, we take our results as a starting point to speculate more broadly about possible links between emotions and expectations in organizational and strategic contexts.

2. Background: Forming Expectations About Behavior of Others

2.1. Adaptive Rationality and Choosing Levels of Reasoning

Objects of expectation formation usually are external events that become observable with the passage of time, for example, the weather in Berlin or the closing price of Gazprom shares next Monday. However, in many social settings, even the ultimate observability of the object of expectations cannot be taken for granted, and higher order expectations tend to fall in this category. For example, in a game of tennis, player *A* may form an expectation about what player *B* thinks of the reliability or power of *A*'s backhand volley before *B* chooses a stroke. The end of the rally does not resolve such uncertainty because, even after the end of the match, *A* may be left with only an approximate idea of *B*'s thoughts. Yet higher order expectations are a necessary component of strategic reasoning. How are they formed? A few possible explanations to that question follow. The individual may employ:

1. Mirroring: To mirror is to attribute one's own knowledge, beliefs, and expectations to others: I know or believe in something and, therefore, expect that others' experience is similar. In a mirrored world, second order expectations equal first order expectations. Aspects of this simplifying principle appear as the Golden Rule in most social and philosophical traditions: treat others as you expect to be treated by others (e.g., *Mahabharata* Udyoga-Parva 5:39.57; Shanti-Parva 12:167:9; and Anushasana Parva 13:114.8).

2. Deduction: Second order expectations may be deduced from observing the actions of others combined with assumptions about mirrored motives. For example, one assumes that others have the same motives as I do and assumes the expectations of other agents implied by their observed actions. This appears in common proverbs in various languages.

3. Direct communication: *X* tells *Y* what *X* believes, and *Y* trusts the content of the communication to accept it as *Y*'s own second order belief.

4. The communication game: *X* tells *Y* what *X* believes, or *Y* deduces *X*'s belief from observing *X*'s actions (assuming mirrored motives). However, *Y* interprets what is learned or deduced as part of a strategic game with *X* and infers *X*'s beliefs in the context of the game.

5. Third-party communication: *X* tells *Z*, who reports the results to *Y* (and others) either individually or as part of a survey or news report about many *X*s. This report becomes *Y*'s second order belief.

All five approaches require explicit or implicit decisions by strategist *Y* about whether and how to reason about *X*'s reasoning about *Y*. For instance, if *Y* uses the mirror, does *Y* assume that *X* uses the mirror, too? Would *Y*'s third and higher order expectations also follow from the mirror? Moreover, if *Y* deduces *X*'s expectations, it makes a difference what assumptions *Y* makes about *X*'s expectations of *Y* because *X*'s behavior in interactions is also driven by *X*'s first as well as higher order expectations. In almost all[7] modes of forming higher order expectations, agents must (at least implicitly) decide when to stop thinking about others. Standard game theory posits no limits on the level of reasoning. Behavioral game theory either suggests that repeated interactions should lead to outcomes as if the reasoning about reasoning is infinite or that the level of reasoning is associated with strategic sophistication (Levine et al. 2017). We return to discuss both these possibilities.

Unlike first order expectations, repeated observations do not necessarily help to form higher order expectations without making additional assumptions. In a stock market, a short-term trader forms expectation of what other traders expect the price of a security to be in the future in order to decide on the trader's own trades. Yet, even after the passage of time, the trader does not learn the magnitude of error in the trader's higher order expectations. For instance, it is difficult or impossible to know if another trader is buying because the trader believes that the stock is underpriced or because the trader believes that other traders believe it to be worth even more (Hirota and Sunder 2007, Hirota et al. 2021). Thus, the buying behavior of another does not imply clear second and third order beliefs. Such difficult-to-verify-ex-post expectations present problems in descriptive and normative analyses of decisions. It is useful to distinguish uncertainties that are resolved with time from those that are *unresolvable* even with the passage of time. Because the range of higher order expectations is unconstrained by logic, we must find plausible alternative mechanisms to keep them bounded within some measurable range.

Returning to the two-generals problem, if the knowledge of their coordination problem is common to them, they could develop a shared protocol, including a specified level of reasoning. They may, for example, agree to general A sending a message about the planned time of attack and general A to act on that plan irrespective of whether general A receives a response from general B. However, this "arranged in advance" argument apparently holds only if no surprises arise between the prior agreement and action. If this were strictly true, the two generals would simply agree in advance on the date and time of attack, and there would be no need for any messaging at all. If the timing is to be chosen based on the circumstances prevailing at the time immediately preceding the attack, it is not clear that a prior agreement on messaging about the time of attack would hold. The two generals may find themselves in a new environment (e.g., change in weather or unexpected terrain), in which they no longer know if honoring a prior agreement still makes sense. Moreover, protocols chosen in advance have a greater chance of being leaked to the opposition.

In an organizational context, repeated interactions needed for achieving expectational coordination become even less plausible. For instance, suppose higher order expectations matter in innovation adaptation dynamic. We may posit that, in thinking about others' response to innovation, people choose their own level of reasoning by habit. But how can they know whether they are in a repeated situation and the structure of the current innovation remains unchanged from their past experience? How can they know if this time it is different and that this knowledge is common to them? For instance, regulatory monitoring and rules may have altered the economic environment over time. Then, using order $k = 2$ expectations and not thinking beyond that is a mistake.

Thus, strategists are forced to choose a level of reasoning consciously or implicitly. Clearly, there are situations in which higher level reasoning helps. For instance, higher levels of reasoning may help an investor make money from riding a price bubble and getting out before it bursts (Keynes 1936). But such examples cannot be generalized, and choosing higher levels of reasoning can be both functional as well as dysfunctional. For instance, if a creative entrepreneur thinks too much about others and their reactions, the entrepreneur may never take the risk to develop something radically new. On the other hand, in a legal interaction, it may be wise to engage in iterative thinking before entering a court of law. Next, we explore a range of possible mediators of reasoning levels, namely, emotions.

2.2. Emotions and Decisions

In the affective sciences, emotions are hypothesized to feed into the decision-making process, especially in uncertain environments, and influence behavior over and above the cognitive calculations of desirability of the consequence of actions and the probability of its occurrence. Typically, theories of anticipatory emotions (e.g., mood-as-information theory, somatic-marker hypothesis, affect heuristic view, risk-as-feeling view) suggest that thinking about outcomes of actions elicits a brief emotional state: anticipating positive outcomes produces a positive affect, and anticipating threatening outcomes produces a negative affect (Finucane et al. 2000, Loewenstein et al. 2001, Bechara and Damasio 2005, Schwarz 2012). These brief emotional responses, either conscious or unconscious, factor into the calculations about the desirability of the behavior. A positive emotion, if attributed to a stimulus (even if incorrectly as is the case in typical affect-as-information experiments) when deciding whether to approach it, would elicit an approach behavior toward the stimulus; conversely, a negative emotion would elicit avoidance (Clore et al. 2001). In decision making under uncertainty or when the cognitive computations needed for making a decision are too demanding (for example, when one is required to act within a short time span), affect can act as a useful heuristic. For example, Schwarz and Clore (1983) show that, when asked a complex question (to report their life satisfaction), people in a happy mood report greater satisfaction than those in a negative mood; furthermore, this occurred only when people are unaware of their current mood's cause (good weather or the experimenter's mood induction procedure). Thus, emotion, much like other heuristics in decision making, can also be discounted when deemed as irrelevant information (see Clore et al. 2001).

These insights from psychology suggest that we can widen our view on rationality and the role of emotions in human interactions. Our theory rests on the idea that emotions may serve a positive function by helping to simplify computations and reasoning processes. However, embodied cognition is an alternative perspective to interpret our findings. As established in psychology and biology (Varela et al. 1991), human cognition is typically embodied. The body is the "home" of a wealth of sensations that (in mammals) extend beyond mere sensation to regulate physical well-being (such as feelings of hunger, heat and cold, etc.) to emotions (such as sadness, anger, and fear). Early in life, sensations and emotions guide interactions almost exclusively. For instance, a mother may instinctively attend to the discomfort implied by her baby's crying without keeping track of how often she does so. The care system in mammals creates the urge to bond with the child without a cost–benefit analysis of the consequences of the maternal behavior with such behavior being regulated by hormonal changes that occur at the end of pregnancy. Emotions continue to regulate interactions later in life. For instance, they regulate attraction to a potential mate, a job, or reaction to a challenging situation. Whether instinctively emotional or deliberately rational behavior in such interactions is cognitively cheaper and yields better outcomes is an open question.

Emotions may be even more fundamental to human interactions. Our findings are compatible with both the interpretation that rationality means calculation—and emotions help to simplify calculation—and the broader perspective in which emotions are fundamental to elicit rational responses in a broader meaning of that term. In both perspectives, emotions may direct humans when to start and stop thinking and deliberate calculation.

3. Do Emotions Regulate Our Level of Reasoning? Outline of an Experiment

To explore any empirical relevance of our theory, we need data from relevant contexts. Expectations are not routinely observable in field data, and survey responses are potentially contaminated by self-interest. Accordingly, we chose a laboratory task in which incentives within the experimenter's control can be designed to help examine the validity and relevance of data. The experiment had to allow for subjects to choose their own level of reasoning, and it allowed the experimenter to infer that level on the basis of established theory and permitted observations under the relevant treatments of affect and feedback. We, therefore, adapted Nagel's (1995) guessing game to our purpose.

3.1. Guessing Game and Level of Reasoning

In a laboratory guessing game (Nagel 1995, Bosch et al. 2002, Coricelli and Nagel 2009), a set of s individual subjects is asked to independently and simultaneously pick and submit a number x_i within a common knowledge range (x_L, x_H). They are informed that the average of the numbers submitted by all individuals in the set will be multiplied by a given constant fraction n ($0 < n < 1$) to arrive at a target number t. The individual whose chosen number is closest to target t receives a monetary reward A (which is shared in case of ties); others receive nothing.

How can the level of reasoning be captured in the guessing game? First, the participants are made aware that all participants' choices affect the outcome of the game. Without this, we would expect the participant to pick a random number between x_L and x_H (set at 0 to 1,000 throughout our experiment, yielding an expected value of 500 for random choices). When the participants ignore the possibility that others, too, might pick a random number from the range, it amounts to zero level of reasoning because the person ignores the presence and behavior of others completely. At the next level of reasoning, the participant may realize that, if others also choose random numbers in the 0–1,000 range, the average of the chosen numbers should be near 500 and, thus, thinking one step ahead of others, guess that a number close to $500n$ should increase one's chances of winning. In this case, the participants anticipate the presence of others using strategies symmetrical to their own, take an extra step based on that recognition without expecting that the others, too, will take that extra step; it amounts to mirroring in all but the last step. Third, the participants could fully attribute to others their own reasoning and produce the number $500n^2$. This iteration can continue further for higher levels of reasoning. Indeed, assuming common knowledge of rationality in the sense of game theory yields a unique equilibrium in the guessing game. As levels of reasoning are unbounded in this theoretical conception, n is taken to ever higher powers. See Table 1 for an ex ante rendition of various processing levels in the guessing game. Given $n < 1$, the unique equilibrium in this game is an action profile in which all players choose number zero. In a classroom/laboratory setting, the winner of the game is the one who best anticipates the anticipation strategies of the other players. For instance, if all other players choose level 2, a player can win by choosing $500n^2 - 1$.

We use data from the guessing game experiment to gain insights into the validity of two contradictory lines of thought about whether positive/negative affect may increase/decrease the level of thinking or vice versa. We review factors that are shown to affect reasoning, thinking about others, problem solving, and working memory, and could, therefore, be theorized to affect performance in the guessing game. Because the guessing game involves an interaction

Table 1. Ex Ante Thinking One Step Beyond Others' Level of Reasoning

Level of reasoning	My beliefs about others	My action
0	Ignore existence of others	Choose at random from 0–1,000 (average ≈ 500)
1	Others exist and behave as I do in level 0 above	Because I think other choose at random from 0–1,000, I choose $500n$
2	Others exist and behave as I do in level 1 above	Because I think others will choose $500n$ on average, I choose $500n^2$
3	Others exist and behave as I do in level 2 above	Because I think others will choose $500n^2$ on average, I choose $500n^3$
>3	And so on...	And so on...

Notes. Target value is group average times n. In our experiment, $n = 2/3$.

between these factors, we had only an approximate, a priori hypothesis regarding how emotions may influence participants' level of reasoning at the outset. Subsequent review of research suggested that results in affective psychology could be used to make predictions that support both a positive as well as a negative emotional effect on a participant's reasoning level in the game. We first discuss how a large literature in psychology suggests that positive emotions increase and negative emotions decrease levels of reasoning about others. Subsequently, we also discuss literature that suggests the opposite: positive emotions could lower and negative emotions could raise the levels of reasoning in the guessing game. In either case, we expect the effect of neutral emotions to lie between the effects of positive and negative emotions.

Positive emotions are shown to concentrate attention on the "big picture" and broaden the focus of a person's perceptual attention. For example, when participants with an optimistic disposition or a positive mood are shown geometric shapes, they tend to pick the global features (triangle if they see a triangle comprising a large number of small squares) (Basso et al. 1996, Fredrickson and Branigan 2005). A positive mood also increases the variety of future courses of action considered before making a choice. In one study, when choosing a snack (from a set of four) for the next 25 days, participants in a positive mood were more likely to make more frequent changes to their snack choice compared with subjects in a neutral mood (Kahn and Isen 1993). A positive affect also induces a more flexible cognitive orientation. When experiencing a positive emotion, participants tend to (a) include more objects in a specified category, suggesting a greater ability to see relationships among disparate objects (Isen and Daubman 1984); (b) show improved performance in a remote association test in which the task is to find a common prefix or suffix word to a set of three otherwise unrelated words (Isen et al. 1987); (c) show better performance on the Duncker's candle task that measures creative problem-solving ability (Isen et al. 1987); (d) produce more normatively unusual word associations (Isen et al. 1985); and finally, (e) better assimilate data (in a study when physicians were asked to read a transcript describing the symptoms of a patient with liver disease, the physician's positive mood had the effect of decreasing the number of lines the physicians read before diagnosing the disease correctly, indicating a superior assimilation of all the information presented; Estrada et al. 1997).

In the guessing game, positive emotion should promote a focus on not just the narrow task of choosing numbers that happen to be close to n times the average of others' choices, but also on information peripheral to the given instructions, such as others' thoughts, their thoughts about one's own thoughts about their thoughts, and so on, which would increase one's level of reasoning and decrease the numbers chosen in the guessing game.

Conversely, negative emotions, especially fear that follows threat stimuli, narrow the focus of attention (Easterbrook 1959, Finucane 2011, van Steenbergen et al. 2011) and reduce thought–action repertoire (Fredrickson and Branigan 2005). We, therefore, expect negative affect to narrow the attention of the subject (to choosing a number in this task) and hamper exploratory thinking about what others are thinking (an action that is not mentioned explicitly in the task instructions), which, therefore, might negatively impact the participant's reasoning levels in the game. Thus, within this framework, by reducing subjects' attention to others' behavior, negative emotions would reduce the level of reasoning and increase the numbers chosen in the guessing game.

However, we also note that a number of studies show that positive emotions also tend to create a disposition to process information heuristically, using prior well-developed schemas to assimilate information and superficial cues in the problem set to arrive at a conclusion (Worth and Mackie 1987). For example, when reasoning about guilt for alleged student misconduct, such as assault or cheating on an examination, inducing a positive (compared with neutral) emotion prior to judgment is found to increase the participant's reliance on whether the student's ethnic group membership is stereotypically associated with such misconduct (Bodenhausen et al. 1994). However, when happy participants were told that they would be asked to defend their judgment, it reduced their reliance on stereotypes (Bodenhausen et al. 1994).

Thus, it appears that positive mood does not reduce elaboration when reasoning, but rather, in a bid to assimilate all information provided, it reduces the motivation to rely on information inconsistent with one's past knowledge (also see Bless et al. 1990). Negative valence, on the other hand, by narrowing the focus of attention, makes subjects process information systematically, taking into account the current stimulus set and reason in a bottom-up manner without resorting excessively to prior knowledge (Bless et al. 1990, Fiedler and Bless 2000). For example, participants in a negative emotional valence do not utilize superficial category information (stereotypes), but rather rely on an individual's specific traits. One might expect that quick heuristic processing in positive emotions would decrease the choice of level of reasoning by participants, whereas negative emotions would induce systematic thinking and increase the participant's level of reasoning.

In light of this evidence, we hesitate to make an a priori prediction regarding the direction of positive and negative emotions on the level of reasoning in the guessing game. The effect of emotion on reasoning is complex, and the guessing game contains several elements, such as the theory of mind, logical reasoning, mathematical reasoning, and working memory dependence, each of which may be differentially acted upon by emotions. Keeping this in mind, we perform a two-tailed test of significance on our data.

In our initial exploration, we use the experimental data to help think through these two mutually contradictory ideas by restricting ourselves to broad emotional categories of positive, negative, and neutral valence. In the experiment, we use videos to expose participants to specific positive (amusement), negative (fear), and neutral emotions (see Gasper et al. 2019 for a review on neutral emotions). Further differentiation of possible effects of specific emotions within these three broad valence categories on the level of reasoning must be left to additional studies in the future.

In the next section, we describe the setup in which the participants play the guessing game. The experimenters' ability to get the subjects to actually play *that* game and not some other larger game depends on the success of fulfilling the conditions of the induced value theory (Smith 1976) in the laboratory. The ultimate success in creating such conditions can only be revealed by replication of outcomes in a variety of settings and with different participants. We provide the relevant details of the experimental design, procedure, and instructions to help readers reach an informed preliminary judgment from our data and to replicate the experiment on their own.

3.2. Effect of Feedback About Others' Behavior

In a secondary experimental treatment, participants were provided realized data on the average responses of all participants in the preceding round of the game. If a person is made aware of some statistics—for example, actually realized numbers, mean, distribution, dispersion, etc.—about their peers' choices, this information goes beyond the ex ante anticipation of those choices (see discussion in Section 3.1 and Table 1), and it could influence their responses. First, feedback on others' actual responses may render others' actions more salient and prime one to think more deeply about others' reasoning, and this could increase their own level of reasoning about others. Second and more importantly, feedback provides the participant information about their peers' level of reasoning, and increases the possibility that one picks a number based not merely on ex ante beliefs about others' adaptive rationality, but on rationality (or irrationality) implied by a concrete ex post realization of their choices. Finally, it could lead one to abandon reasoning beyond a certain iteration in favor of trying to adjust one's answer to the trend that the target number (the recent average multiplied by n) follows. If all the participants try to come close to the target number and also apply reasoning to what they think others are thinking, they will choose ever decreasing numbers (as also shown in Table 1) as a consequence of both an increase in level of reasoning ex ante as well as of recognizing a pattern in the available data ex post. Thus, under feedback, the choice of numbers in the game may be influenced by different aspects of the cognitive strategies employed by the participants. A variety of cognitive strategies potentially interact with the participant's choice of a level of reasoning. As a static measuring rod, we define the level of reasoning by the inverse of the mapping provided in Table 1 throughout this paper. Thus, if a participant chose $500n$ in a no-feedback round, we say that this participant employs level of reasoning 1. If the same participant in the same treatment, after receiving feedback, subsequently chose $500n^2$, we say that this participant employs level of reasoning 2.[8]

To summarize our hypotheses, we expect emotions to differentially affect the reasoning levels that the participants achieve in the guessing game, and this would be reflected in the numbers they choose. Moreover, we do not make strong a priori predictions about which emotions would induce greater levels of reasoning because past studies provide evidence to expect both positive and negative emotions to either increase or decrease the levels of reasoning.

The experiment was conducted using zTree software (Fischbacher 2007). The participants played the guessing game in two sets of rounds. In the first set, they played nine rounds without feedback about their peers' choices. The target value ($n = 2/3$ of the group average) for the ninth round was announced to the participants for the first time, and they played the next seven (feedback) rounds with the understanding that, following each round, they would be shown the target number for that round (which is two thirds of the group average that includes their own chosen number). In such a setup, we expect feedback about the target number of the previous round to affect participants' reasoning about the other participants' thinking and strategy, which should, in turn, affect the numbers they choose with emotions influencing the numbers chosen to the extent it affects the participants' reasoning processes.

4. Parameters and Results

The guessing game was implemented with parameters described later. Analysis of data to test the hypotheses as well as to document some new observations are also given.

4.1. Effect of Emotions on the Level of Reasoning

The experiment had nine sessions: three sessions for each of the three emotion groups. A 10th session suffered software malfunction, and it has been excluded from analysis in this paper. All data are available from the authors on request. Each emotion group had either 10 (sessions 1, 2, 4, 5, 7, and 8) or nine (sessions 3, 6, and 9) participants. No participant attended more than a single session. Each session had a total of 16 rounds with the first nine being no-feedback and the last seven being feedback rounds. The 10th round was the first round the participants played after having seen the target number (of the ninth round), which makes it the first feedback round. The experiment had a total of 144 rounds across all sessions, in which a total of 87 different individuals participated.

To induce neutral emotion, two one-minute clips from Disney's production *Earth* were chosen; to induce negative emotion, two two-minute horror movie clips from *The Ruins* and *Hostel* were chosen, and to induce positive emotion, two two-minute clips found on the internet depicting pranks (table topping and cake in the face) were chosen. Evidence about the validity of affects induced by the neutral and negative affect videos is available from the Emotional Movie Database (Carvalho et al. 2012). For a review of the effectiveness of different emotion-induction procedures, see Westermann et al. (1996).

4.1.1. Results for No-Feedback Rounds. The mean of the numbers chosen in the no-feedback round (from range 0–1,000) is 321 (SD[9] = 204). We interpret this as participants choosing level 1 of reasoning. In the feedback rounds when participants learn about the target numbers, the mean number chosen across all seven rounds is considerably lower at 154 ($SD = 195$), the difference being statistically significant ($p < 0.001$).

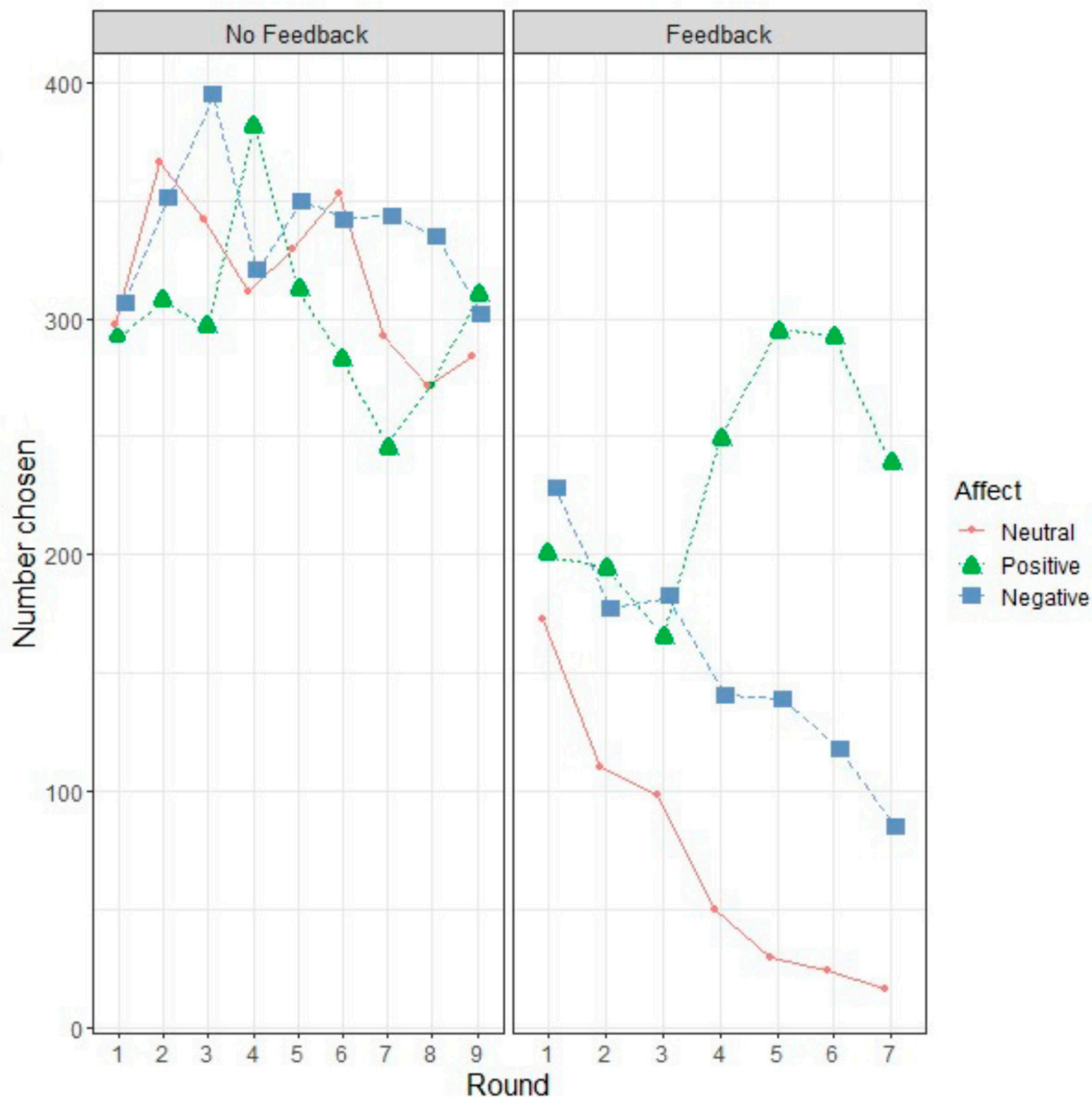
Without feedback about the target numbers, a one-way ANOVA compared the effect of emotions on the numbers the participants chose. The analysis revealed a marginally significant effect of emotion manipulation on the chosen numbers, $F(2, 771) = 2.4$, $p = 0.091$, partial eta squared = 0.006. Despite a lack of significance, because we have only three groups, we conducted a post hoc least square difference (LSD) test, which revealed that the positive emotions group chose the smallest numbers ($M = 299.8$, $SD = 204.7$), significantly smaller ($p = 0.031$) than the negative emotions group ($M = 338.3$, $SD = 210.3$). The neutral emotions group fell in between the positive and negative emotions groups ($M = 324.9$, $SD = 196.1$) and did not differ significantly from either (see Figure 1). Because the observed size of the effect is extremely small and a further mixed model regression did not reveal a significant effect of emotion (see Appendix B), we conclude that, given no feedback, emotions did not have a predictable effect on the numbers chosen over all rounds considered together. Note that our results do not replicate Weber's (2003) finding that the level of thinking increases after repetition even in the absence of feedback. The difference in our results must be resolved through future experimentation designed for that purpose.

Is there a decrease in the numbers chosen over the sequence of the nine no-feedback rounds that might reveal an increase in the static level of reasoning over these rounds of the guessing game? An ANOVA reveals that there is no significant decrease in numbers (i.e., no increase in level of reasoning) over the rounds in the absence of feedback: $F\ (8, 765) = 0.99$, $p = 0.439$.

Thus, it appears that, in the absence of feedback, emotions have little effect on the numbers chosen (see Figure 1). We conclude that, under no-feedback, (a) the null hypothesis of no-effect (or no differential effect across emotion groups) on participants' reasoning by the three emotion treatments cannot be rejected, and (b) the null hypothesis of no-improvement in the level of reasoning (indicated by a reduction in numbers chosen by subjects) from playing the game over the nine rounds also cannot be rejected.

4.1.2. Results for Feedback Rounds. In the feedback condition in which participants were given the target number resulting from their chosen numbers (two thirds of average of numbers chosen) at the end of

Figure 1. (Color online) Means of Numbers Chosen in Nine No-Feedback Rounds and Seven Feedback Rounds Across Positive, Neutral, and Negative Emotions Groups

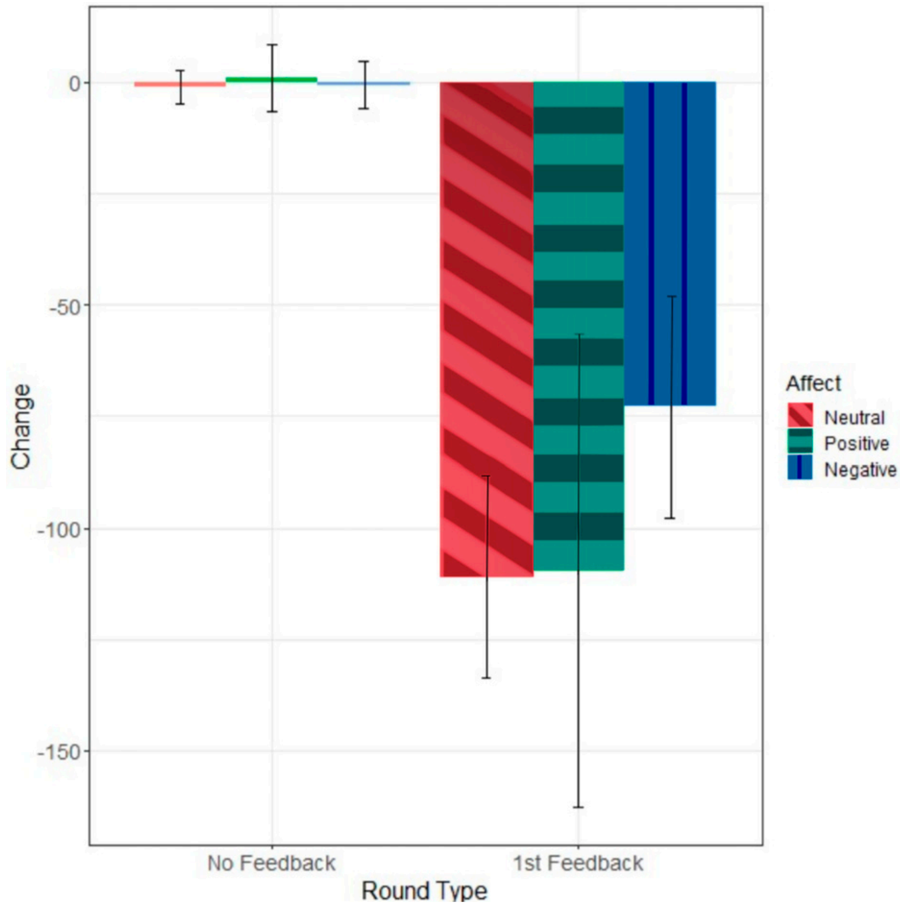


each round, a Welch test revealed a significant effect of emotion manipulation on the chosen numbers: $F(2, 599) = 37.21$, $p < 0.01$, partial eta squared = 0.11. A post hoc Games–Howell test revealed that the neutral emotion group ($M = 74.1$, $SD = 98.3$) chose the smallest numbers, followed by the negative emotions group ($M = 152.6$, $SD = 195.7$). The positive emotions group ($M = 233.8$, $SD = 258.1$) chose the largest numbers (see Figure 1, Panel B). All group differences were significant at the $p < 0.01$ level. A mixed model regression revealed the same result (see Appendix B).

Whereas, in the last no-feedback round, all groups had the same average of approximately 300, in the first feedback round (that immediately followed), participants in the neutral emotion group chose the smallest numbers (178.7), followed by the positive emotion group (199.6) and the negative group (229.2). We compared the average difference between the numbers chosen by neutral and negative emotion groups (of approximately 50) with the average difference between these two groups in the no-feedback rounds and found them to differ significantly: $t(8) = 2.99$, $p = 0.02$. This is likely because of a greater level of reasoning in the neutral emotions groups compared with the negative emotions groups when the first feedback number was mentally processed (see Figure 2).

The negative and neutral emotions groups show similar monotonic downward trajectories in the average

Figure 2. (Color online) Comparison of Average Change Across the First Nine (No-Feedback) Rounds Within the Positive, Neutral, and Negative Emotions Groups and Comparison of Change in Numbers Chosen from the Ninth (Last No-Feedback) to 10th (First Feedback) Round (Average and Standard Error)



numbers chosen but with the latter starting from a lower number. The positive emotions groups chose a larger initial number compared with neutral groups and had a no significant subsequent decline in the numbers chosen. Taking the decline in the first feedback round as well as the subsequent monotonic decreases in numbers chosen into consideration, the negative emotions groups show changes at an average rate of −15% per round $(=(84.1/229.2)^{(1/6)}-1)$, whereas the neutral emotion groups show changes at an average rate of −33% per round $(=(16.0/172.6)^{(1/6)}-1)$. The positive emotions groups show an insignificant change at the rate of +3% per round $(=(238.3/199.6)^{(1/6)}-1)$ in numbers in consecutive rounds of play.

4.1.3. Analysis. This experiment was designed to test the ex ante null hypothesis that emotions have no effect on the level of reasoning. Our results show that the null is not rejected in the absence of feedback, but with round-by-round feedback on target numbers, the null hypothesis is rejected; emotions do indeed affect the level of reasoning and the pattern of responses during the game. This is indicated by the observation that, when given feedback, under negative emotions (as well as neutral emotions), participants tend to choose smaller numbers than under positive emotions. In other words, over time, we observe rational adaptation to feedback under negative and neutral emotion treatments. We return to the implications of this main result of the paper for organizations and strategy in the concluding section of the paper.

Beyond the test of the main hypothesis, we also present in Appendix B tests of auxiliary hypotheses on the data gathered in the laboratory, including some post hoc analysis and theorizing that might be useful in future research.

4.1.4. Conclusions. We interpret these findings as follows: In the absence of feedback, emotions have no detectable effect on the static level of reasoning. In contrast, under round-by-round feedback about the target number in the preceding round, the level of reasoning is influenced by the affect to which participants have been exposed. The null hypothesis of no-effect is rejected in favor of our primary alternative hypothesis that emotions do have a differential influence on levels of reasoning with a qualification that this rational adaptation occurs only when participants are provided with feedback about the target number that depends on the actions of all subjects in the preceding round. Regarding the nature of the differential effect of emotions, we find that participants in the neutral group showed a high one-time decrease in the numbers chosen following the first feedback, the subsequent numbers chosen showed a steep monotonic decline, and both combined to produce an overall change of −33% per round, the steepest across the three emotion groups. Under negative affect, the first decrease in the numbers chosen from feedback round 1 to 2 is smaller than that under the neutral emotion and is also continued in the subsequent six feedback rounds; both combine to produce an average change of −15% per round. With positive affect, feedback induced a one-time increase in the level of reasoning, but this increase was not sustained in the subsequent rounds. Thus, in the feedback rounds, the neutral emotions groups displayed the highest levels of reasoning, positive emotions groups the lowest, and negative emotions groups' reasoning levels lay in between.

4.2. Does a Deeper Level of Reasoning Earn Greater Rewards?

Does a deeper reasoning confer a strategic advantage on the participants in the form of increasing their chances of winning rewards? One maximizes the chances of winning by being one step ahead of the average of others in the cohort—not much more or much less. In this sense, the guessing game has elements of social coordination. If the average level of reasoning of other members of the group is 1, a participant maximizes the chances of winning the reward by reasoning at level 2—not at 1 or 3. It is disadvantageous to be behind or too far ahead of the crowd.

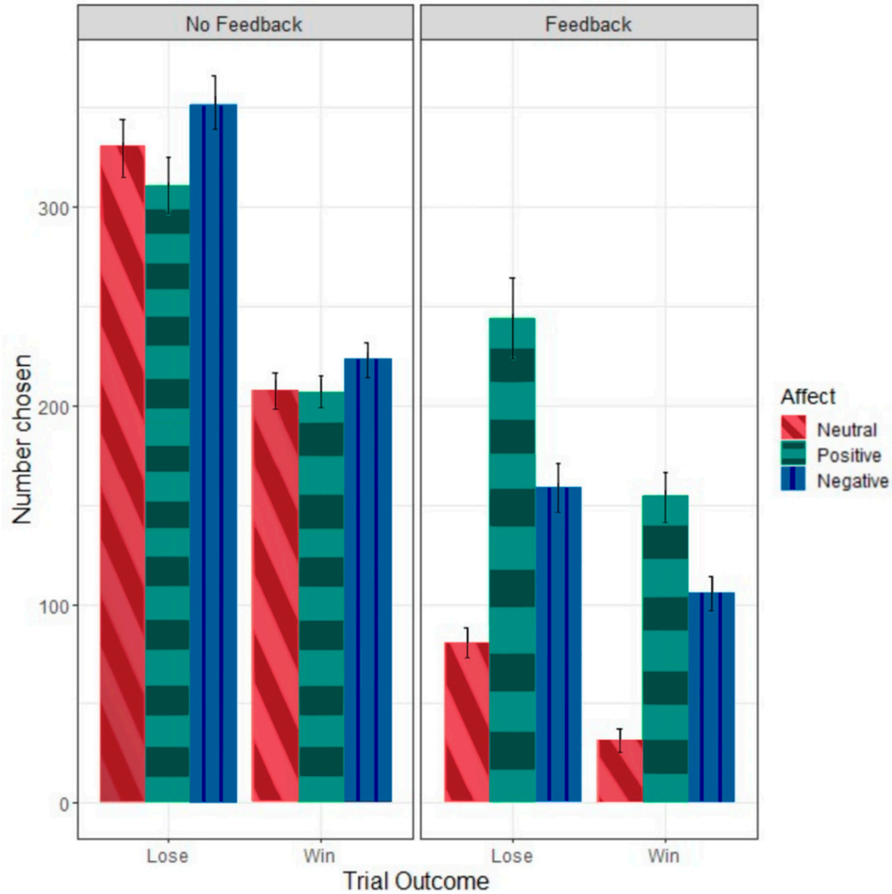
How well did the subjects perform under each emotion treatment in choosing a number close to the target? We calculated the difference between the target number and the participant's chosen number for every feedback round and conducted a Welch test with this distance from the target as dependent and the emotion groups as the predictor variable. We found that the distances from target across the neutral (M = 35.01, SD = 73.47), negative (M = 70.14, SD = 140.7), and positive (M = 126.85, SD = 221.36) emotions were significantly different, $F(2, 344.5) = 18.35$, $p < 0.01$, from one another. A post hoc Games–Howell revealed that the differences between all three emotion groups were significant at $p < 0.01$. Participants in the neutral emotions groups were the most accurate in picking numbers close to the target, whereas the positive emotions groups were the least accurate. Note that, in the no-feedback group, no significant group difference emerges across emotions for the participants' distance from target, $F(2, 518) = 0.11$, $p = 0.892$, with the mean distance from target for neutral (M = 165.4, SD = 142.7), negative (M = 170, SD = 153.1), and positive (M = 164, SD = 149.4) emotion groups being approximately equal.

Further, as Figure 3 shows, it appears that the winners chose numbers about 30%–40% lower than the losers in all six treatments (two feedback levels under each of the three affects). Winning this game calls for correctly guessing others' average level of reasoning and then choosing about two thirds of others' average. Because all subjects are in an identical situation, the game has no equilibrium other than the limiting value of zero under rational adaptation by all subjects. We expected participants demonstrating higher levels of reasoning to achieve greater success in the game, at least in the no-feedback rounds. We found a negative Kendall's Tau-b correlation between the numbers chosen and the binary outcome of winning (versus losing, $Tau\text{-}b = -0.169$, $p < 0.01$). Thus, the lower the numbers the participants chose, the higher their likelihood of winning in the no-feedback rounds. This would be the case because the target number is lower than the group average because of the effect of multiplying the participants' average by $n < 1$. Because the multiplier is two thirds in our experiment, we expected that choosing a number smaller than the group average would be more advantageous. The same should hold for the feedback rounds: indeed, we found in the feedback rounds a negative Kendall's Tau-b correlation between the numbers chosen and the binary outcome of winning (versus losing, $Tau\text{-}b = -0.137$, $p < 0.01$). Just as in the no-feedback rounds, choosing lower numbers when presented with the target number increased the likelihood of winning that round. In other words, the rounds in which participants won had a smaller number chosen compared with rounds in which they lost. This was true in both the no-feedback ($p < 0.01$) and feedback rounds ($p < 0.01$) and for all three emotion groups as seen in Figure 3.

4.3. Limitations

Although it is not a part of our initial intent, theory, or experimental design, we note some observations about individual behavior that will have to be validated by future independent experimental observations. First, it remains to be verified whether various positive emotions—humor, exhilaration, mirth, or amusement—that we used to induce positive affect differ in their effects on levels of reasoning. It is possible that emotions, such as happiness, elicited by watching scenes of gratitude and love, may lead to deeper reasoning.

Figure 3. (Color online) The Mean and Standard Error of the Numbers Chosen by Participants in the Trials They Won/Lost by Feedback and Affect



Second, humorous videos elicit an appraisal of "benign violations"—things that violate social norms or even cognitive expectations but not too seriously (McGraw and Warren 2010). An appraisal of benign violations, in which a situation is perceived as both a violation of expectations or norms but not serious enough to induce a negative emotion of fear or disgust, is often found in the context of "play," in which participants commit apparent hostile acts (e.g., pushing away) but also accompanied by a nonhostile facial expression, indicating that the norm violation was, in fact, benign (Van Hooff 1972). Following an appraisal of benign violation after our positive emotion video, instead of playing the guessing game as we intended them to play, some participants could have tried to contradict group expectations when experiencing appraisals related to amusement emotions. Such actions would induce expectations of such subversion and the consequent failure of the expectation of a drop of target numbers in consecutive rounds. This post hoc suggestion arises from the absence of an increase in the level of reasoning under positive affect with feedback and calls for further exploration of observed behavior in the guessing game for reasons other than the direct effect of positive affect on the level of reasoning.

Third, an alternative possibility is that, in the feedback rounds, behavior is influenced by the differential effect of emotions on an individual participants' ability to discern target number patterns in consecutive rounds and to choose their numbers based on their perceived patterns. How human beings recognize patterns in data and form expectations is a complex subject that is not pursued here. In this context, it is also notable that the decrease in the level of reasoning from the last no-feedback round to the first feedback round is *larger* under positive emotion compared with negative emotion and similar for positive and neutral emotions (see Figure 2). Thus, an alternative explanation of our data is that positive emotions do not decrease the level of reasoning compared with neutral emotions, but that positive emotions (in the humor treatment) make subjects play a different game. In that case, however, the result that negative emotions induce lower levels of reasoning than neutral emotions still holds. Moreover, our overall result that different emotions induce different levels of reasoning holds in any case.

Fourth, it is interesting that emotions do appear to only have an effect on the level of reasoning when participants are exposed to feedback. This raises a question: how is thinking about others related to feedback? In this context, we note that we defined the concept of "level of reasoning" as the depth of iterative reasoning. The measurement of this construct via the chosen numbers in the guessing game is, like any measure, imperfect. To further inquire into the effect of feedback on levels of reasoning (and emotions as a mediator in this context) we need measurements of levels of reasoning in different real-world contexts, for instance, the ones we point to in the introduction (e.g., the team coordination context). Not just laboratory, but also field experiments should be conducted in various organizational contexts to shed light on the specific interactions of levels of reasoning, feedback, and emotion. Whereas we establish a simple baseline result in this paper—emotions do influence the level of reasoning under feedback—shedding light on the detailed interactions is left for future work.

5. Discussion: The Link Between Emotions, Expectations, and Strategy

Our results suggest that emotions do indeed affect the degree to which strategists reason iteratively when they receive feedback about others' behavior. Whereas induced emotions show no significant effect in the absence of feedback, given feedback about others' behavior, negative emotions increase the levels of reasoning when compared with positive emotions. In other words, strategists think more about others' thinking when under negative than positive emotions. However, even deeper levels of reasoning are induced under neutral emotions. Our results provide a glimpse into the broader question of how thinking about others, bounded rationality, adaptations, and emotions are potentially linked. In the next section, we explore and speculate about this link and implications of the findings for strategic management research.

5.1. Emotions, Expectations, and Strategic Management

As discussed in Section 2.1, strategists are often forced to choose a level of reasoning when interacting under novel contexts. Our results suggest that specific emotions differentially influence such levels of reasoning, especially after strategists receive feedback from their interacting partners for the first time.

As discussed in the introduction, emotions may indeed be an important component of heuristics used for strategic interaction. In line with Simon's (1967) hypothesis, our experiment's results point to emotions as instruments that help regulate thinking. Equilibrium responses are of little value when strategists need to learn about their interaction context from the few observations in their hands (Fudenberg and Levine 1998). Our results suggest that reasoning about others and the levels of reasoning used in such social interactive processes varies with a subject's emotional state.

Choosing a level of reasoning is one way to simplify and, thus, economize on computation in games (Spiliopoulos and Hertwig 2019). As emotions serve this purpose, they are likely a component of heuristics used in strategic interaction. Such heuristics are especially important when the contexts of strategic interaction are ill-defined (Bettis 2017), for example, when potential new entrants in a home market are unknown or if relevant technological changes cannot be fully known. A new firm may surprise an incumbent by entering the latter's market. In such cases, strategists need to adaptively adjust their expectations about others' behavior and learn about the context of interaction during the interaction. We discuss in Section 2.1 that choosing a level of reasoning is often a mere necessity in such contexts; the rational ideal of game-theoretical equilibrium is of little value if it is unknown or not computable. In such situations or if it is unclear whether opponents play along the equilibrium path, strategists can employ heuristics to respond to their interaction partners.

Limiting the level of reasoning is one of several simplification strategies to cope with strategic interaction. The prior literature highlights human tendency to simplify, for instance, by only partially representing interaction partners (Menon 2018, Ehrig et al. 2021) or by taking shortcuts in game-theoretical computations (Spiliopoulos and Hertwig 2019). Our results suggest that emotions may serve as a neurophysiologically "hard-wired" regulatory device to help us simplify.

That strategists need to simplify, especially in novel environments, is already known. The vagueness of goals, opportunity sets, and their linkages make problems too complex, and simplification becomes a practical necessity. Sarasvathy's (2001) effectuation theory of entrepreneurship is a good example. She captures the unstructured and fluid environments faced by most entrepreneurs in four simplifying principles: bird-in-hand (working with what you have instead of dreaming about what you don't have), making lemonade from lemons (looking for new opportunities encountered by inevitable errors and unexpected events), crazy quilt (patching together help from new partners and their resources to strike out in new directions), and affordable loss (avoiding losses beyond what is acceptable). Effectuation, such as emotions, points to the gains from placing bounds on reasoning to avoid paralysis-by-analysis and make it possible to act.

Current scholarship starts to address the role of emotions in such simplification (Brusoni et al. 2020) in contexts that do not involve others. Our results suggest that emotions may be of particular importance for heuristics used in strategic interaction. The special importance of regulation of reasoning by emotions is emphasized already by Simon (1967), and the present preliminary study underlines the importance of further deeper enquiries into this topic. Whereas emotional regulation is long argued to be a managerial enabler of team performance (Barsade 2002, Reus and Liu 2004) our results suggest that emotions may also be a central component of heuristics to cope with competition, team members, and strategic environments more broadly. As we argue in Section 2.1 and in this section, uncertainty of strategic environments adds value to this instrument.

In a broad context, our results are in line with current views on the role of heuristics in strategic contexts (Bingham and Eisenhardt 2011, Bettis 2017, Ehrig et al. 2021). Our findings suggest the possibility that various emotions may differentially enable or disrupt rational responses in strategic environments. We note, however, that we still need to develop a notion of rationality in adaptive and interactive strategic contexts. The overall argument of this article implies that the idea of a "common knowledge of rationality" in the sense of game theory may not be the most suitable notion of rationality in strategic management contexts, such as market entry, competitor strategy evaluation, or evaluation of transition speed toward novel technologies. In Ehrig et al. (2021, p. 1750), the concept of reciprocal bounded rationality is proposed, and it refers to situations in which "interaction partners are mutually aware of and adapted to the fundamental uncertainty of the task and their limited resources." This condition implies that it is rational to simplify and to regulate a level of thinking (Simon 1967). Our results suggest that emotions may indeed enable such regulation and may, therefore, supplement reciprocal bounded rationality.

5.2. Open Questions and Future Work

Our experimental results only provide a glimpse into potential links among rationality, adaptation, emotions, and strategic interaction. An obvious open question is whether our results imply that emotional regulation is a key coping capability in strategic interactions. Because different levels of reasoning are needed in different contexts (see our example earlier), emotional regulation may implicitly help to choose a functional level. However, whether such regulation enhances strategic performance is not answered by this paper and has to be addressed in future work.

Our results leave open how emotions enter heuristics to cope with strategic interaction. A particularly important puzzle is the role feedback plays in mediating emotions when forming higher order expectations. We don't know why emotions do not have a significant effect on strategic behavior in the absence of feedback about the actions of others. Is feedback necessary to evoke a theory of mind, and do emotions play a role in its formation? Future experiments may shed light on this question.

As we have argued earlier, emotions may be of particular value for adaptation processes in novel interaction situations, that is, when strategists just start to receive feedback about others' reactions to their own actions. In future work, it would be useful to explicitly link emotions and Knightian uncertainty in interactive, strategic decision making. How do emotions help to form expectations about others when it is unknown who the relevant others might be or how they might act? In sum, we hope that this article stimulates deeper research into exploring the possibility of fascinating links between human emotions and strategic interaction.

Acknowledgments

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Appendix A. Script of Procedures and Instructions for Decision-Making Trials

Thank you for coming to this session on decision making. This session will last for about 30 minutes. During this session, you and others in the room will receive instructions, make decisions, and earn cash rewards that depend on what you as well as others do. All of your actions will remain private between you and the administrator. What you do in the session has no bearing on your academic status in the university. You may leave the session at any time, but in that case, you will forfeit any earnings you may have earned until that time. You are not to speak or communicate with anyone other than the administrator during the session. If you have a question, please raise your hand, and the administrator will come to you to address it. Before we begin, please watch this short video clip.

A.1. After Watching the First Video Clip

Please rate, on the scales provided, your current emotional state. You have to tick one of the nine boxes corresponding to the face shown to you. The first scale is the valence scale where you have to rate your feelings from positive (good) to negative (bad). The second scale is the arousal scale where you rate how energetic or aroused you feel. Remember that this arousal is independent of the valence scale; you can be highly aroused when feeling either positive or negative. Finally, the third scale is the dominance scale where you rate how big, great, or grand you feel. Remember each rating should reflect how you feel now. This is not a rating of the movie.

A.2. Game Instructions

You are playing what is known as the "guessing game" and competing with nine (or eight) other players. Each of you have to choose a number from 0 to 1,000; the person that chooses a number closest to the average of all chosen numbers multiplied by two thirds wins the round and receives a small cash reward. For example, if the participants have chosen the numbers 100, 300, 600, and 900, the total will be 1,900; the average is 475; and two thirds of average is approximately 316. This is the target number, and the person who chooses closest to 316 wins that round. The winner for the round will be paid 10 rupees. There will be a total of 16 rounds, and each round is expected to last approximately 60 seconds (after the allotted response time, the clock indicating the time elapsed turns red, and the experimenter asks the participants to quickly input their choice). You will not know what numbers others have chosen. Before we begin the game, we will watch another short clip, followed by the same rating task as earlier.

A.3. Second Video Clip

Please refer to the same instructions from the first video clip.

A.4. Game with No Feedback

You will be seated in front of a computer. You will have 30 seconds to enter your number. You can press "OK" to move ahead before 30 seconds are over, but the screen only changes when either everyone has pressed "OK" or at the end of 30 seconds. There will be nine such rounds.

A.5. Game with Feedback

In the next seven rounds, after you input the number, you will be shown the number you have entered, and the target number (two thirds of average). You can see how far your number was from the target. You can press "OK" to move ahead, but the screen only changes when either everyone has pressed "OK" or at the end of 30 seconds.

A.6. Postexperiment

At the end of the game, you have to write down your thought process behind choosing the numbers. Remember, in some rounds, you were unaware of what others had chosen, and in some rounds, you were given the target number. Try and recall the reasons/strategy (or lack thereof) you used when choosing the numbers.

Please record if you have played or known about this game before.

Please write down the number of people in this participant group that you have known for at least a year.

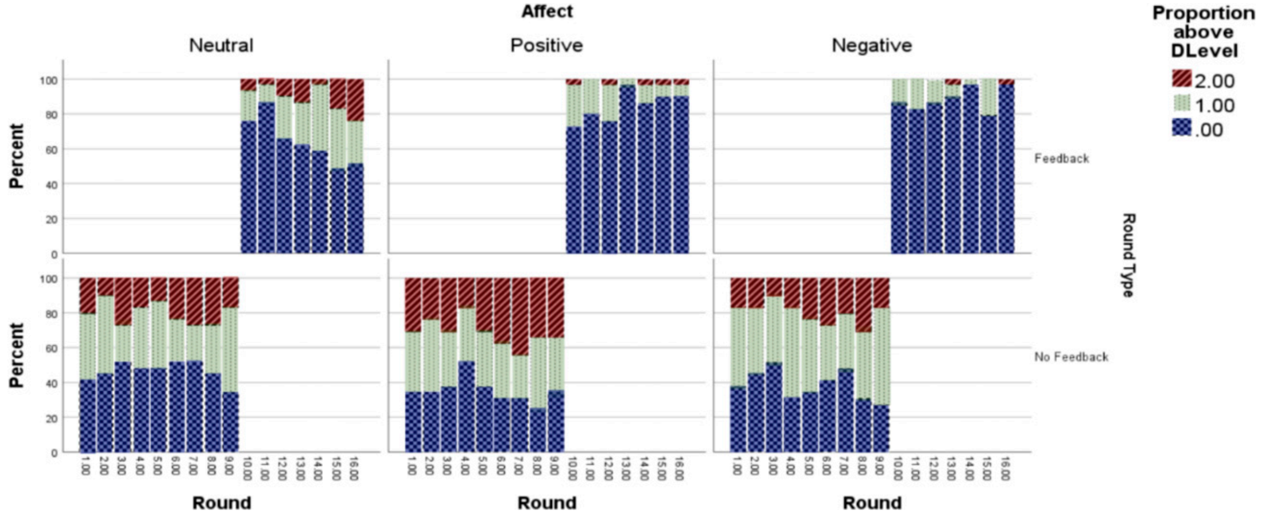
Appendix B. Additional Analysis of Results

B.1. Manipulation Check

Participants were shown two videos of the chosen emotional valence during each session. Watching the two negative emotion videos yielded high negative valence (M = 5.52, SD = 2.19; M = 7.24, SD = 1.69) and high arousal (M = 5.38, SD = 2.12; M = 5.89, SD = 1.99) in participants. The neutral emotion videos elicited moderate negative valence (M = 4.96, SD = 1.52; M = 4.37, SD = 1.49) and moderate arousal (M = 4.36, SD = 1.84; M = 4.11, SD = 1.65). The positive emotion videos elicited low negative valence (M = 4.19, SD = 2.03; M = 4.03, SD = 2.12) and moderate arousal (M = 4.43, SD = 1.67; M = 4.62, SD = 2.08).

An LSD test for valence revealed that the difference between positive and neutral emotion groups, although in the expected direction, did not reach significance (p = 0.195),

Figure A.1. (Color online) Proportion of Participants Who Chose Numbers Considered Above the Dynamic Level (DLevel) Less Than One, Between One and Two, and Greater Than Two Across the Three Emotion Levels and Feedback Rounds



whereas the negative emotion group was significantly higher in negative valence compared with both positive and neutral emotion groups with $p < 0.001$ for each. The negative valence group was higher in arousal compared with both positive ($p = 0.01$) and neutral emotion groups ($p < 0.01$), whereas the positive emotion group did not differ significantly from the neutral group ($p = 0.261$) although the means did differ in the expected direction with the positive group's results higher than the neutral group's results.

B.2. Mixed-Model Analysis of the Effect of Emotions on Numbers Chosen

Because each participant chose multiple numbers in an experimental session, and they were grouped in sets of 8 to 10 participants, we performed a repeated-measured analysis using a mixed-model linear regression with participants (level 2) and participant group (level 3) as randomly varying intercepts, emotion as a participant level fixed factor, the round number as the trial level (level 1) fixed factor as well as a randomly varying slope for a participant, and numbers chosen by the participants as the outcome variable. We found that group cluster did not account for any significant variance in the model in either the no-feedback (Wald $Z = 0.86$, $p = 0.39$) or feedback rounds (Wald $Z = 1.657$, $p = 0.098$) and was, therefore, removed from analysis. Our final analysis was a mixed model linear regression with participants as a randomly varying intercept, emotion and round number as a fixed factor, round number as the random slope, an unstructured covariance matrix, and numbers chosen by the participants as the outcome variable.

Analysis did not reveal a main effect of emotion on the numbers chosen in the no-feedback rounds, $F(2, 85.32) = 0.55$, $p = 0.635$; no main effect of rounds, $F(1, 1{,}350.6) = 1.84$, $p = 0.175$; and no interaction between emotion and rounds, $F(2, 85.32) = 0.09$, $p = 0.911$. Thus, there was no difference in the numbers chosen across the three emotion groups, and the numbers chosen did not differ across the rounds for each of the three emotion groups. For the feedback rounds, we first did the analysis with only the emotion groups as the predictor variable and found a main effect of emotion on the numbers chosen, $F(2, 83) = 16.06$, $p < 0.001$, with the positive group higher than negative, $B = 81.1$, $SE = 27$, $p = 0.007$, and the neutral group lower than the negative group, $B = -78.52$, $SE = 28.12$, $p = 0.005$. Adding the round number as a predictor variable to this model revealed a main effect of rounds, $F(1, 4{,}878.5) = 4.55$, $p = 0.033$, with the numbers chosen decreasing over rounds, $B = -21.36$, $SE = 8.6$. Whereas affect had no overall main effect, $F(2, 697.6) = 2.43$, $p = 0.089$, a significant interaction between emotion and rounds was found, $F(2, 4{,}878.5) = 7.15$, $p = 0.001$. The negative slope for negative and neutral emotions was similar, $B = -4.89$, $SE = 12.21$, $p = 0.689$, and there was an interaction between positive and negative slopes, $B = 37.15$, $SE = 12.1$, $p = 0.002$, such that, whereas neutral and negative emotions show a decrease in numbers chosen across rounds, positive emotions show an average increase over rounds (see Figure 1).

B.3. Testing for Effects of Gender, Sociality of Context, and Emotion Intensity

A two-way ANOVA revealed no main effect of gender, $F(1, 732) = 1.14$, $p = 0.29$, partial eta squared < 0.01, and no interaction between gender and emotion, $F(2, 73) = 0.38$, $p = 0.69$, partial eta squared < 0.01, in explaining the numbers chosen in the no-feedback rounds.

Next, we used the number of friends in the group as a covariate to see if the presence of known social actors increased subjects' level of reasoning and thereby decreasing the numbers chosen. A one-way ANOVA with emotion as a factor and number of friends in the group as a covariate revealed that the number of friends did not affect the numbers chosen, $F(1, 770) = 0.04$, $p = 0.85$, partial eta squared < 0.01.

Using the individual's reported valence intensity as a covariant, we performed a one-way ANCOVA with the emotion groups as a factor and found that the individual valence reported did not significantly affect the numbers chosen over and above the emotion groupings, $F(1, 770) = 2.41$, $p = 0.12$, partial eta squared < 0.01. Further, the same test revealed that individual reported arousal intensity was also not a significant factor, $F(1, 770) = 0.21$, $p = 0.65$, partial eta squared < 0.01.

In the feedback rounds, just as in the no-feedback rounds, we found that gender, number of friends in the group, and the individual valence and arousal ratings did not significantly influence the numbers chosen over and above the affect treatment.

B.4. Analysis of Additional Questions

Strategies reported by the participants fell into the following categories: (a) random response, (b) two thirds of 1,000 (upper limit of choice), (c) two thirds of 500, (c) 2/3 × 2/3 of 500, and (d) choosing either b or c after realizing that the iteration is unbounded. In the feedback rounds, the participants also reported choosing (e) a number smaller than the target number and (f) a number 2/3 or 2/3 × 2/3 of the target number. The strategies were not analyzed any further because they were results of end-of-the-session recall and may not accurately reflect the participant's actual round-by-round behavior and/or accurately differentiate the feedback from the no-feedback round strategies.

A total of four participants (two in positive and two in neutral treatment) were familiar with the same or a similar game. None had played the game before participating in our experiment.

B.5. Analysis of the Data Using a Dynamic Measure of Level of Reasoning

Our main analysis suggests that emotions do have an effect on levels of reasoning but only in the feedback rounds and, in the feedback rounds, the negative and neutral emotions induce deeper levels of reasoning. In analyses given, we estimate the levels of reasoning in no-feedback as well as feedback rounds statically (as defined in Table 1 in which ~U (0, 1,000) with a mean of 500 is always defined as level 0). This static interpretation ignores the changes in the information set of participants that occur in the feedback rounds. A dynamic interpretation takes the continually changing target number (= mean number × 2/3) from the preceding round as the baseline (DLevel 0) for estimating participants' observed levels of reasoning in the feedback rounds. Because both static as well as dynamic estimates of levels of reasoning are informative of the

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participants' behavior in feedback rounds, we present supplemental analysis of dynamic estimates in this section in Figure A.1 and the following paragraphs. We report (1) the proximity of numbers chosen to the preceding round's target number, numbers smaller than the target number being interpreted as reflecting higher reasoning levels, and (2) proportion of participants in each emotion group that chose a number less than two thirds of the preceding target numbers, which is DLevel 1. We use both these interrelated measures—proximity and proportion—as useful bases for dynamic analysis of levels of reasoning in feedback rounds across the emotion groups.

Analysis of the proximity of chosen numbers to the dynamically changing target numbers of the preceding rounds revealed to the participants, using a mixed model regression analysis with emotion as fixed effect and participant as random intercept, the target difference (chosen number (j) − target number ($j-1$)) shows a significant effect of emotion, $F(2, 83) = 3.57$, $p = 0.033$. A target difference of zero indicates no difference between the chosen number in feedback round j and the target number in feedback round $j-1$, and a positive target difference indicates that the participant's chosen number was larger than the previous target number. Our analysis reveals a significant effect of emotion, $F(2, 83) = 3.57$, $p = 0.033$. The positive emotion groups had the largest target difference among the three emotion groups, ($M = 71.2$, $SD = 254.3$), and their target difference was significantly greater than that of the neutral emotions groups ($M = 0.1$, $SD = 77.8$, $p = 0.009$) but not significantly greater than the target difference of the negative emotions groups ($M = 30.1$, $SD = 154.2$, $p = 0.125$); the target difference of the neutral and negative emotions were also not found to be significantly different from each other. A simple ANOVA followed by a Games–Howell test for unequal variances reveals similar results except that the negative emotion groups had a significantly higher target difference compared with neutral emotion groups. Adding the round number as a factor to the mixed model and allowing a random slope for emotion revealed no effect of round number, $F(1, 161.6) = 0.79$, $p = 0.374$, and no interaction between emotion and round number, $F(2, 161.6) = 1.5$, $p = 0.227$. We next added a quadratic component to the round number term to account for any nonlinearity in how participants might react to the target numbers of the preceding rounds revealed to them. We found a main effect of emotion, just as before, but also a main effect of both round number, $F(1, 514) = 7.54$, $p = 0.006$ and the squared term of the round number, $F(1, 514) = 6.77$, $p = 0.01$. This result suggests that participants (on average, across all emotion groups, feedback rounds) exhibited an inverted U-shaped reaction to the preceding target number, being closer in the early and late rounds and deviating more in the intermediate rounds.

Importantly, our analysis reveals that the neutral emotion group chose numbers closest to the preceding target numbers, which they followed closely with only a small variance among members of the group, suggesting a reasoning that could be described as following the previous target number without reasoning about the upcoming target that was likely to be two thirds of the preceding target if others acted similarly to themselves. The positive emotion group was not only the farthest from the preceding target number (they chose numbers larger than that target), it also had higher variance among the group members. This suggests that participants in the positive emotion group had lower levels of reasoning compared with neutral emotion groups, and they showed high interindividual differences in their number choice around the target numbers in consecutive rounds. The negative emotion group fell between the neutral and positive emotion groups with mean target difference larger than the neutral emotion group but not significantly smaller than the positive emotion group and with a variance in target difference among participants that was higher compared with neutral emotion group and lower compared with positive emotion group.

The second part of the dynamic analysis of the feedback rounds shifts attention from proximity to the proportion of chosen numbers that are equal to or less than two thirds times the preceding target numbers (DLevel $\geq$ 1). We found that, first, the average proportion of participants (in all three emotion groups) who chose numbers less than two thirds times the preceding round's target number was about 20% across the seven feedback rounds (22.1%, 17.4%, 24.4%, 17.4%, 19.8%, 27.9%, and 20.9% in rounds 10, 11, 12, 13, 14, 15, and 16, respectively). However, an important indicator of whether participants deliberately followed the strategy of choosing numbers smaller than two thirds times the preceding target was the consistency with which they made this decision; after all, these proportions could be a result of different participants reaching the target number in different rounds while keeping the average proportion across rounds constant at about 20%. We found that, whereas no participant chose numbers equal to or less than two thirds times the preceding target across all seven rounds, 62.8% made such a choice for at least one round; 24.4% did for at least three of the rounds, and 15.1% did for at least four of the rounds. Given these results, can we suggest that perhaps 15% to 25% of the participants displayed at least a DLevel 1 reasoning in the feedback rounds? We looked at the number of participants who chose numbers in the final three feedback rounds that were equal to or less than two thirds times the preceding target. Across all emotion groups, this proportion was 9.3% of all participants: 25% in neutral emotion, 3.4% in positive, and none in negative emotion group. For the last four rounds, these numbers were 3.5% in total (10.7 neutral, 0 positive, 0 negative); for the last two rounds, the numbers were 17.4% in total (46.4 neutral, 6.9 positive, and 0 negative). Thus, neutral emotion groups had substantially more participants who consistently chose in the final rounds numbers that showed a dynamic level of reasoning equal to or greater than 1 compared with positive and negative emotion groups. Based on the consistency with which numbers below target numbers were chosen, perhaps in total about 10% of the participants in the feedback rounds across all emotion groups showed dynamic level 1 or greater levels of reasoning with substantially greater proportions in neutral compared with positive and neutral emotions groups.

In sum, our analysis reveals that the neutral emotions group had the smallest difference on average from the preceding target number and the highest proportion of participants that chose numbers smaller than two thirds times that target number. Positive emotions groups chose numbers that were farthest away from as well as substantially larger than the preceding target numbers and had a low proportion of participants choosing numbers smaller than two thirds times the preceding target number. The negative emotions group chose numbers closer (but not significantly) to the preceding target compared with the positive but not the neutral emotions group and had a low proportion of participants choosing two thirds times the preceding target—similar to the positive emotions group, but a lower proportion than the neutral emotions group. Thus, just as in the main (static) analyses, in the feedback round, the neutral emotions groups displayed levels of reasoning higher than positive and negative emotions groups, and positive emotions groups had the lowest reasoning levels.

Note that, in static analyses of the participants' average number choice in the main text of the paper, the chosen numbers were constant across the no-feedback rounds at an approximate reasoning level of 1, suggesting no change across rounds in their reasoning levels. In feedback rounds, participants' chosen numbers showed a decrease in every round, suggesting an increase in the level of reasoning across rounds, thus showing a much higher average level of reasoning compared with no-feedback rounds (see Figure 1).

Analysis in this section of Appendix B highlights the difference between the static and dynamic interpretations of reasoning levels in the feedback rounds; dynamic analysis considers reasoning levels (labeled DLevel) relative to the changing information set available to the participants in each round as they learn about the target number of the preceding round. In static analysis, the number 500 reflects reasoning at level 0, but in dynamic analysis, the target number of the preceding round reflects DLevel 0. The proportion of participants in the no-feedback rounds that chose a number equal to or less than two thirds of 500 consistently across the final three rounds was 44% across all emotion groups (42.9% for neutral and 44.8% for positive and negative emotions groups). The proportion of participants who consistently made such choices in the last four rounds was 34% (32% for the neutral emotions group, 41% for the positive and 31% for the negative emotions group). Overall, 19.8% of the participants met the most stringent criterion of choosing a number less than two thirds of 500 across all nine no-feedback rounds (21% for neutral, 27.5% for positive, and 10% for negative emotions groups). We suggest that, if we take the consistency in achieving the target number in the final three rounds as the indicator of level of reasoning (as we did in the analysis of data from feedback rounds given earlier), about 45% of the participants showed a level of reasoning of equal to or greater than 1—substantially greater than the 10% reported in the feedback rounds. Furthermore, there was only a small difference, and no consistent difference, in these proportions across the three emotion treatment groups.

Finally, we note that the proportions for DLevel ≥ 2 (chosen numbers that are equal to or less than one third times the preceding target numbers) in the feedback rounds are small. No participant consistently chose numbers less than two thirds times the preceding target for all seven or even in the last three rounds. Across the seven feedback rounds, the proportions were less than 10% in each round (3.5%, 1.1%, 4.6%, 5.8%, 2.3%, 6.9%, and 9.3% across the seven rounds). For the no-feedback rounds, the proportions were slightly higher with 9.3% of the participants choosing numbers lower than one third times 500 in the last three no-feedback rounds and 4.6% in all nine no-feedback rounds. Across the nine no-feedback rounds, the proportions choosing numbers considered DLevel ≥ 2 were significant (although considerably smaller than DLevel ≥ 1): 23.2%, 17.4%, 23.2%, 17.4%, 23.2%, 30.2%, 31.4%, 31.4%, and 23.2% across the nine no-feedback rounds. See Figure A.1 for the proportions for DLevel less than one, between one and two, and greater than two.

Endnotes

[1] Because "expectations" is often used as a synonym for "beliefs" as well as in its statistical meaning (first moment of a probability distribution), we use "belief" when there is possibility of confusion between the two meanings.

[2] Strategists *may* follow game-theoretic prescriptions (Helfat and Peteraf 2009, endnote 3), but we do not know the degree, circumstances, and consequences of such behavior.

[3] Related concepts of depth of reasoning and theory of mind also have a variety of connotations in various literatures; we use level of reasoning in this paper.

[4] A similar dynamic arises in Rubinstein's (1989) email game. When there is nonzero probability of a message getting lost on the network during transmission, senders of emails can ask for a receipt of delivery by the receiver. However, then the receiver may also ask for a receipt of delivery of the delivery report by the sender and so on. A mechanism for a coordination on a level k is necessary to make the email exchange work.

[5] A related argument for the functionality of lower levels of reasoning can also be derived from epistemic game theory (Brandenburger 2007). In many contexts, choosing a bounded level of reasoning is consistent with common belief in rationality and, thus, unbounded iterated reasoning. Thus, strategists may often (but not always) do well by economizing on cognitive resources by choosing a low value of k.

[6] We thank an anonymous reviewer for informing us about the debate between Argyris and Simon.

[7] An exception is the approach to treat others like objects and not form a theory of mind at all.

[8] We *do not* analyze the data in the body of this paper using the lens that each feedback number F creates a new anchor and that, in the next round, Fn corresponds to level 1 reasoning, Fn^2 to level 2 reasoning, and so on. Such an analysis (using a dynamic measure) is performed in the appendix to provide further insights in the context of the specifics of the guessing game.

[9] Standard deviation of all the numbers chosen by the participants in the sample.

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